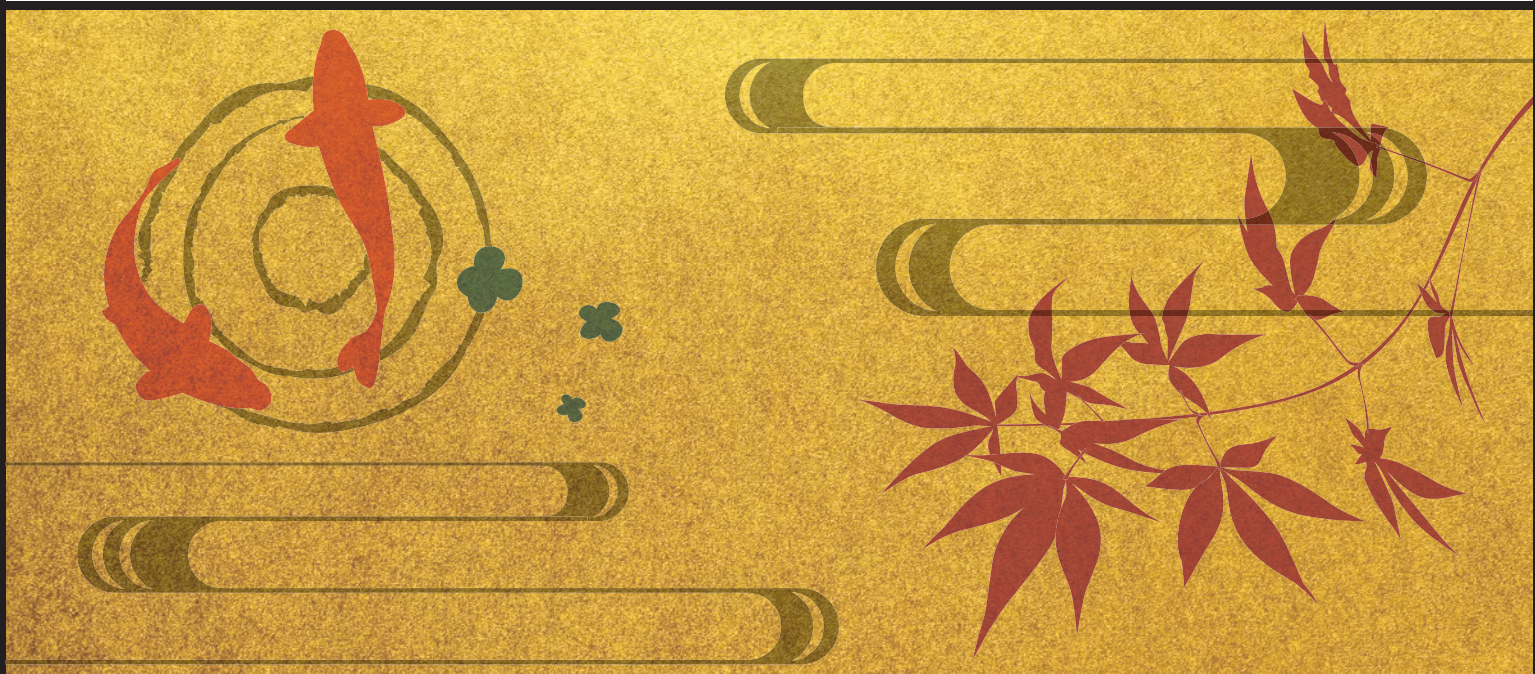




The 22nd  
INTERNATIONAL CONFERENCE ON  
COMPUTERS IN EDUCATION

Main Conference Proceedings

— NOV 30 - DEC 4, 2014 NARA, JAPAN —



**Proceedings of the  
22<sub>nd</sub> International Conference  
on Computers in Education  
ICCE 2014**

**November 30, 2014 - December 4, 2014**

**Nara, Japan**

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# 1. MESSAGES

## Message from the Conference Chair

---

We would like to extend our warmest welcome to all participants of the 22nd International Conference on Computers in Education (ICCE) 2014. This year, the conference is held in Nara, a beautiful city at the center of Japan and an important hub of Japanese traditional culture. Building on the continuous success of the conference series in recent two decades, the program aims to foster vibrant exchanges and dynamic collaborations among the academic and research communities of technology enhanced learning around the world.

We are pleased to have outstanding scholars as conference speakers to share their insights across varying areas in the field of computers in education. As for the three keynote speeches, Marlene Scardamalia will discuss the designs for principle-based innovation in education; Yvonne Rogers will talk about how new technology can change learning for the better; and Kurt Squire will highlight the research and development on integrating digital games into science learning for fostering authentic participation among learners. For the three theme-based invited speeches, Yasuhisa Tamura will introduce the trends and standardization of digital textbooks; Yu-Ju Lan will discuss the unique features of virtual worlds in supporting learners in second language acquisition; and Huang-Yao Hong will talk about the ways of cultivating teaching professionals with the design thinking in teaching with technology. In addition, Noriko H. Arai will give a distinguished invited speech on sharing the experience of universities in Japan of using an AI system for supporting university entrance examinations; and Miguel Nussbaum will give a special invited speech on discussing the use of technology for scaffolding learners to develop critical thinking skills in the classroom learning process. We look forward to these informative and illuminating speeches for inspiring us to sharpen the synergy among technology, pedagogy and education.

The organization of such the large-scale conference of ICCE 2014 requires the concerted efforts and unfailing supports from our conference organization team members and conference paper reviewers, with their names enlisted in the proceedings. We would like to express our sincere gratitude to all the kind individuals who have rendered their help in every possible way to make this conference a reality. We would also like to thank all the paper authors and registered participants for their exciting academic contributions to the fruitful intellectual exchange in this conference.

We hope all participants will have further opportunities to create new friendships and professional collaborations, and to leave fond memories for their stays in Nara. With the breathtaking scenery and historic culture in Nara city, as well as the intellectual sharing and social bonding in conference program, it will definitely be a unique ICCE experience for everyone.

Thank you!  
“Arigatou!”



Siu Cheung KONG  
Conference Chair  
(Hong Kong)

## Message from Local Organizing Committee Chairs

---

It is a great pleasure to welcome you to the 22nd International Conference on Computers in Education (ICCE2014). ICCE2014 is held in Nara, Japan. Nara has over 1300 years of history. The first capital of Japan was built in Nara, "Heijokyo". Nara is the starting place of Japanese cultures and spirits. There are many historical sites including UNESCO's World Heritage in the city of Nara. We are very honored to hold ICCE2014 in the wonderful place.

ICCE2014 takes place in the Nara Prefectural New Public Hall. The hall is located in Nara National Park, which is surrounded by the famous historical shrine (Kasuga Taisha) and temple (Todaiji) registered as World Heritage sites. We hope that all participants enjoy not only the conference but also the beautiful city of Nara.

The conference series of ICCE is organized by APSCE. In ICCE2014, we worked particularly with the executive committee of APSCE. We greatly benefited from their valuable advice. ICCE2014 is also hosted by Japanese Society of Information and Systems in Education (JSiSE), Japan Society for Educational Technology (JSET), and Japanese Association for Education of Information Studies (JAEIS). We deeply thank the sincere support from these societies.

In addition, we would like to warmly acknowledge the financial support of sponsors: KANSAI-OSAKA 21st Century Association; KDDI Foundation; Support Center for Advanced Telecommunications Technology Research, Foundation; The Telecommunications Advancement Foundation; Tateisi Science and Technology Foundation; Nara Visitors Bureau. We would also like to thank cooperate sponsors for their financial support: UCHIDA YOKO Co., LTD. and Epson Sales Japan Corp. (at the Platinum level); DATA PACIFIC (JAPAN) LTD., PHOTRON LIMITED, Asahi Net, Inc., and Fujitsu Limited (at the gold level); Pro-Seeds Co., Ltd (at the silver level). Without the support from these sponsors, this conference would not have been a success. We are deeply thankful to the many student volunteers and staff volunteers from a lot of universities in Japan.

Finally, we cordially welcome all of you to Nara, Japan. We believe your participation and contribution to ICCE2014 will make it much more productive and successful. We also hope that you enjoy the conference and Japan to gain wonderful experience.

November 2014



Akihiro Kashihara  
The Local Organizing Committee Chair  
(Japan)

## Message from the Program Coordination Chairs

The International Conference on Computers in Education (ICCE) is a series of annual conferences encompassing a broad range of issues related to using information technology for education, organized and sponsored by the Asia-Pacific Society for Computers in Education (APSCE). This year, ICCE 2014 is taking place in Nara, Japan from 30 November to 4 December 2014. Following the tradition of previous conferences in this series, ICCE 2014 is structured as a meta-conference that allows researchers from all over the world to connect with each other, to disseminate and share research, and to develop and deploy ideas that span the field of Computers in Education. There are seven interrelated sub-conferences focusing on specialized themes, each of which is organized by a program committee appointed by the respective special interest group (SIG – see [http://www.apsce.net/sigs\\_list.php?id=1026](http://www.apsce.net/sigs_list.php?id=1026)), constitute the five-day Conference schedule. They are:

- C1:** ICCE Conference on Artificial Intelligence in Education/Intelligent Tutoring System (AIED/ITS) and Adaptive Learning
- C2:** ICCE Conference on Computer-supported Collaborative Learning (CSCL) and Learning Sciences
- C3:** ICCE Conference on Advanced Learning Technologies, Open Contents, and Standards
- C4:** ICCE Conference on Classroom, Ubiquitous, and Mobile Technologies Enhanced Learning (CUMTEL)
- C5:** ICCE Conference on Digital Game and Digital Toy Enhanced Learning and Society (GTEL&S)
- C6:** ICCE Conference on Technology Enhanced Language Learning (TELL)
- C7:** ICCE Conference on Practice-driven Research, Teacher Professional Development and Policy of ICT in Education (PTP)

The Program Committee is comprised of a strong team that includes the Conference Chair, the Program Coordination Chair and co-Chair, seven executive Sub-Conference Chairs and 365 experts in the field of Computers in Education from 41 different countries or economies. Former ICCE local organizing and program coordination chairs have played the role of consultants in overseeing the conference organization process.

In total, the conference received a total of 266 papers (155 full, 52 short, and 59 posters) from 30 different countries or economies. Table 1 provides the submissions by country of the first author of individual paper. All papers were subjected to a rigorous review process by 2-4 reviewers from the respective sub conference program committees. After a discussion period within the individual program committees led by the sub conference Executive Co-Chairs and Co-Chairs, recommendations were made to the Coordination Committee Chair and Co-Chair. They made sure that the review process for all sub-conferences maintained the highest standards. This resulted in 39 full, 90 short, and 79 poster acceptances across all of the sub-conferences. The overall acceptance rate for full papers is 25%, and overall acceptance rate is 78%. The complete statistics of paper acceptances is shown in Table 2.

Table 1: Distribution of Paper Submissions for ICCE 2014

|                |    |                |    |
|----------------|----|----------------|----|
| country        |    |                |    |
| Australia      | 2  | Malaysia       | 14 |
| Austria        | 1  | Netherlands    | 1  |
| Brazil         | 1  | New Zealand    | 3  |
| Canada         | 3  | Philippines    | 2  |
| China          | 14 | Singapore      | 13 |
| Czech Republic | 1  | Spain          | 4  |
| Finland        | 2  | Sri Lanka      | 1  |
| Germany        | 8  | Swaziland      | 1  |
| Hong Kong      | 6  | Sweden         | 6  |
| India          | 3  | Taiwan         | 61 |
| Indonesia      | 9  | Thailand       | 7  |
| Ishida         | 1  | Tunisia        | 1  |
| Israel         | 1  | United Kingdom | 3  |
| Japan          | 98 | United States  | 3  |
| Kenya          | 1  | Viet Nam       | 1  |
| Korea          | 2  |                |    |

The acceptance rate for the full papers in the individual sub-conferences closely mirrored the overall acceptance rate. This is a testimony to the continued maintenance of the quality of presentations in our conference. The number of submissions and the acceptance rate for each sub conference is summarized in Table 3.

Table 2: Results of the overall reviewing process for ICCE 2014

|  |             |              |         |
|--|-------------|--------------|---------|
|  | Full papers | Short papers | Posters |
| Submissions  | 155         | 52           | 59      |
| Results: Full page acceptance rate= 25% Overall acceptance rate= 78% |             |              |         |
| Full papers  | 39(25%)     |              |         |
| Short papers   | 56          | 34(65%)      |         |
| Posters  | 37          | 6            | 36(61%) |
| Reject   | 23          | 12           | 23      |

Table 3: Breakdown of submission and acceptance by sub-conference

| Sub Conference | C1                   | C2    | C3     | C4     | C5    | C6     | C7     |
|----------------|----------------------|-------|--------|--------|-------|--------|--------|
|                | accepted (submitted) |       |        |        |       |        |        |
| Full           | 6(24)                | 6(27) | 5(18)  | 7(29)  | 4(14) | 4(16)  | 7(27)  |
| Short          | 3(8)                 | 6(6)  | 10(13) | 7(16)  | 6(10) | 10(14) | 10(23) |
| Poster         | 6(14)                | 6(18) | 7(11)  | 12(14) | 6(9)  | 11(14) | 4(6)   |

Last, the main conference schedule includes the all-important keynote speakers: (1) Professor Marlene SCARDAMALIA from OISE/University of Toronto, Canada (“Designs for Principle-Based Innovation in Education,” representing sub-conference C2), (2) Professor Yvonne ROGERS from University College London, UK (“Can new technology change learning for the better? ,” representing sub-conference C4), and (3) Professor Kurt SQUIRE from University of Wisconsin-Madison, USA (“Fostering authentic participation in science through games ,” representing sub-conference C5); the distinguished invited speaker: Professor Noriko H. ARAI from National Institute of Informatics, Japan (“The impact of A.I. on education - Can a robot get into the University of Tokyo?”); the theme-based invited speakers: (1) Professor Yu-Ju LAN from National Taiwan Normal University, Taiwan (“Language learning in virtual worlds: embodied, immersive, and interactive,” representing sub-conference C6,) (2) Professor Yasuhisa Tamura from Sophia University, Japan (“Digital Textbooks: Trends and Standardization,” representing sub-conference C3), and (3) Professor Huang-Yao HONG from National Chengchi University, Taiwan (“Cultivating design thinking in teaching with technology,” representing sub-conference C7); and the special invited speaker: Professor Miguel NUSSBAUM from The Computer Science Department of the School of Engineering of Pontificia Universidad Católica de Chile (“Using Technology as Scaffolding for Teaching Critical Thinking in the Classroom”).

In addition, there will be two panel sessions: (1) “Can or should learning be seamless most of the time? The flip side of Mobile Seamless Learning ...” (moderator: Professor Lung-Hsiang Wong from Nanyang Technological University, Singapore), (2) “Innovative programs and national policy of ICT in education in the Asia-Pacific region: looking back and moving forward” (moderator: Professor Fu-Yun YU, National Cheng Kung University, Taiwan).

The first two days of the conference are devoted to pre-conference events. This year they include 16 workshops, two interactive events, one tutorial, and the Doctoral Student Consortia, which will include 12 pre-doctoral student presentations followed by mentoring activities conducted by top-notch researchers. The Workshop papers are published in separate proceedings with its own ISBN number.

We would like to thank everyone who has been involved directly or indirectly in making these proceedings come to fruition, and we hope for a resounding success. We would like to thank all paper authors for your exciting research contributions and choosing ICCE 2014 as the outlet to present your works. Moreover, we would like to thank the IPC and the Executive Chairs who undertook the responsibility of selecting and reviewing papers. We also would like to thank our keynote and invited speakers for accepting our invitations. Last but not least, the biggest thank goes to the Local Organization Committee for their hard work under the tremendous schedule pressure.



We hope that you will find all the activities in ICCE 2014 to be insightful, interesting, and inspiring. Please enjoy the academic activities of ICCE 2014 and the vibrant and colorful culture experiences in Nara.

**Program Coordination Chairs:**



Chen-Chung LIU (Chair)  
National Central University  
Taiwan



Hiroaki OGATA (Co-Chair)  
Kyushu University  
Japan

## 2 ORGANIZATION

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Asia Pacific Society for Computers in Education

### **HOSTED BY:**

Japanese Society for Information and Systems in Education  
Japan Society for Educational Technology  
Japanese Association for Education of Information Studies

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Siu Cheung KONG, Hong Kong Institute of Education, Hong Kong

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**C1: ICCE Conference on Artificial Intelligence in Education/Intelligent Tutoring System (AIED/ITS) and Adaptive Learning (AL)**

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Barbara WASSON, University of Bergen, Norway

**C2: ICCE Conference on Computer-supported Collaborative Learning (CSCL) and Learning Sciences (LS)**

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Wenli CHEN, Nanyang Technological University, Singapore  
Ulrike CRESS, Knowledge Media Research Center, Germany  
Clark CHINN, Rutgers University, USA

**C3: ICCE Conference on Advanced Learning Technologies, Open Educational Content, and Standards (ALS)**

Yukihiro MATSUBARA, Hiroshima City University, Japan (Executive Chair)  
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Robby ROBSON, CEO and Chief Scientist, Eduworks Corporation, USA

**C4: ICCE Conference on Classroom, Ubiquitous and Mobile Technologies Enhanced Learning (CUMTEL)**

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KINSHUK, Athabasca University, Canada  
Marc JANSEN, University of Applied Sciences Ruhr West, Germany

**C5: ICCE Conference on Digital Game and Digital Toy Enhanced Learning and Society (GTEL&S)**

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Li ZHANG, University of Northumbria, UK  
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**C6: ICCE Conference on Technology Enhanced Language Learning (TELL)**

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Regine HAMPEL, The Open University, UK  
Lara LOMICKA-ANDERSON, University of South Carolina, USA

**C7: ICCE Conference on Practice-driven Research, Teacher Professional Development and Policy of ICT in Education (PTP)**

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Hsiu-Ping YUEH , National Taiwan University, Taiwan

### **3. Distinguished Researcher and Young Researcher Leader Awards**

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APSCE conducts Distinguished Researcher Award (DRA) and Early Career Research Award (ECRA) every year. DRA recognizes an active APSCE Member who has showed distinguished academic accomplishments and contributions in the field of Computers in Education. The awardee of DRA must be under 50 at the time of nomination. Early Career Research Award recognizes an active APSCE Member in the early stages of his or her career no later than 10 years after receipt of the doctoral degree who has produced international quality research outputs, and be able to demonstrate ambitious and aspirations consistent with the potential to achieve world-leading status. The Awards also recognize contributions to APSCE (e.g. related activities to ICCE or SIGs) or APSCE appointments (e.g. Executive Committee member of APSCE). These awards had been provided every two years since 2009. Starting from 2014, they are provided every year. The awardees are required to contribute a paper to RPTEL, the journal of APSCE, within two years of receiving the award.

For the year 2014, APSCE received one nomination for DRA and one nomination for ECRA. Through the examination of the qualification by the award subcommittee, the two nominees were accepted as a candidate for each award. As there was only one candidate nominated for each award, the 1st voting step for selecting the finalist was skipped. In the next selection step, the finalist will need "2/3" votes of agreement from all the EC members. This is very tough and competitive condition to be a winner.

We are now pleased to announce the award winner of this year's APSCE DRA: Professor Hiroaki Ogata. There is no award winner for ECRA.

In the following page, you will find a record of his scholarship and his services to APSCE. The DRA award winner will receive a Certificate, award money, and will have his/her name publicized on APSCE web site and on the ICCE proceedings. He will also receive nomination for the Keynote/Theme-Based Speaker for the next ICCE.

APSCE Award Subcommittee:

Tsukasa Hirashima(Chair),  
Chee-Kit Looi,  
Riichiro Mizoguchi

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## 2014 APSCE Distinguished Researcher Award Winner

**Dr. Hiroaki Ogata, Kyushu University, Japan.**

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Dr. Ogata is one of the top researchers from the Asia-Pacific region in the areas of mobile and ubiquitous learning environments (MULE) and computer supported collaborative learning (CSCL). He has very high visibility and reputation world-wide for his contributions to these fields. In his professional research field, he proposed several new concepts of contextualized and ubiquitous language learning in the authentic world which have initiated a new research and development direction in the field of ubiquitous learning.

His outstanding research results have been recognized by the mobile learning community as he was invited to be the keynote speaker in several top-tier conferences of mobile learning such as IEEE WMUTE 2008 in China, Mobile Learning 2009 in Spain, ICET 2009 in Turkey, ICCE 2011 in Malaysia.

The publication record of Dr. Ogata is outstanding with high quality research publications sustained over a longer period of time, notwithstanding that he is still rather young. His publications include over 60 refereed journal articles, more than 200 international conference papers. Several Best Paper Awards (JSiSE 1998, WebNet 1999, IPSJ 2004, ICALT 2006, CollabTech 2008, ICCE 2008, mLearn 2009 and ICCE 2010) underline the excellence of his work. For more details, please visit <http://sites.google.com/site/hiroakiogata/> and <http://scholar.google.com/citations?user=eNbutSkAAAAJ>

Dr. Ogata has been involved in a large number of externally funded research projects such as Grant-in-Aid for Scientific Research from the Ministry of Education (MEXT) and Japan Society for the promotion Science (JSPS), and also PRESTO from Japan Science and Technology Agency (JST). He has been a member of numerous international conference committees and international journal editorial boards and has been invited as guest editor special issues several times. Dr. Ogata organized IEEE WMTE 2005 in Tokushima and has also provided substantial services to the international research community through organizing a series of international workshops on MULE and by providing professional discussion forums for young researchers and PhD students.

Dr. Ogata is currently an executive committee (EC) member of APSCE, and was an EC member of IamLearn (International Association for Mobile Learning) and SOLAR (Society for Learning Analytics and Research). Also Dr. Ogata is currently an associate editor of IEEE Transactions on Learning Technologies (SSCI), RPTTEL (Research and Practice in Technology Enhanced Learning Journal) and IJMLO (International Journal of Mobile and Learning Organization), and an editorial board member of IJCSCL (International Journal of Computer Supported Collaborative Learning) (SSCI), and SLE (International Journal of Smart Learning Environments).



## 4. Keynotes and invited speakers

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### KEYNOTE SPEAKER 1

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#### *Designs for Principle-Based Innovation in Education*

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#### **Marlene SCARDAMALIA**

Institute for Knowledge Innovation & Technology, OISE/University of Toronto, Canada

#### **Abstract**

Iterative idea improvement requires boundless inventiveness. Direct pursuit of idea improvement as an explicit, guiding principle defines Knowledge Building/knowledge creation and contrasts sharply with rule-based processes, scripts, and procedures implicit in most school-based inquiry and learning activities. Idea improvement as a core principle aligns education with creative work as conducted in knowledge creating organizations where work on ill-defined problems fosters emergence of new competencies and outcomes. Schools, in contrast, tend to favor well-defined problems with clear end points. In this talk I pursue the Knowledge Building proposition that principle-based innovation offers a realistic possibility of achieving results in knowledge creation, in addition to addressing common standards and what are popularly known as 21st century skills. By going beyond a skills approach a Knowledge Building design community aims to

extend the range of the possible in education. Participants are globally distributed and represent a diverse network of practitioners, policy makers, researchers, administrators, students, parents, engineers, disciplinary experts and sponsors--all engaged in iterative, interactive knowledge building. To realize opportunities and address challenges the approach is systemic; to function as a coherent program, the models, technologies, assessments, and results serve local needs while evolving to address the needs of a global, research-intensive design lab and test bed. "Knowledge Building hubs of innovation" will demonstrate yearly, measurable advances in principled practice and achievement, with international courses and professional development provided to help achieve this goal. A global open source community will provide essential infrastructure: technology to foster knowledge creation, to amplify collective achievements, and to provide feedback to empower individual teachers and students as well as groups as agents in knowledge advancement. Design research will span elementary to tertiary education, all subject areas, a broad range of socio-economic levels and sectors, and represent great cultural and linguistic diversity. Resultant data repositories will provide the world's most valuable resource for studying knowledge creation in education, positioning the Knowledge Building design community to produce exportable "know-how," meet needs of the public and policy makers, and contribute significantly to knowledge of what students are capable of as junior members of a knowledge society.

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## KEYNOTE SPEAKER 2

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*Can new technology change learning for the better?*

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**Yvonne ROGERS**

Interaction Centre, University College London, UK

**Abstract**

There has been a lot of excitement recently about how new technologies can transform learning. MOOCs, the internet of education and flipped classrooms are the latest hotly debated ways of changing how students learn in the modern world. At the same time, a diversity of innovative learning apps has been developed for tabletops, tablets and phones, supporting new forms of learning – mobile, collaborative and situated. New electronic toolkits and programming environments are also emerging intended to introduce new generations to coding and computation in creative and engaging ways. Never before has there been so much opportunity and buzz to make learning accessible, immersive, interactive, exciting, provocative and enjoyable. To realize the true potential of these latest technological developments, however, requires designing interfaces and apps to not only match learner's needs but also to encourage collaboration, mindful engagement, conversational skills and the art of reflection.

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## KEYNOTE SPEAKER 3

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### *Fostering authentic participation in science through games*

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#### **Kurt SQUIRE**

Curriculum & Instruction, University of Wisconsin-Madison, USA

#### **Abstract**

Digital games have received widespread attention among science educators for their capacity for raising interest in science, improving identification with science, introducing inquiry-based learning activities, and produce conceptual understandings. A perennial challenge for educators is how to design such games so as to not just work in schools, but also transform educational practices. This talk highlights research and development from the Games + Learning + Society Center using games to support learning across a wide variety of ages and learning domains. It will cover both design principles and research findings, suggesting how games might contribute to a future of learning in a digitally connected society.

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## DISTINGUISHED INVITED SPEAKER

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### *The impact of A.I. on education - Can a robot get into the University of Tokyo?*

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**Noriko H. ARAI**

National Institute of Informatics, Japan

#### **Abstract**

“Todai Robot Project (Can a robot get into the University of Tokyo?)” was initiated by National Institute of Informatics in 2011 as an AI grand challenge. The goal of the project is to create an AI system that answers real questions of university entrance examinations consisting of two parts, the multiple-choice style national standardized tests and the written test including short essays. The task naturally requires the development of ground-breaking elemental technologies in the research areas including natural language processing, image processing, speech recognition, automated theorem proving, computer algebra, and computer simulation. At the same time, it requires the interdisciplinary research synthesis.

In 2013, our software took the mock test of the National Center Test with more than five thousands students. The result shows that its ability is still far below the average entrants of Tokyo University. However, it is beyond the mode: it is competent to pass the entrance exams of 400 out of 800 private universities in Japan. The rapid rise of new AI technologies may affect the labor market negatively in the short term, and it will demand us to reconstruct our education systems.

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**THEME-BASED INVITED SPEAKER: TELL (C6)**

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*Language learning in virtual worlds: embodied, immersive, and interactive*

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**Yu-Ju LAN**

Department of Applied Chinese Language and Culture, National Taiwan Normal University, Taiwan

**Abstract**

Social interaction plays an important role in the second language acquisition (SLA), whereby the learners and the social context in the real world are connected in an inseparable relationship. In particular, the context-dependent social interaction is most important to SLA because it provides second language (L2) learners essential scaffolding for acquiring an L2. Language learning is actually something that happens both inside the head of the learner and in the world in which the learner experiences the learning. The inseparability of external and internal mediation during context-dependent interaction in sociocultural SLA is in line with the argument of embodied cognition. That is, virtual immersion environments, such as Second Life (SL, a multiuser virtual environment), have drawn the attention of cross-disciplined

researchers because they make both avatar-self movement and different immersive interaction between the learner and the virtual environments possible. This speech will focus on (1) understanding the unique features of virtual worlds in providing language learners an immersive environment for embodied, social interactions via learners' avatars; and (2) how those unique features benefit learners' SLA.

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## THEME-BASED INVITED SPEAKER: ALT(C3)

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### *Digital Textbooks: Trends and Standardization*

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**Yasuhisa Tamura**

Dept. Information and Communication Sciences, Sophia University, Japan

#### **Abstract**

Paper based traditional learning materials like textbooks, dictionaries and references are gradually replaced into digital ones all over the world. This trend is initiated not only by classroom teachers and learning technology researchers, but also policy makers in various countries. This digitalization of learning materials will provide more efficient learning activities, less routine works of teachers, and significant change of special needs education.

Some standardization organizations are trying to establish technical specification of the digital textbooks. Among them, IDPF (International Digital Publishing Forum) started to establish EDUPUB specification on October 2013,

which stands on a digital book format of EPUB3. It includes DAISY specification, so it solves various accessibility issues. However, because a digital book assumes to be read in a stand-alone environment, EPUB3 does not specify communication with another networked server, nor collaboration with another application program. Also, there are many education specific needs and functions of various stakeholders. EDUPUB community members are discussing to enhance EPUB3 to support these functions.

With use of these digital materials, platforms like tablet PCs, and network environment, a classroom 10 years after will be dramatically changed. This change will not only affected by the digitalization, but also new ways of teaching and learning with use of digital and open materials: active learning, flipped classroom, peer assessment and so on.

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**THEME-BASED INVITED SPEAKER: PTP(C7)**

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*Cultivating design thinking in teaching with technology*

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**Huang-Yao HONG**  
National Chengchi University, Taiwan

**Abstract**

As the demand to help students develop 21st century competencies is increasing in the knowledge-based society, the ways we used to prepare prospective teachers and support teacher professional development also need to be re-examined. To address the 21st century challenge, teachers need to be more than just efficient knowledge transmitters. They need to develop capacity to work creatively with knowledge and ideas in order to advance their teaching beyond best practice. In particular, they need design-thinking skills to help better integrate various technological, pedagogical and content knowledge into their instructional and lesson designs for cultivating 21st century learners. However, while the concept of design thinking is widely embraced by professional fields (e.g., engineering, business, and architecture), it is still new to most teachers and to the teaching profession as a whole. In this talk I will first discuss about the important role of design thinking in teaching, especially, teaching with technology. Then I will talk about ways to foster pre-service and in-service teachers' design capacity through innovative pedagogy such as knowledge building. Finally, some suggestions regarding future direction of developing design capacity in the field of teacher education and development will be made.

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## SPECIAL INVITED SPEAKER

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### *Using Technology as Scaffolding for Teaching Critical Thinking in the Classroom*

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#### **Miguel NUSSBAUM**

The Computer Science Department of the School of Engineering of Pontificia Universidad Católica de Chile

#### **Abstract**

Critical thinking has become a key requirement for any list of essential 21st Century skills. The ability to think critically often determines one's level of personal development, career success and even effective participation within a community. The central problem that we address is how to operationalize critical thinking for its proper use in the classroom. We propose using technology to provide appropriate scaffolding for promoting critical thinking, helping learners to engage with their cognitive articulation and the reflective process. The scaffolding is based on the skills defined by the Delphi Report and integrates concepts of transferability and metacognition. We exemplify this with activities implemented in the classroom for third grade math and language arts, as well as high school science.



## 5. Panels

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**PANEL 1** *Can or should learning be seamless most of the time? The flip side of Mobile Seamless Learning ...*

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Seamless learning is a notion that emphasizes the continuity and bridging of learning across a combination of locations, times, technologies and social settings (such as formal and informal learning, individual and group learning, and learning in physical and digital realms). Earlier work on seamless learning has focused on developing ICT-based solutions (in particular, in 1:1 or one-mobile-device-per-student settings) and teacher-facilitated pedagogies, particularly leveraging mobile technology, to enable and enhance learners' ability in switching quickly from one learning activity to another.

Therefore, seamless learning had been perceived as a special form of mobile and ubiquitous learning. Recent studies have also ventured into supporting one's learning journeys and enculturating learners in the self-directed disposition of seamless learning that may spans a person's life transitions. Thus, a new perspective of seeing seamless learning as a learning notion on its own right (with mobile and cloud computing as possible technological tools to support it) has been developed.

As an evolving area of research and practice, the landscape of seamless learning will continue to be shaped and reshaped by academics and practitioners. This panel will gather scholars from various countries to explore the provocative questions of should learning be seamless all the time, and how far we are we in understanding and designing for seamless learning – with the support of mobile technologies. Is there a flip side to too much focus on seamless learning? Should learning be continuous and technology supported all the time? What do we mean by continuous?

Implications to the advancements of seamless learning based on the explorations to these questions will then be elicited, thus promoting a dialogue among the panellists and the audience on the future directions of seamless learning.”

**MODERAT**

**OR**

Lung-Hsiang WONG, Nanyang Technological University, Singapore

## **PANELISTS**

Gwo-Jen HWANG, National Taiwan University of Science and Technology,  
Taiwan

Jari LARU, University of Oulu, Finland

Chee-Kit LOOI, Nanyang Technological University, Singapore

Marcelo MILRAD, Linneaus University, Sweden

Hiroaki OGATA, Kyushu University, Japan

Hyo-Jeong SO, Pohang University of Science and Technology, South Korea

Marcus SPECHT, The Open University of the Netherlands, the Netherlands

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**PANEL 2** *Innovative Programs and National Policy of ICT in Education in the Asia-Pacific Region: Looking Back and Moving Forward*

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There has been a rapid growth in the use of ICT in education in the Asia-Pacific region in recent years. Various parties, including academics, governments, non-profit organizations, the private sector and teaching groups in many parts of the Asia-Pacific are currently investing considerable efforts and financial resources in support of large-scale innovative programs, and the planning of master plans and policies for the scalable and sustainable integration of ICT in education. However, the different cultural and socio-economic backgrounds of these areas may require different rationales, goals, foci, programs and policies with regard to this.

Nine senior academic researchers situated in the Asia-Pacific region (including Hong Kong, Taiwan, Singapore, Japan, Malaysia, Indonesia and India) will serve as panelists to share details of innovative programs, policies and regulations with regard to ICT in K-12 and tertiary education in their respective countries and regions, and provide insights based on their experiences and the implications of these.

The panel will conclude with an open discussion that invites researchers, policy-makers, practitioners and graduate students to exchange ideas on the forming, implementation and evaluation of innovative programs and policies for the greater use of ICT in education in a scalable and sustainable manner, and to share professional insights into the future directions of ICT in education, both in the Asia-Pacific region and beyond.

**CHAIR** Fu-Yun YU, National Cheng Kung University, Taiwan

**PANELISTS**

Tak-Wai CHAN, National Central University, Taiwan

Hirashima TSUKASA, Hiroshima University, Japan

Ronghuai HUANG, Beijing Normal University, China

Sridhar IYER, Indian Institute of Technology Bombay, India

Siu Cheung KONG, The Hong Kong Institute of Education, Hong Kong

Chee Kit LOOI, Nanyang Technological University, Singapore

Hiroaki OGATA, Kyushu University, Japan

Gunawan SURYOPUTRO, University of Muhammadiyah Prof. Dr. HAMKA, Indonesia

Lung Hsiang WONG, Nanyang Technological University, Singapore

Su Luan WONG, Universiti Putra Malaysia, Malaysia

## 6. Interactive Event

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**Event 1**    *Let's try SCROLL (ubiquitous learning log system) for seamless learning analytics*

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In this event, we will demonstrate a ubiquitous learning log system called SCROLL (System for Capturing and Reminding of Learning Log). Ubiquitous Learning Log (ULL) is defined as a digital record of what learners have learned in the daily life using ubiquitous technologies. It allows learners to log their learning experiences with photos, audios, videos, location, and sensor data, and to share and to reuse ULL with others. Also the organizers will discuss how we can use SCROLL in the participants' courses for seamless and flipped learning, collaborative learning, and learning analytics. So the participants should bring their own notebook PC, smartphones, or tablets to try the SCROLL system.

### **EVENT ORGANIZER**

Hiroaki OGATA, Kyushu University, Japan  
Kousuke MOURI, Kyushu University, Japan  
Songran LIU, Tokushima University, Japan  
Noriko UOSAKI, Osaka University, Japan

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**Event 2**    *Active Learning Practicum for Trust Building in Team-Based Learning with Empathy*

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This event is to make participants submerged into the first-hand win-win approach for the advanced communication for trust building as well as consensus building in terms of empathy in the team-based learning (henceforth, TBL), which is based on the concept of social constructivism with heads-on and hands-on practices. In the team based learning, it is usually disregarded or overlooked that the essence of TBL is fundamentally initiated from the trust building. Thus, the TBL would end up with failure.

This practicum will draw the audience to the importance of the trust building that will lead to the success of the consensus building. Throughout the course, thinking tools (Smartphone APPs) for visualization will be introduced to activate team discussion.

The target audience for this event is undergraduate students through the junior faculty members, who are interested in the learning effectiveness in TBL

### **EVENT ORGANIZER**

Tosh YAMAMOTO, Kanasai University  
Maki OKUNUKI, Kansai University, Kobe Shinwa Women's University  
Chiaki IWASAKI  
Tagami MASANORI

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# Using Technology as Scaffolding for Teaching Critical Thinking in the Classroom

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## Extended Abstract

### Critical Thinking Skills

Critical thinking has become a key requirement for any list of essential 21<sup>st</sup> Century skills (Griffin, McGaw & Care, 2012; Greenhill, 2009). The ability to think critically often determines one's level of personal development, career success and even effective participation within a community (Nussbaum, 2006). In the words of Marques (2012), critical thinking has become a prerequisite for survival. The shift towards experience-based learning has left little room for reflection. Prensky (2001) acknowledges that the most interesting challenge of teaching digital natives is to find ways to include critical thinking in their learning.

There is a considerable amount of literature on critical thinking (Kennedy, Fisher & Ennis, 1991; Pithers & Soden, 2000; Lai, 2011; Dwyer, 2014). However, this has led the concept to become dispersed, with a number of views that fail to converge. There is also no view put forward on how to operationalize critical thinking in the classroom. In order to do so, integrated processes for transference and assessment are required (Halpern, 2003).

Therefore, the central problem that we address is how to operationalize critical thinking for its proper use in the classroom.

Not all mental events can be considered as critical thinking. One way to conceptualize critical thinking has been to define it in relation to higher-order thinking skills, such as analyzing, interpreting and explaining (Dwyer, 2014). In an attempt to homogenize critical thinking, Facione (1990) defines it as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based". It is important to note that this definition includes precisely those skills which experts consider as being fundamental to any critical process.

Transference between domains is one of the greatest challenges faced when implementing critical thinking in education (Halpern, 1998). Whoever learns a skill must be capable of using it in contexts other than the one in which it was originally learned (Housen, 2012). Transference demands that any concept of critical thinking find a balance between the generalization of the skills involved and the learning of these skills in specific contexts (Facione, 1990).

Van Gelder (2005) suggests that the difficulty of transference with critical thinking stems precisely from its generalized nature. The fact that critical thinking skills can be applied to such varied domains, contents and contexts means that there is a very good chance of not applying the correct principle. He therefore recommends teaching explicit procedures for each domain and making these general enough to transfer across domains. In order to do so, he refers to Halpern's (2003) model for teaching critical thinking. As well as meeting the above requirements, Halpern's model also includes metacognitive monitoring. By monitoring the thought process, the quality of this process improves, i.e. the correct procedures are applied to the appropriate contexts. This is achieved by distinguishing between mechanical application of the rules and inferential comprehension, by which we mean identifying the inferential relationships between the elements of an activity (Mulnix, 2012).

### Scaffolding model

We propose using technology to provide a scaffolded framework for teaching critical thinking in the classroom. Providing appropriate scaffolding is fundamental for promoting critical thinking (Kim



et al., 2013), while technological support helps learners engage with their cognitive articulation and the reflective process (Lajoie et al., 2001). The scaffolding is designed to support the assessment and teaching of critical thinking in the classroom. Furthermore, it also aims to allow students to exercise the skills explicitly (Halpern, 2003) and help the teacher monitor how the skills are learned.

A learning environment must support active engagement in the learning process (Dawson, 2000); provide adequate scaffolding and opportunities for practice (Macknish, 2011); and engage students in higher-order thinking tasks such as questioning, analysis, synthesis, and evaluation through instructional strategies such as small-group activities, simulations, and case studies (Meyers & Jones, 1993).

The scaffolding is based on the skills defined by the Delphi Report (Facione, 1990), and integrates the concepts of transferability and metacognition (Halpern, 2003). The proposed model consists of sequential scaffolding for solving problems, in which learners elaborate thoughts (interpretation), explain results (explanation), evaluate solutions (metacognition), explore and clarify inconsistencies and knowledge gaps (analysis and inference), and thus benefit from the cognitive restructuring that underpins cognitive change (Garside, 1996). The sequence consecutively intersperses higher-order thinking skills (analysis, interpretation and inference) with the metacognitive process (evaluation and self-assessment), produced by explicitly forming arguments based on questions about the problem solving process itself.

As an example of such a sequence, we can use the case of teaching problem solving for division in 3<sup>rd</sup> grade. The activity begins by posing the problem, in this case: "I have six bananas and 3 boxes. If I divide them equally, how many bananas would be in each box?". In order to put into practice the first step in the sequence, i.e., interpreting, the student must graphically depict the number of elements needed to solve this problem, in this case 6 bananas and 3 boxes. Once the problem has been interpreted, and in order to explicitly practice the skill of evaluating, an erroneous interpretation of the problem is then presented. For this particular exercise, an uneven distribution of bananas in each box is shown. This step can only be completed if the student is able to identify the mistake and explain it explicitly by forming an argument, thus showing they are capable of metacognitive monitoring. The following step is to solve the problem by correcting the mistake, where the student must apply the skills of analyzing and inferring. The solution to the problem is then interpreted, again putting into practice the skills of interpreting and evaluating. In order to do so, the student is shown an incorrect interpretation of the operation that was carried out. In this case, the erroneous interpretation would be: "We can summarize this operation as follows:  $6:3 = 3$ ". The student must first identify the mistake, then explain and correct it. In each step, if the student makes a mistake, immediate feedback is given so that they can reflect upon their error and make the necessary corrections.

It is worth noting that this process requires a high level of interaction with the activity from the student. Technology therefore plays a vital role in the proposed problem solving process. This technological support also allows each student to advance at their own pace according to the difficulties they face, as well as making them pass through every step. Furthermore, appropriate feedback is given at each step depending on the student's performance. By doing so, the teacher can focus on monitoring the activity and helping those students who struggle the most.

## **Conclusion**

We have proposed a scaffolded framework for teaching critical thinking using a sequence for solving problems where both higher-order thinking skills and the metacognitive process are practiced explicitly. This proposal is far from being a recipe for solving problems; by requiring a metacognitive process at each step the students are constantly forced to reflect, making it difficult for the process to become mechanical. This therefore allows the process to be generalized and applied to different domains.

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# A Web-based Intelligent Handwriting Education System for Autonomous Learning of Bengali Characters

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**Abstract:** In this paper, we describe a prototype of web-based intelligent handwriting education system for autonomous learning of Bengali characters. Bengali language is used by more than 211 million people of India and Bangladesh. Due to the socio-economical limitation, all of the population does not have the chance to go to school. This research project was aimed to develop an intelligent Bengali handwriting education system. As an intelligent tutor, the system can automatically check the handwriting errors, such as stroke production errors, stroke sequence errors, stroke relationship errors and immediately provide a feedback to the students to correct themselves. Our proposed system can be accessed from smartphone or iPhone that allows students to do practice their Bengali handwriting at anytime and anywhere. Bengali is a multi-stroke input characters with extremely long cursive shaped where it has stroke order variability and stroke direction variability. Due to this structural limitation, recognition speed is a crucial issue to apply traditional online handwriting recognition algorithm for Bengali language learning. In this work, we have adopted hierarchical recognition approach to improve the recognition speed that makes our system adaptable for web-based language learning. We applied writing speed free recognition methodology together with hierarchical recognition algorithm. It ensured the learning of all aged population, especially for children and older national. The experimental results showed that our proposed hierarchical recognition algorithm can provide higher accuracy than traditional multi-stroke recognition algorithm with more writing variability.

**Keywords:** Intelligent handwriting education system, Hierarchical recognition, Handwriting errors, Automatic stroke error detection, Modified Dynamic Programming Matching (DPM), JSP (JavaServer Page), WWW client-server interface.

## 1. Introduction

### 1.1 Motivation and our contribution

Literacy in Bangladesh is a key for socio-economic progress, and the Bengali literacy rate grew to 55% in 2010 from 5.6% at the end of British rule in 1947. Despite government programs, the literacy rate was improved very sluggishly (only about 10 times within 60 years) [1]. Because of socio-economical limitation, all of the population, especially children and older national, do not have the chance to go to school. Although government has various educational activities, the number of school was not adequate yet. Considering this educational background, traditional handwriting teaching system is not enough to improve the Bengali literacy rate at 100%. Because, in the traditional handwriting teaching system, the teacher must write a Bengali character on the blackboard and the students should rewrite the handwritten character on their copy books. After that, the teacher tries to check the handwriting errors in the student's notebooks and provides a feedback in the next time, because it's impossible for a teacher to verify and check every student's handwriting in the limited time of the lesson. This system can be successfully acquired only though practice regularly and for long periods. In this context, Z. Hu et al. [2] define three drawbacks of the traditional education, such as time-consumption, faultiness, teacher-oriented. In addition, these techniques have many more drawbacks in aspects of socio-economical view point. It motivated us to develop web-based intelligent handwriting education system for autonomous learning of Bengali characters. The learning process becomes much more

effective, if the handwritten character is checked just after the students have finished their handwriting. On the other hand, the students can learn without the teacher supervision and they can correct the committed errors. Also, the students can repeat the same exercise several times to speed up the learning process. In this research project, we are aiming to develop a web-based (iPhone/smartphone or computer browser) intelligent handwriting education system that can ensure the learning of Bengali characters for those population, especially children or older national, who do not have chance to go to school. Thus, 100% literacy improvement can be established within a very short period. To the best of our knowledge, this is a pioneering attempt for the development of web-based intelligent handwriting education system to improve Bengali literacy.

Bengali is a multi-stroke input characters with extremely long cursive shaped where it has stroke order variability and stroke direction variability. The difficulty in online recognition of handwritten Bengali characters arises from the facts that this is a moderately large symbol set, shapes are extremely cursive even when written separately. In addition, there exist quite a few group of almost similar shape characters in their handwritten format. Fundamentally, multi-stroke recognition algorithm results very slow recognition speed in case of long cursive characters. For the structural limitation of Bengali characters, existing multi-stroke recognition algorithm is not applicable for the development of Bengali handwriting education system, because it needs to provide the real-time students feedback. To address this problem, we have developed hierarchical online recognition algorithm to improve the recognition speed with considerably higher accuracy. It makes our system adaptable for web-based language learning and ensured immediate feedback about student's handwriting errors. In this hierarchical online recognition algorithm, we applied a series of matching filters to reduce a small number of candidates characters for final dynamic programming matching (DPM) where local features (angular feature) are used to guide DPM. Then character with low matching cost is selected as recognition results. Finally, it returns the recognition results. Using the structural information stored in a predefined structural dictionary, our algorithm can identify the handwriting errors automatically and feedback to students together with recognition results. Here, we have modified the traditional DPM algorithm that allows writing speed free variability and improve the recognition accuracy.

## *1.2 Related Background*

In recent years, several research efforts have been done on e-learning system [3, 4] which aims to guide students to get more useful advice in their autonomous learning. They had developed an intelligence tutoring learning method to provide autonomous learning environment to the students. With the development of pen-based devices, it is now possible to apply e-learning techniques to handwriting education. Several handwriting education systems have been provided for different languages such as: Chinese, Latin and Arabic. It can be organized on three categories: read only systems, guided ones and systems with automatic errors detection. In case of Chinese handwriting education systems, the work proposed in [5] can find both the stroke production error and stroke sequence error but they did not consider the spatial relationship errors.

To develop a web-based handwriting education system for learning of handwritten Bengali characters, we need to develop an online recognition algorithm for cursive Bengali characters. Extensive research on cursive handwriting recognition has been done during the last few decades for different languages. However, there has not been much work on handwriting recognition of Indian scripts. Particularly, there have very few attempts for the recognition of online Bengali handwritten characters [6, 7]. But both of these two approaches are not applicable for the development of web-based handwriting education system, because of slow recognition speed. In our proposed education system, we have developed efficient hierarchical online recognition algorithm to speed up our system. Here, the student can practice their writing on the digital tablet accessed from both of iPhone/smartphone or computer browser. Then, our recognition engine can analysis the student's handwriting input and checks the handwriting errors to provide useful feedbacks.

## **2 Bengali Handwriting Education System**

### *2.1 Handwritten Bengali Character Set*

Bengali is official language/script of Bangladesh and used by 211 million people of India and Bangladesh. It is also second most popular language/script in India and fifth most popular language in

the world. Bengali, like other major Indian characters, is a mixture of syllabic and alphabetic scripts. It came from the ancient Indian script, Brahmi. The concept of upper/lower case is absent here and the direction of writing policy is left to right. Examples of Bengali characters are shown in Table 1. Bengali language consists of 50 basic characters including 11 vowels and 39 consonants. Most of the characters in Bengali language have a horizontal line at the upper part. We call this line as head-line or matra. Vowels have their modified shapes called vowel modifiers (VM). In Bengali script a vowel following a consonant takes a modified shape. Depending on the vowel, its modified shape is placed at the left, right (or both) or bottom of the consonant. These modified shapes are called modified or syllabic characters. In Bengali, there have 10 vowel modifiers which are joined with 35 of consonants and make 350 modified syllabic Bengali characters. On the other hand, several consonants or a vowel in conjunction with a consonant form a large number of possible different shapes, called compound characters. However, in the present day Bengali text, the occurrence of compound characters is less than 5% and the rest is only basic characters and vowel modifiers. So, our proposed autonomous learning system is focused on the learning and recognition of Bengali basic characters.

Table 1: Different shape of Bengali Characters

| Type       | Characters  | Number |    |
|------------|---|--------|----|
| Vowels     | অ(a) আ(aa) ই(i) ঐ(ii) উ(u) ঊ(uu) ঋ(ri) এ(e) ঐ(ai) ও(o) ঔ(au)  | 11     | 50 |
| Consonants | ক(ka) খ(kha) গ(ga) ঘ(gha) ঙ(nga) চ(ca) ছ(cha) জ(ja) ঞ(jha)<br>ণ(nya) ট(tta) ঠ(ttha) ড(da) ঢ(dha) ন(na) ত(ta) থ(tha) দ(da)<br>ধ(dha) ন(na) প(pa) ফ(pha) ব(ba) ভ(bha) ম(ma) য(ya) র(ra) ল(la)<br>শ(sha) ষ(ssa) স(sa) হ(ha) ঝ(rra) ঞ(rha) ঞ(yya) ঞ(khandata)<br>ঞ(visarga) ঞ(anus -vara) ঞ(chad) | 39     |    |

## 2.2 System Architecture

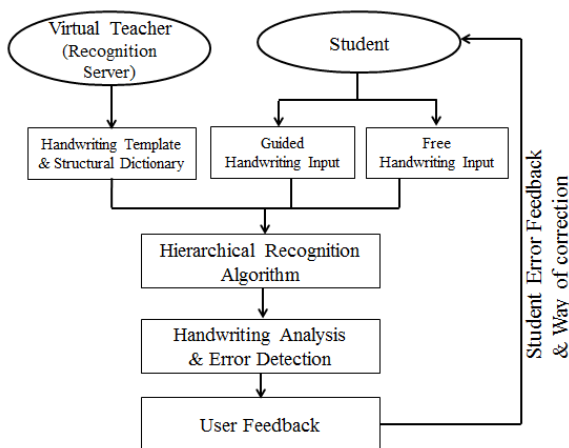


Figure 1: The architecture of the proposed Bengali Handwriting Education System

Figure 1 represents the operational flow of our proposed Bengali handwriting education system for autonomous learning. The proposed system is composed of two modules: the guided writing mode and the free writing one. The architecture of the system is detailed in figure 1. As shown in figure 1, students have the choice to practice the guided handwriting mode or the free one. In case

of free handwriting mode, writing will be done on a blank area, figure 2(b). The guided writing mode is one of the first levels of education designed for the children's who are in the early stages of learning. This tool displays a transparent image onto the digital web interface comprising this handwriting template, figure 2(a). Then, the user is invited to follow this image to replicate the pattern of script. After student submits their sample character, handwriting input was received in our recognition server (saying as virtual teacher) through WWW client-server interface. Then, by matching the handwriting template and the handwriting input, the recognition of the inputted character will be carried out. Finally, the automatic stroke error detection can immediately locate the student's handwriting errors and provide an immediate feedback to the student about the location of the error; their type and how to correct them (table 2 and table 3). The details of the automatic stroke error detection will be described in the following section.

We have developed a digital web interface that can access from both of iPhone/smartphone or computer browser. Figure 2 shows the snapshot of our web-based digital interface. It has three fields:

(1) Handwriting character input field, (2) Recognized character output field, and (3) Options buttons field. While the users write Bengali characters with an input device (e.g., pen, mouse, finger etc.) on the character input field. Then, our digital web interface gets the corresponding stroke data (sequence of points)

and sent to recognition server. Those data stored at the database, later we used it to evaluate our proposed education system. Once the interface gets the recognition result from the server, result is displayed at the character output field with system font including student's error feedback.

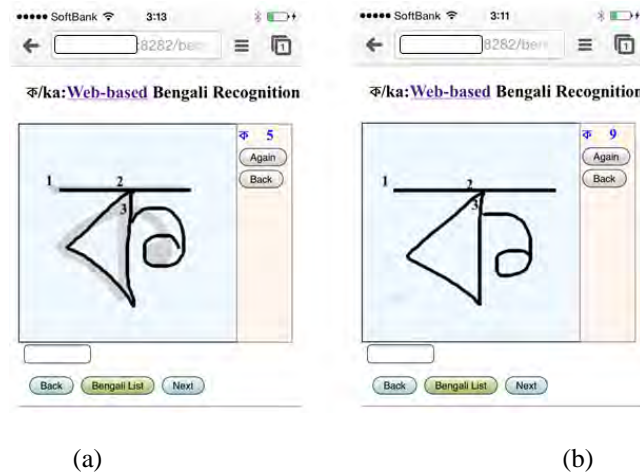


Figure 2: Digital web interface for Bengali handwriting education System that can be accessed from both of iPhone/smartphone or computer browser: (a) Guided handwriting mode (b) Free handwriting mode.

### 2.3 Automatic Stroke error detection & Stroke Feedback

#### 2.3.1 Student Feedback for Autonomous Learning

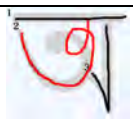
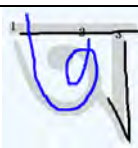


In our Bengali handwriting education system, we have developed an automatic stroke error detection methodology. It aims to identify the handwriting errors in student's handwriting and provide immediate feedback. We classified the handwriting errors as stroke production error and stroke relationship error and stroke order error. Stroke production error consists of reverse stroke direction, split stroke and merge stroke errors etc. On the other hand, stroke relationship error is the error where students write the stroke with extra length and the stroke order error is the error of wrong stroke sequence.

Our automatic stroke error detection engine identifies the student's handwriting error and provides feedback to correct them. This error detection methodology was implemented using JSON: JavaScript Object Notation technology, see in figure 5. In this methodology, we marked erroneous strokes using different color models depend on the student's handwriting errors as shown in table 2 and 3. The notation of `{"r":["অ", "score"], "d":[1,-2,3], "c":["black", "red", "black"]}` is an example to clarify our proposed JSON technique. Here, we marked the reverse direction input stroke for character অ[a] by the red color. In this notation, "r" stands for the recognized character and its recognition score, "d" represents the stroke orders, and "c" is the color combination to mark the reversely inputted stroke. While the students write any stroke with reverse direction then our system

Table 2: Bengali handwriting error and idea of student's feedback

| # | Error Category            | Error Details            | Color Marked Feedback |
|---|---------------------------|--------------------------|-----------------------|
| a | Correct handwriting       | Correct Stroke           | <b>Black</b>          |
| b | Stroke production errors  | Reverse direction        | <b>Red</b>            |
|   |                           | Split/broken stroke      | <b>Purple</b>         |
| c | Stroke relationship error | Stroke with extra length | <b>Blue</b>           |
| d | Stroke order error        | Wrong Stroke Sequence    | <b>Brown</b>          |

Table 3: Examples of handwriting error patterns of Bengali characters: (a) Stroke production error. (b) Stroke relationship error. (c) Stroke order error. (Numeric symbols means stroke no. and its start point)

| # | Student's Error Feedback  | Error Type                               | # | Student's Error Feedback   | Error Type                                |
|---|---|--|---|--|---|
| 1 |  | Reverse stroke direction<br><b>(Red)</b> | 3 |  | Stroke with extra length<br><b>(Blue)</b> |
| 2 |  | Split stroke<br><b>(Purple)</b>          | 4 |  | Wrong stroke order<br><b>(Brown)</b>      |

detect it and feedback with appropriate color marking. In this case, the second stroke was marked as red color. Thus, our proposed education system feedback student's error using different color models depend on their handwriting errors as shown in table 2 and 3.

### 2.3.2 Automatic stroke error detection: How does it work

In our web-based intelligent handwriting education system, we developed predefined structural dictionary based on the structural information of Bengali characters. Table 4 is the snapshot of structural dictionary for a single Bengali characters অ[a]. Based on this information, our recognition engine can successfully recognize the handwriting errors of Bengali characters and then feedback to students with necessary color marking.

Table 4: Snapshot of our predefined structural dictionary

| #Unicode  | Char. | Index | Positional Condition | Stroke order  | Comments       |
|-----------|-------|-------|----------------------|---------------|----------------|
| 0985 0000 | অ     | 0     | y2-b1! y2-j1! a3-x2! | 1 2 3         | #Correct       |
| 0985 0000 | অ     | 1     | y1-b3! y1-j3! a2-x1! | <b>2 3 1</b>  | #Order errors  |
| 0985 0000 | অ     | 2     | y1-b2! y1-j2! a3-x1! | <b>2 1 3</b>  | #Order errors  |
| 0985 0000 | অ     | 3     | y1-b2! y1-j2! a3-x1! | 1 <b>3 2</b>  | #Order errors  |
| 0985 0000 | অ     | 4     | y2-b1! y2-j1! a3-x2! | 1 <b>-2</b> 3 | #Reverse error |

In table 4,  $(x, y)$  and  $(i, j)$  with corresponding stroke number represents the starting and ending point of input stroke respectively.  $(a, b)$  is the central point and calculated as  $a=(x+i)/2$ ;  $b=(y+j)/2$ . For example,  $(x_1, y_1)$ ,  $(i_1, j_1)$  and  $(a_1, b_1)$  represents the starting, ending and central point of first stroke. Similarly, the  $(x_2, y_2)$ ,  $(i_2, j_2)$ ,  $(a_1, b_2)$  and  $(x_3, y_3)$ ,  $(i_3, j_3)$ ,  $(a_3, b_3)$  represent the starting, ending and central point of second and third stroke. In this structural dictionary, single template character was presented with multiple structural patterns depend on its probable handwriting errors [8]. For example, the Bengali character অ[a] has 5 structural patterns considering its probable error case. Here, the third column, index is used to identify the handwriting error pattern of corresponding student's input. The fourth column, positional condition is used to locate stroke relationship error and provide correct recognition output together with necessary error feedback. Finally, the fifth column, stroke order is used to identify which stroke sequence was inputted and then provides colorful feedback to students about their wrong stroke sequence. Also, it identifies the reverse stroke direction errors by checking the negative value in stroke order column (5<sup>th</sup> column in Table 4). The all of this error detection mechanism will be discussed as below:

In our online handwriting recognition engine, we used client-server interface to extract the feature points and relevant structural information as  $(x, y)$  coordinates along the trajectory of the input device (e.g., pen, mouse, finger etc.) onto the digital web interface. Then, we convert it to angular

feature and match those angles with the angular features of preselected template characters and obtain a matching distance between them. In our system, each template character has its different structural patterns (index 0~4, as shown in table 4). Finally, it selects the optimal distance as the recognition results. Below is the mathematical notation:

$$k = \underset{k \in K}{\operatorname{argmin}} \{d_k\} \dots\dots\dots (1)$$

$K$  = Total number of template characters

$k$  = Student's sample character

$d_k$  = Angular distance between sample characters and template characters considering multiple structural patterns of each template.

$O_k$  = Stroke order patterns

As discussed above, the character with optimal  $d_k$  is selected as recognition result and thus the corresponding index number can easily be identified. After the identification of index number, the relevant stroke order,  $O_k$  can also be located from the column 5 in table 4. Then we return the feedback to students about their writing mistake by marking the wrong strokes with brown color.

If the identified stroke order  $O_k$  has any negative value then our recognition engine can detect that the student has inputted a stroke with reverse direction. Then it returns feedback to students by marking the reverse strokes with red color. After the identification of reverse stroke direction, our recognition algorithm reverses the angular feature of corresponding template characters and matches with sample characters. In our system, angular feature of original template characters is stored into an array  $t[]$ . After the detection of reverse stroke direction, our algorithm automatically converted angular feature of original template characters using a common angular conversion rule ( $180^\circ - \text{angle}$ ) and stored into an array  $r[]$ . Then we match the student's input stroke with corresponding reversed stroke of template characters. Thus, our recognition engine can successfully accept the reverse stroke input and provide students the correct recognition result.

In table 4, the fourth column is used to identify the stroke relationship errors, such as Stroke with extra length. In case of Bengali characters ঞ[a], the second stroke position is bottom of the first stroke. In correct recognition case, it satisfies the condition of  $y_2 > b_1$  ( $y_2 - b_1!$  in 4<sup>th</sup> column) where  $y_2$  is the start point of second stroke and  $b_1$  is the central point of first stroke. From the student input stroke data, our automatic error detection engine can judge that whether  $y_2 > b_1$  or not. If  $y_2 > b_1$  then handwriting was correct otherwise there have a stroke relationship error and then feedback to the students by marking the inputted stroke with blue color. In this way, our proposed intelligent handwriting education system can successfully provide the error feedback together with recognition output.

## 2.4 Recognition Methodology

In our bengali handwriting education system, a web-based handwriting client-server interface technique has been used for character recognition and student's feedback. We have designed the proposed system with the following distinctive features: (1) it is a web-based system developed by Java web application technology and works on WWW client browser (PC or iPhone/Smart phone browser) (2) Easy character input environment is provided according to use of rich editing functions and the input device (e.g., pen, mouse, finger etc.) (3) HTML5 canvas technology was used to detect and draw user input (4) Apache tomcat web server and PostgreSQL database was used for system implementation (5) Consecutive handwriting and recognition is possible (6) immediate student feedback.

Figure 3 shows the handwriting recognition architecture that contains both of web-based handwriting interface and character recognition servers. Handwriting interface was developed by JSP and runs on WWW client, such as PC browser or iPhone/Smartphone browser. On the other hand, JSP based character recognition engine works on Apache tomcat web server (Linux server). While the students write Bengali characters with an input device (e.g., pen, mouse, finger etc.) on the character input field. Then, our digital web interface gets the corresponding stroke data as  $(x, y)$  coordinates and sent to the character recognition server. After that, the recognition engine converts the student's stroke data into angular feature in feature extraction stage, see in right side of figure 3. After applying smoothing to those extracted angular feature, our algorithm entered into hierarchical filtering stage. In



this stage, we have applied a series of filters in a hierarchical manner to reduce the search space of final DP matching. The first filter performs coarse classification on a large number of candidates based on the high level features of stroke patterns, such as stroke number. It reduces the candidate character models. Then the second filter performs structural preselection among the resulted samples of filter 1, based on the structural information of Bengali characters stored in our predefined structural dictionary (table 4). Again, it reduces to a small number of candidates for final DP matching. In the final matching stage, low-level features (angular feature) are used to guide a dynamic programming matching algorithm. In this stage, it calculates distance between input strokes and template strokes of each preselected characters by using our modified DPM. The character with optimal distance is selected as recognition result. After that, our recognition engine returns  $k$  top ranked characters as recognition results to client side browser. Then, it displayed the results into recognized character output field of our digital web interface.

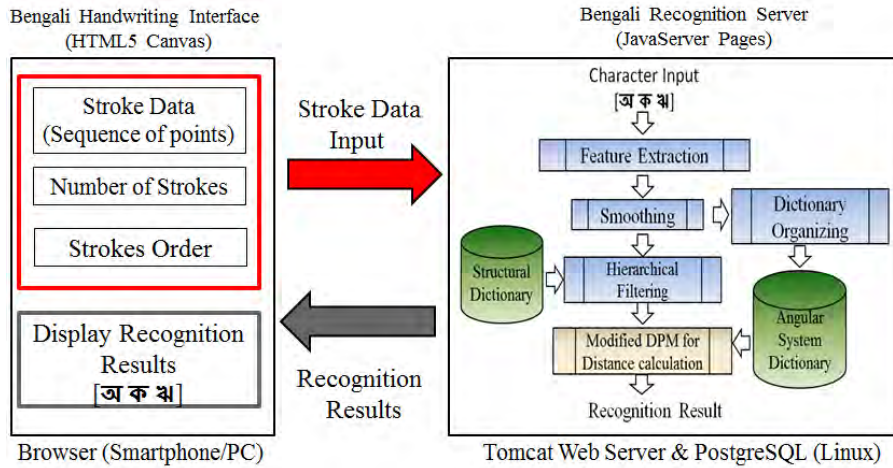


Figure 3: Handwriting recognition architecture for Bengali handwritten education system

#### 2.4.1 Modified Dynamic Programming for writing speed-free recognition

In this section we explained about our proposed modified dynamic programming algorithm that support writing speed free recognition. In our proposed system, the recognition scheme is carried out using dynamic programming concept which is modified by accepting different length of input feature points to support writing speed free recognition. According to dynamic programming matching algorithm, handwritten input pattern is matched with template patterns by calculating optimal matching cost, also known as character distance [9, 10, and 11]. In our recognition scheme, the term character distance stands for the angular difference between input stroke's angles and corresponding template stroke's angles. Then the character with optimal distance is selected as our recognition output and return back to students with necessary feedback. The mathematical notation for DP matching is explained as follows.

To match handwritten input character with the template characters, we calculate character distance,  $D_k$  for corresponding template pattern  $k$ . A normalize distance  $D_k$  for the candidate character  $k$  can be calculated as follows,

$$D_k = \frac{1}{L} \sum_{l=1}^L d_{kl} \dots\dots\dots(2)$$

Where,  $L$  is the number of total input strokes,  $k$  is the candidate template characters, and  $l$  is the number of handwritten strokes. The candidate character with smallest  $D_k$  is selected as the recognition result for current handwritten input character. The stroke distance for each template character can be calculated using dynamic programming matching technique as follows,

$$d_{kl} = \frac{g(I_l, J_{kl})}{I_l + J_{kl}} \dots\dots\dots(3)$$

Where,  $g(I_l, J_{kl})$  represents the DPM distance between input feature vector  $I_l$  and  $k_{th}$  template feature vector  $J_{kl}$  for corresponding stroke  $l$ . The following recurrence relation is used to find the DPM distance between two sequences,

initially,

$$g(i, j_{kl}) = \begin{cases} 0 & (i = 0, j_{kl} = 0) \\ \infty & (\text{other}) \end{cases}$$

recursively,

$$g(i, j_{kl}) = \min \left\{ \begin{array}{l} g(i, j_{kl} - 1) + d(i, j_{kl}) \\ g(i - 1, j_{kl}) + d(i, j_{kl}) \\ g(i - 1, j_{kl} - 1) + 2d(i, j_{kl}) \end{array} \right\} \dots\dots\dots(4)$$

Where,  $g(I, J_{kl})$  is the cumulative distance up to the current template character,  $d(i, j_{kl})$  is local cost for measuring the dissimilarity between  $i^{th}$  and  $j_{kl}^{th}$  point of two sequences.

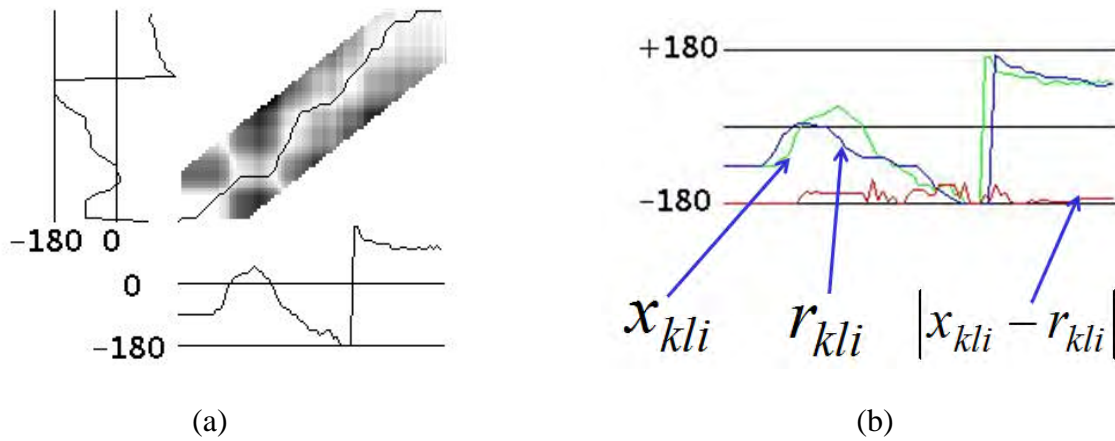


Figure 4: Dynamic programming matching: (a) illustration of wrapping path for the 2<sup>nd</sup> stroke of Bengali character  $\text{দা}$  (b) Calculation of local distance also known as dissimilarity between two strokes sequences of input and template.

Figure 4 represents illustration of wrapping path for DP matching and dissimilarity measurement between two strokes sequence. Here,  $x_{kli}$  represents the student's input stroke angles and  $r_{kli}$  represents the template stroke angles. The local distance as well as dissimilarity between the two stroke sequences can be measured as below:

$$d(I_l, J_{kl}) = \begin{cases} |x_{kli} - r_{kli}| & \{-180^\circ \leq |x_{kli} - r_{kli}| \leq 180^\circ\} \\ 180^\circ - |x_{kli} - r_{kli}| & \{|x_{kli} - r_{kli}| < -180^\circ\} \text{ or } \{180^\circ < |x_{kli} - r_{kli}|\} \end{cases} \dots\dots\dots (5)$$

To establish writing speed free recognition, we modified the traditional dynamic programming algorithm. As we explained in previous section, our handwriting digital web interface extracts the user stroke data (feature points) and sent to our recognition server. Fundamentally, the number of extracted feature points is inversely proportional to student's handwriting speed. Slow writing speed provides large number of feature points, and oppositely fast writing has small number of feature points.

$$\text{Number of input stroke data} \propto \frac{1}{\text{Students handwriting speed}} \dots\dots\dots (6)$$

As in equation 5, local cost as well as dissimilarity measurement between  $i^{th}$  and  $j_{kl}^{th}$  point of two sequences can be calculated by  $d(I, J_{kl})$  where  $I$  is the number of input stroke and  $J_{kl}$  is the number of  $k^{th}$  template stroke. For slow handwriting case,  $I$  may greater than or equal to  $2 * J_{kl}$ . Oppositely in case of fast handwriting,  $J_{kl}$  may greater than or equal to  $2 * I$ . In this condition, the calculation of local stroke

distance, dissimilarity measurement  $d(I, J_{kl})$  (in equation 5) may fail due to the adaptability problem of adjustment window size in DPM algorithm. To avoid this problem, we modified the existing DPM to accept the input strokes data of any length wherever it greater or smaller than two times of corresponding template stroke's length. By using the following settings of adaptive adjustment window size as equation 6, our modified DPM can accept any length of handwriting input. Here,  $W$  represents the adjustment window size. From the experimental analysis, we found the optimal value of  $W=18$ , that makes our system highly adaptable to recognize rough handwriting characters.

$$1 \leq i \leq I_l, \max\{1, i \times \frac{J_{kl}}{I_l} - W\} \leq j_{kl} \leq \min\{J_{kl}, i \times \frac{J_{kl}}{I_l} + W\} \dots\dots\dots (7)$$

In practical, our intelligent Bengali handwriting education system was developed to improve the Bengali literacy rate by considering both of children and older students. Basically, children have slow handwriting speed and aged people have fast handwriting speed. By the above modification, our recognition engine can accept both of input patterns from children and older people. In this way, we can successfully implement the writers' independent recognition algorithm for our web-based Bengali handwriting education system. By using this writing speed free recognition technique, the accuracy was improved considerably. In next section, we evaluate our proposed system using a rich Bengali handwritten character database.

### 3 Experimental Results

For our experiment, handwritten patterns were collected from 24 Bengali native writers of different groups with respect to age, education and gender, where each has written almost 10 times of every character sample. There are 50 basic characters in Bengali and therefore the proposed system has been evaluated by using 12,500 handwritten online character samples. We study the performance of proposed web-based intelligent handwriting education system by the three criteria: average recognition accuracy, average recognition speed, and automatic error detection capability.

**Table 5: The Experiment Results**  
**Scheme1: Modified Dynamic Programing Algorithm**  
**Scheme2: Traditional Dynamic Programing Algorithm**

| Recognition Scheme | No. of Database | Top1 (%) | Top2 (%) | Top3 (%) | Speed (ms/char) |
|--------------------|-----------------|----------|----------|----------|-----------------|
| Scheme1            | 12500           | 87%      | 92%      | 95%      | 40ms            |
| Scheme2            | 12500           | 78%      | 80%      | 83%      | 880ms           |

Average recognition accuracy can be calculated by dividing the number of correctly recognized test patterns with the total number of test patterns. Average recognition speed is calculated by dividing the total recognition time with number of recognized test patterns and its unit is characters per millisecond (ms). Average recognition accuracy is given up to top 3 choices. In this experiment, we used two different recognition schemes, Scheme1 and Scheme2, writing speed free modified DPM was used for final matching stage in Scheme1 whereas traditional DPM was applied in Scheme2. Table 5 gives the experimental results of our proposed system. We noticed that Scheme1 achieved the highest recognition accuracy for every top choice; particularly it achieved 95% accuracy considering Top3 choice. Moreover, the recognition time for Scheme1 is about 22 times lower than that of Scheme2. These facts ensured that proposed hierarchical recognition with modified DPM reduced the inherent computational complexity and speed up the recognition.

Figure 5 represents the snapshot of student's feedback result to correct their error handwriting. As we described in section 2.3, our proposed education system can successfully feedback to the students about their error handwriting using colorful marking technology. We implemented this method to our system by JSON: JavaScript Object Notation technology. In our preliminary experiment, we gathered stroke data from high level native Bengali speakers. In future we will do the experiment for various levels of Bengali learners with different age. Finally, we made a survey among 100 (almost) of native Bengali speakers for the acceptance of our education system. We considered the user's viewpoints about the system effectiveness. The user's comments confirmed that the proposed Bengali handwriting education system can be very helpful to improve the Bengali literacy rate in near future.

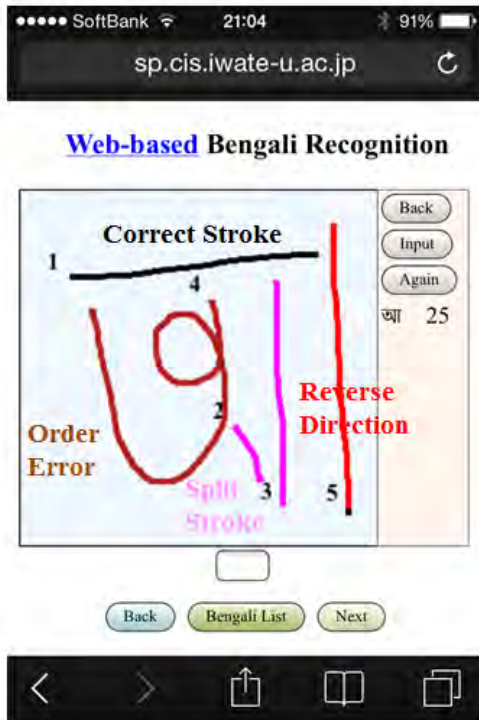


Figure 5: Automatic error detection and colorful feedback to correct student's error handwriting. (Numeric symbols means stroke no. and its starting point)

## 4 Conclusion and Future Work

In this paper, we have described about the implementation details of web-based intelligent handwriting education system for autonomous learning of Bengali handwritten characters. Here, we developed a web-based (iPhone/Smartphone or computer browser) handwriting client-server interface using JavaServer Page (JSP) technology to improve the Bengali literacy rate. We used 12500 of Bengali isolated character database for system evaluation. Our experimental results showed that the use of hierarchical recognition algorithm together with writing speed free modified DPM improved the recognition accuracy to 95% as well as recognition speed of 40ms. It makes our recognition algorithm adaptable for the application of web-based language learning application. Our automatic error detection methodology ensured the necessary feedback to the students to learn about their handwriting mistake autonomously. In future, we will focus our research on the development of Bengali handwriting education system considering Bengali word learning. Furthermore, partial function of our system can be accessed from the following URL:

"<http://www.sp.cis.iwate-u.ac.jp/icampus/b/>"

## Acknowledgements

We would like to thank all the people who supported to accomplish this work.

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# The Effect of Visualizing Lesson Structures in a Teacher Education Program

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**Abstract:** We have built an instructional design support system called “FIMA-Light” which reasons about a teacher’s intentions from his/her lesson plan and automatically produces I\_L event decomposition trees. The decomposition tree expresses the ways of achieving a learner’s state change that should be realized in a whole lesson in the form of a tree structure. In this paper, we discuss the difficulty of attaining the goals of university education without using our approach. We also report on practical use of FIMA-Light in teacher training at university in order to investigate changes in students’ awareness of teaching strategies brought about by providing them with I\_L event decomposition trees.

**Keywords:** Instructional Design, Ontology, Teacher Training, Teachers’ Professional Ability

## 1. Introduction

Alignment between teaching practices in school and teacher education provided at university is an important aspect in improving teacher education programs (The Central Education Council, 2006). However, almost all universities provide only abstract descriptions in their policies, such as “Bridging Theory and Practice” (Department of Teaching & School Leadership, Okayama University, 2013; Fujimura & Sakanashi, 2010; Graduate School of Teacher Education, Waseda University, 2013) about the alignment between teaching practices and university education. One group (Mishima, Saito & Mori, 2009) analyzed the awareness of trainee teachers before and after their teaching practices in the classroom and found that they tend to notice the importance of their university education only after completing their teaching practices. This tendency suggests that alignment between teaching practices and university education is not necessarily successful. In this study, we examined the ability of teachers to instruct learners (the ability to properly design and practice instruction). We also clarified the respective roles of teaching practice and university education in teacher education programs, as well as the relationship between them (Kasai, Nagano & Mizoguchi, 2013). From this investigation, we identified the following two main goals that university students (trainee teachers) should aim to achieve in their university education before their teaching practices:

- To understand that there are various strategies (instructional/learning theories, teaching knowledge obtained from practices, etc.) for students to attain educational goals.
- To improve their skill at interpreting global and local strategies included in lessons designed by themselves or others
  - in order to learn skills from lessons designed by expert teachers, and
  - in order to improve their skills through discussion with peer students.

We considered that the I\_L event decomposition tree (described in 3.1), which is defined based on the OMNIBUS ontology (Hayashi, Bourdeau, & Mizoguchi, 2009), might be suitable for such university education. We think that the goal of the university education should be to let university students learn the skills needed to produce not only lesson plans but also I\_L event decomposition trees. Since university students cannot think in the structure of lessons, it is difficult

for them to produce I\_L event decomposition trees. We have proposed the use of a system called “FIMA-Light” (Kasai, Nagano and Mizoguchi, 2011) which automatically produces I\_L event decomposition trees. In that study, we showed that I\_L event decomposition trees that FIMA-Light produces had effective information for university education in a teacher training course. In this paper, we report the results of practical use of FIMA-Light in university lectures in a teacher training course. The aim of this practical use was to investigate changes in students’ consciousness about strategies brought about by providing them with I\_L event decomposition trees.

The remainder of this paper is structured as follows: In Section 2, we explain the difficulties in attaining the goals of university education without using our approach. In Section 3, we describe the features of our study that can overcome these difficulties. In Section 4, we report the results of the practical use of FIMA-Light in lectures in a teacher training course. This is followed by a discussion of some related work and concluding remarks in Section 5.

## **2. Difficulties in Attaining the Goals of University Education**

In this section, we explain the difficulties in achieving the goals of university education in the current situation (without using our approach). In order to achieve the goals, it is necessary to achieve the following four sub-goals for goal achievement. Below, we explain the difficulty in achieving each sub-goal.

- Professors who have the skills that university students should acquire and who can instruct them should exist in the teacher training course.

Since professors in various domains instruct university students, it is important to share various strategies (instructional/learning theories, teaching knowledge obtained from practices, etc.) among the professors so that university students do not become confused. However, it is often difficult to share strategies (especially teaching knowledge obtained from practices) among them, since their fields of specialty are different.

- Professors should teach university students various strategies.

What university students should learn is that various strategies exist to attain an educational goal. Therefore, it is important to teach them every strategy in the same representation format so that they can compare them. However, it is difficult to attain this sub-goal, since representation formats differ among different learning/instructional theories.

- Professors should teach strategies that are applied in expert lessons from global to local viewpoints.

This sub-goal is to make university students understand the relations between various strategies and actual lessons. Here, in order to represent outlines of lessons, most universities (faculties) offering teacher education and school teachers utilize a format called a “lesson plan”. Though there is no standardized format for a lesson plan, in general, teachers use a lesson plan to describe the learning activity, instructional activity, evaluation method, and points to consider while teaching in every scene of their lessons. However, since a lesson plan describes mainly superficial concrete activities, it is difficult to describe strategies that include the teachers’ deep intentions. Therefore, in order to attain this sub-goal, professors have to extract global and local strategies that are included in each lesson by interpreting the lesson plan. Even if professors have sufficient skills, it is difficult for them to interpret teachers’ intentions that are not described.

- Professors should make university students aware of the relations between various strategies and lesson plans designed by the university students.

In university education, university students should improve their skills in designing lessons that integrate a global strategy for attaining an overall goal in the whole lesson and local strategies for attaining sub-goals. However, before they attain this goal, they themselves cannot interpret relations between strategies and lessons that they design from global to local viewpoints. Therefore, professors have to interpret the lesson plans that university students design. Since

lesson plans designed by university students often include illogical and unnatural flows, it is more difficult for professors to interpret the lesson plans.

The purpose of this study is to solve the difficult problems explained in this section and to provide a method that supports the achievement of the goals of university education.

### **3. Features of this Study**

In this section, we explain the I\_L event decomposition tree and FIMA-Light which we propose for practical use in university education in order to solve the problems described above.

#### *3.1 The I\_L event decomposition tree and its features*

In the format of a “lesson plan”, teachers describe the learning activity, instructional activity, evaluation method, and points to consider while teaching in every scene of their lessons. This format is generally used also in teaching practices. Therefore, it is important for trainee teachers to learn how to describe their plans for their lessons in the format of a lesson plan before their teaching practices. However, since a lesson plan describes mainly superficial concrete activities, it is difficult for university students to consider strategies to be applied in the lesson from global to local viewpoints. Therefore, we think that effective instruction in university education cannot be realized using only the lesson plan as a format to represent lessons. Another representation format that will help university students to think from a more global viewpoint is required.

We considered that the I\_L event decomposition tree, which is defined based on the OMNIBUS ontology (Hayashi, Bourdeau, & Mizoguchi, 2009), might be suitable for such university education. The OMNIBUS ontology has been constructed to organize a variety of learning/instructional theories and empirical knowledge extracted from best practices independently of learning paradigms. The core concepts of the OMNIBUS ontology are an I\_L event and its decomposition structure. An I\_L event is a basic unit of learning and instruction and is composed of a state change of a learner, an instructional action, and a learning action. A method for realizing the state change (macro I\_L event) is expressed by a decomposition relation with multiple micro I\_L events, called a WAY. In the OMNIBUS ontology, every piece of knowledge extracted from learning/instructional theories and practices can be described as a WAY. A macro I\_L event is decomposed into several micro I\_L events by applying a WAY. With this modeling framework, the flow of a lesson is modeled as a tree structure of I\_L events that is called an I\_L event decomposition tree. The root node of the decomposition tree is an I\_L event that shows the intended learner’s state change that should be realized in the whole lesson. In the decomposition tree, higher layers express instructional strategies of more global viewpoints. And by decomposing these into lower layers, this decomposition tree can express instructional strategies of more local viewpoints.

We think that these features of the OMNIBUS ontology and the I\_L event decomposition tree can solve the problems caused by the lack of a unified representation format for various strategies.

#### *3.2 Overview of FIMA-Light*

FIMA-Light automatically produces relevant I\_L event decomposition trees from the trainee teachers’ lesson plans based on the OMNIBUS ontology. In order to input lesson plans to FIMA-Light, teachers select concepts prepared as instructional and learning activities for each step in the flow of their lesson plans. The current version of FIMA-Light produces I\_L event decomposition trees based on 100 Ways that were extracted from learning/instructional theories

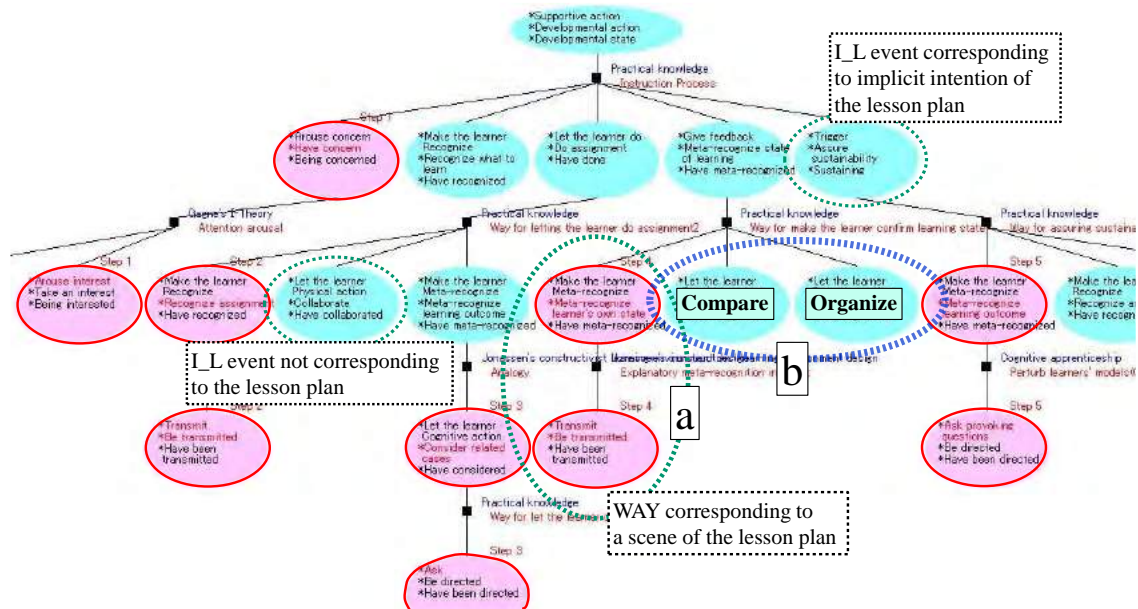


Figure 1. An example of an I\_L event decomposition tree and its structure.

and 20 Ways that were extracted from practice lessons. An example I\_L event decomposition tree that FIMA-Light produced by interpreting an actual lesson plan is shown in Figure 1. An I\_L event decomposition tree includes two kinds of nodes. One includes pink nodes that show I\_L events which FIMA-Light judged corresponding to the lesson plan. The other includes blue nodes that show I\_L events that FIMA-Light judged not corresponding to any steps explicitly described in the lesson plan. The aim of FIMA-Light is to help teachers to deeply reflect on their lesson plans by providing them with the I\_L event decomposition trees. By doing so, it is expected that they themselves will notice how to improve their lessons. We evaluated FIMA-Light in actual use. The results of the evaluation showed that FIMA-Light produced I\_L event decomposition trees that were sufficiently relevant to the designed lessons (teachers answered that, on average, 89.2% of the nodes were relevant to the designed lessons). Thanks to the I\_L event decomposition trees provided by FIMA-Light, teachers found 2.5 improvement points in each lesson plan, on average.

In university lectures of a teacher training course, FIMA-Light produced 30 I\_L event decomposition trees by interpreting lesson plans that university students designed (refer to Section 4). We think that the interpretation of these 30 lesson plans could not have been realized without this system.

## 4. Use of FIMA-Light in University Lectures

### 4.1 Purpose of the Use of FIMA-Light

The lectures in which we used FIMA-Light were “Studies on Information Study Method A” and “Studies on Educational Contents of Technology Education (Information)”, given at the Faculty of Education that one of the authors of this paper belongs to. Ten students attended these lectures in 2013. All students had learned how to write lesson plans in other lectures and had experience of teaching practice. The purpose of this investigation was to find answers to the following three questions:

- Can university students on teacher training courses be aware of the relations between the flow of instructions and the educational goals of instructions (whole goals and sub-goals of instructions) from descriptions of lesson plans?
- Can FIMA-Light produce I\_L event decomposition trees that are sufficiently relevant to lessons designed by university students?



- Can I\_L event decomposition trees improve university students' awareness of strategies from global to local viewpoints, whose aim is to let school students attain the educational goals?

In order for university students to efficiently attain the above goals in their university education, it is necessary to create suitable feedback based on I\_L event decomposition trees according to the situation. As a preliminary stage to a discussion of suitable types of feedback, we focused on the changes in university students' awareness brought about by providing them with I\_L event decomposition trees. The investigation was conducted via the following steps.

1. The instructor (the first author of this paper) directed the university students to create lesson plans and describe what teachers should consider in each scene of the lessons to attain the overall goal of the whole lesson or sub-goals, if they noticed something.
2. The instructor directed the university students to evaluate learning/instructional flows of lesson plans that other students created and to give their comments.
3. The instructor provided every university student with other students' comments and directed them to improve their lesson plans.
4. The instructor explained the I\_L event decomposition tree.
5. The instructor inputted data of all lesson plans into FIMA-Light and provided every university student with two I\_L event decomposition trees which FIMA-Light produced based on his/her lesson plans (two versions of the lesson plan before and after improvement).
6. The instructor asked every university student whether or not every node of his/her I\_L decomposition tree was relevant to his/her designed lesson, independently of whether this was done explicitly or implicitly.
7. The instructor directed them to improve their lesson plans.
8. The instructor inputted data of improved lesson plans into FIMA-Light and provided the university students with the I\_L event decomposition trees. The instructor asked them whether or not every node of the I\_L event decomposition trees was relevant to his/her designed lesson.
9. The university students gave a score between one and five (with one being the lowest and five being the highest) in response to the question, "Did you think that your awareness of strategies from global to local viewpoints, whose aim was to let students attain the educational goals, was enhanced by the I\_L event decomposition tree?"

The investigation was conducted by using the following five steps:

- A) We analyzed a rate the number of comments that evaluated the flow of the lesson based on the relation with the overall goal of the whole lesson or the sub-goals.
- B) We analyzed the 30 I\_L event decomposition trees (FIMA-Light produced three I\_L event decomposition trees for every university student).
- C) We analyzed how the number of descriptions of what university teachers should consider in attaining the overall goal of the whole lesson or the sub-goals changed by improving the lesson plans.
- D) We analyzed the results of the questionnaire conducted at the end.
- E) We analyzed how the university students improved their lesson plans when provided with the I\_L event decomposition trees.

#### 4.2 Results of the Investigation and Discussion

Table 1 shows the results of step A). The flow of a lesson plan cannot be evaluated without considering the relations with its purpose, which is to attain the goal of the whole lesson or the sub-goals. Therefore, the relations with goals should be included in all comments. However, the relations with goals were included in only 21 out of 50 (42%) comments. In particular, the relations with sub-goals were included in only 2 out of 50 (4%) comments. This result shows that university

Table 1. The result of the analysis of a rate of comments related to goals

| Total number of comments | The number of comments related to overall goals | The number of comments relate to sub-goals |
|--------------------------|---|--|
| 50                       | 19 (38%)  | 2 (4%)                                     |

students on teacher training courses are hardly aware of the strategies that are applied in order to attain the goals (especially sub-goals) of instructions from the descriptions of lesson plans.

Table 2 shows the results of step B). Some lesson plans designed by the university students included illogical and unnatural flows. However, FIMA-Light could produce I\_L event decomposition trees that included all scenes in the flow of 30 lesson plans (every university student designed three versions of the lesson plan). The university students answered that on average about 90% of nodes were relevant to designed lessons. These results show that the current version of FIMA-Light can produce I\_L event decomposition trees that are sufficiently relevant to the lesson plans that university students design.

Table 3 shows the results of step C). Every scene described in a lesson plan should have the role of attaining the overall goal of the whole lesson and the sub-goals. Therefore, one or more descriptions that include the relations with the goals of the instructions for every scene should exist. However, before providing the university students with I\_L decomposition trees, there was on average only one description in each lesson plan, though the instructor directed them and provided them with examples. This result shows that the university students were hardly aware of strategies (especially local strategies) whose aim was to let school students attain the educational goals. After they referred to the I\_L event decomposition trees, there were on average 5.1 such descriptions (including 1.6 descriptions related to sub-goals) in each lesson plan. The number of descriptions in the improved lesson plans is not enough either. We think that the increase in the number of descriptions related to goals in the instructions does not show that the skills which university students should learn in the university education improved, because global and local strategies in their lessons were provided explicitly by I\_L event decomposition trees. However, from the results of the questionnaire (university students gave an average score of 4.6 in step D)), we judged that providing students with I\_L event decomposition trees produced the following effects:

- improved the university students' awareness that there are various sub-goals according to strategies for attaining the overall goal of the whole lesson.
- improved the university students' awareness that there are various strategies for students to attain educational goals.
- improved the university students' awareness of strategies from global to local viewpoints, whose aim is to let school students attain the educational goals.

Table 2. The result of the analysis of 30 I\_L event decomposition trees

| Average of 10 I_L decomposition trees for each version               | The number of scenes of a lesson plan | The number of scenes included in a tree | Total number of nodes in a tree | The number of nodes related to the lesson plan (judged by university students) |
|--|---------------------------------------|---|---------------------------------|--|
| I_L event decomposition trees of the first versions of lesson plans  | 6.3                                   | 6.3 (100%)                              | 28.9                            | 24.6 (85.1%)   |
| I_L event decomposition trees of the second versions of lesson plans | 7.1                                   | 7.1 (100%)                              | 32.4                            | 28.1 (86.7%)   |
| I_L event decomposition trees of the final versions of lesson plans  | 8.9                                   | 8.9 (100%)                              | 37.6                            | 34.0 (90.4%)   |

Table 3. The result of the analysis of descriptions in the lesson plans.

| Average of 10 Lesson plans          | The number of scenes of a lesson plan | The number of descriptions related to goals of the whole lesson | The number of descriptions related to sub-goals in a lesson plan |
|-------------------------------------|---------------------------------------|---|--|
| The first versions of lesson plans  | 6.3                                   | 1.2   | 0.1  |
| The second versions of lesson plans | 7.1                                   | 1.3   | 0.1  |
| The final versions of lesson plans  | 8.9                                   | 3.5   | 1.6  |

Finally, we discuss concrete ways in which the university students improved their lesson plans when provided with the I\_L event decomposition trees (step E)). Most of the improvements were achieved by adding scenes in which “I\_L events not corresponding to the lesson plan”, as judged by FIMA-Light, were embodied. Figure 1 shows an I\_L event decomposition tree that FIMA-Light actually produced from a lesson plan on information technology for high schools, designed by one of the university students participating in the investigation. The educational goal of the lesson was that students should understand “the characteristics of digitization of still pictures”. In the original lesson plan before it was improved, there was a flow containing a scene, “the teacher has students answer some questions” (“a” in Figure 1). The description for this scene was “have students confirm their understanding of knowledge that they learned in the instruction”. This description shows the relation between this scene and the goal of the whole instruction. However, we could not interpret the university students’ awareness that they regard “students confirm their understanding of knowledge” as a sub-goal. In the I\_L event decomposition tree that FIMA-Light produced from the lesson plan, there were I\_L events (“b” in Figure 1) aimed at letting students “compare” and “organize” after the above scenes. The university students added a scene “students discuss in groups” based on these nodes. Furthermore, they added a description “have students discuss in order to deepen their understanding of knowledge” for the added scene. In the I\_L event decomposition tree before the lesson plan was improved, there was no node which can be interpreted as “students deepen their understanding of knowledge”. Therefore, we thought that the university students themselves could become aware of the existence of such a sub-goal and the strategy for attaining it.

Although our investigation was preliminary, the results suggest the possibility that using I\_L event decomposition trees in university education can contribute to enhancing the quality of teacher education programs.

## 5. Related Work and Concluding Remarks

We have built an instructional design support system called FIMA-Light based on the OMNIBUS ontology. FIMA-Light can automatically produce I\_L event decomposition trees from teachers’ lesson plans. We have previously evaluated FIMA-Light in practical use by incumbent teachers. In the present study, first, we considered effective alignment between university education and teaching practice in teacher education programs, and we reported the results of an investigation into the possibility that FIMA-Light can be utilized effectively for university education.

Here, we would like to discuss some related work on a system known as SMARTIES (Hayashi, Bourdeau, & Mizoguchi, 2009) to contrast it with FIMA-Light. SMARTIES is an authoring system that aims to support teachers in designing learning/instructional scenarios based on the OMNIBUS ontology and that is compliant with the standard technology of IMS Learning Design. By using SMARTIES, teachers can make I\_L event decomposition trees that are compliant with learning/instructional theories through deeply reflecting on the design intentions of their lessons. In addition, SMARTIES can suggest WAYs, described in the OMNIBUS ontology as strategies for achieving state changes in learners. In this approach, in which teachers employ a so-called top-down method, when they design scenarios, they have to think about deep intentions that they may not usually be explicitly aware of. For such instructional design, it is necessary for teachers to think deeply about the lessons from global to local viewpoints. Therefore, though this approach is effective for expert teachers, it is very difficult for novice teachers and university students (trainee teachers) to employ.

On the other hand, our approach employs a bottom-up method and can automatically produce I\_L event decomposition trees through reasoning about teachers’ design intentions from given lesson plans that they usually design. With our approach, therefore, even novice (trainee) teachers can participate in this process. This is one of the features of our approach. To support

incumbent teachers, FIMA-Light does not directly improve, or tell them how to improve, their lesson plans by itself, because such support would prevent teachers from improving their professional skills. Therefore, by providing teachers with the I\_L event decomposition trees that is produces, FIMA-Light aims at letting them themselves think about how to improve their lessons and in what respects. However, to support university students (trainee teachers), even though FIMA-Light provides them with I\_L event decomposition trees, we cannot expect that they will recognize their underlying intentions. In order to support university students' learning, it is necessary to create suitable feedback based on I\_L event decomposition trees according to their learning situation. To the best of our knowledge, there is no system that can automatically reason teachers' deep-level intentions from their designed lesson plans, and can support them based on the results of such interpretation.

The purpose of the university education that we proposed in this study is to provide university students with the ability to make I\_L event decomposition trees themselves through thinking deeply about their lessons. Therefore, we think that, in the final stages of their university education, SMARTIES rather than FIMA-Light can support them more effectively. In future work, we intend to clarify how FIMA-Light should be utilized in university education in order to let university students efficiently attain the educational goals for teacher education. In particular, we intend to examine the following two topics: 1) the generation of suitable feedback based on I\_L event decomposition trees produced by FIMA-Light, and 2) effective alignment between FIMA-Light and SMARTIES for university education in teacher education programs.

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# An intelligent tool to assist architecture students in the early stages of design

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**Abstract:** In this paper we present BH-ShaDe, an educational software tool that assists architecture students in the process of learning to design single-family dwellings. To this end, BH-ShaDe generates and proposes housing units schemes, which can serve as starting points in student's exercises and projects. The tool has been designed and implemented based on the ideas of reinforcement learning and shape grammars. The students can select the more promising schemes (among those generated by the tool), and then transform them in complete architectural plans, and finally use them to develop a complete residential project. To evaluate the validity of this approach, BH-ShaDe has been tested with 78 architecture students of the University of Málaga. The results have shown that the starting points were suitable, diverse and useful, and that they have helped students to learn how to design residential projects.

**Keywords:** architectural education, software tool, learning to design, meta-cognitive abilities

## 1. Introduction

In any design task it is not easy to start a new project, so architecture students usually struggle when they need to start a new design and face nothing but a blank sheet of paper. To this end, designers often use inspiration sources. The expression “*inspiration source*” describes the conscious use of different resources or even previous designs, as references for the solution to a problem (Eckert et al., 2000). These inspirations sources or starting points can act as triggers for the generation of new ideas, and even accelerate or facilitate the design process, especially in the case of novice designers. For that reason, computer-aided design tools or design assistants can be very useful in these early stages, allowing the exploration of different alternatives and providing feasible starting points.

To this end, we have developed BH-ShaDe (Basic House Shape Design), a software tool that is able to generate raw, schematic proposals (*schemes*) for housing units according to a given guideline (Montaner and Muxi, 2008). To generate these schemes automatically, BH-Shade uses shape grammars (Stiny, 1980), and to do it in an intelligent way, it uses reinforcement learning techniques (Sutton and Barto, 1998). In this way, architecture students can benefit from the existence of many feasible and varied starting points (basic house schemes) for their residential projects, which have been obtained effortlessly. In order to analyze the usefulness of such starting points in the process of learning to design, we have performed an experiment with a group of 78 architecture students of the University of Málaga, with promising results.

In the next section, we will briefly review some related work. The section 3 describes the software tool and its implementation, while Section 4 is devoted to the description of the experiment performed with architecture students. The results of the study are shown and discussed in Section 5. The paper finishes with some concluding remarks in Section 6.

## 2. Related Work

The computers have been used in Schools of Architecture and introduced in experimental laboratories for design with varied purposes: as a support to imagination and creativity (Elsen and Leclercq, 2008) (Peng and Jones, 2004) (Iordanova, Tidafi and Paoli, 2007); to assist in teaching and learning tasks

(McGill, 2001) (Jain, Kensek and Noble, 1998) or even to introduce virtual reality in architectural education (Redondo et al., 2011).

In relation to design learning, a number of tools have been implemented and tested. For example, SketSha (Elsen and Leclercq, 2008), which is a tool that helps students in the initial stages of collaborative design by supporting free-hand sketches, drawn in real-time in distant locations on a shared workspace. Another example is SUCoD (Peng and Jones, 2004), a web-based virtual city information system that supports 3D urban design. SUCoD allows students to link their CAD skills with knowledge of urban history to carry out urban design proposals. VRSolar (Jain, Kensek and Noble, 1998) and Shaper 2D (McGill, 2001) are examples of more specialized software tools that complement architecture teaching. VRSolar is a web-based teaching tool that helps in teaching topics related to the movement of the sun and its effects on the built environment, while Shaper2D is a design tool that assists students for learning about shape grammars and their uses in the design process. Other works also report innovative uses of computers in learning how to design. (Iordanova, Tidafi and Paoli, 2007) present a study (using case-based-reasoning) performed with architecture students that use a library of referents during their work on the design of a summer theater. Finally, (Redondo et al., 2011) use virtual reality in architecture teaching practices. They merge pictures and virtual models that allow students create interactive photomontages and facilitate the evaluation of the visual impact of their projects.

Our goal is to assist architecture students in the process of learning to design single-family dwellings. Design problem solving is considered a particularly complex task, since these kinds of problems are ill-structured (Simon, 1973), that is, they are characterized by the absence of a unique, well-defined solution. These types of tasks are difficult to teach. Certainly, an educational software tool that generates and proposes different starting points can be quite worthy for design stakeholders in the first stages of the design process. In this way, even though the system does not provide the students with the traditional resources of the tutorial systems (problem evaluation, reading texts,...), they obtain *feedback* on the rules and guidelines in the form of the generated schemes.

This approach is not new: architects frequently use this resource. For example (LeCuyer, 1996) cite Eisenmann's use of computer-generated forms as starting-points. The sources of inspiration or starting points more commonly used by architects or designers include: i) visual stimuli, like for example sketches (Goldschmidt and Smolkov, 2006), objects of nature (Demirkan and Afacan, 2012), or pictures (Casakin et al., 2000); ii) text as graphs words –for example, the tool Idea Space System (Seger, de Vries and Achten, 2005) which gives designers a word graph that contains architect's annotations and semantic associations based on them-; or iii) a mixture thereof, like (Malaga, 2000) that compares the generation of ideas in response to visual or textual stimuli and a combination of both.

However, none the above approaches generate the inspiration sources/starting points automatically. Moreover, to our knowledge, there is no computer-aided tool that provides students with automatically generated starting points. Therefore this is a distinctive feature of BH-ShaDe, which not only generates the schemes automatically, but also uses intelligent techniques and shape grammars to provide an unlimited number of schemes adapted to a given housing guideline.

### 3. The Tool

In this section we describe BH-ShaDe, a software tool that assist architecture students in the process of learning to design single-family dwellings. To this end, BH-Shade generates and proposes housing units schemes that can serve as starting points in students' exercises and projects. The tool has been designed and implemented based on the ideas of reinforcement learning and shape grammars. By means of reinforcement learning, an agent learns autonomously how to interact with the environment in such a way that the total reward is maximized. Learning occurs through interaction with the environment, by receiving positive or negative rewards after the execution of an action. The agents learn which sequences of actions (policies) yield a good total reward. In our case, reinforcement learning techniques (namely, Q-learning) are applied to “an agent” (a generator of architectural schemes) to obtain an improved version of the agent, which is able to provide good starting points for the student. BH-ShaDe is based on the formalism of shape grammars, so every action of the agent is the application of a rule of the grammar.

Shape grammars have been widely used in design and specifically in architectural research (Cagdas, 1996). A shape grammar is a formal language that represents visual thinking. To this end there is an initial shape (usually called axiom), and a set of design rules or transformations that can be applied

to different shapes. Figure 1 represents an example of an axiom, rule, and five successive applications of the rule, starting from the original axiom.

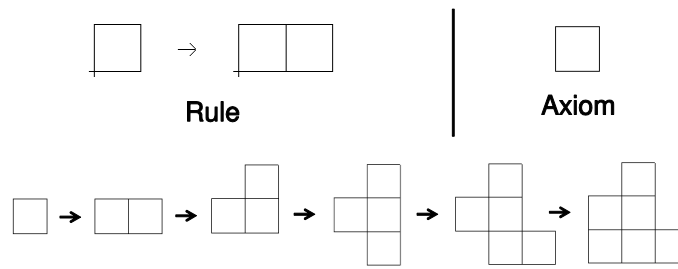


Figure 1. Simple shape grammar that adds squares, with one possible derivation

From the standpoint of generative CAD tools (Chase, 2002), shape grammar-based systems are particularly well suited to easily automate the design, allowing a great deal of exploration.

In what follows we will describe the main characteristics of BH-ShaDe. First we will present the architectural guideline in which it is based. Then we will briefly show BH-ShaDe main features, interface and architecture.

### 3.1 Criteria for the design of basic houses

Our goal is that students learn to design functionally feasible single-family dwellings. To this end, we have used an existing guideline, originally proposed by Montaner and Muxí architecture studio. This guideline is useful for architecture students to learn how to design dwellings. It also guides the generation of schemes for “*basic houses*” in our software tool. In our context, a basic house is defined as a house that, besides satisfying some minimum habitability conditions, also offers some *adaptability*, i.e., its spatial composition may be modified if the number of inhabitants varies. To generate such basic houses in an *intelligent* way, the tool makes use of reinforcement learning techniques. Therefore, BH-ShaDe is able to intelligently generate two-dimensional floor distribution schemes of basic, two-person housing units. All the schemes produced are distributed over one floor and its total area is restricted to 46 m<sup>2</sup> (as recommended in the guideline).

In Montaner & Muxí’s proposal, several kinds of spaces are considered: (1) *specialized spaces* (which need specific installations), (2) *non-specialized spaces* (do not need specific installations, and their use is determined by its inhabitants: dining-room, living-room, bedroom) and (3) *complementary spaces* (such as *distribution hall*, that allows circulation between spaces).

This set of criteria has been implemented as a set of *requirements*. By requirements we mean either constraints (for example, the area of each non-specialized space must be bigger than 9m<sup>2</sup>) or goals (the contour must be as compact as possible). The core of the software tool is a very simple set of rules, together with and an interpreter for them. Random sequences of rule applications would lead to schemes that would not satisfy the set of requirements. To avoid this, violations are automatically detected and *punished*. In this way, and by applying reinforcement learning algorithms, random sequences of rules are gradually replaced by “intelligent” ones (that avoid punishment). The process continues until we obtain a version of the rule interpreter (BH-ShaDe) that generates only *good* schemes. All these *good* schemes are created equal and they are not categorized by the tool. Note that the reinforcement learning process is performed off-line, just once, and prior to the use of the system by students. A detailed description of the interpreter and the learning procedure can be found in (Ruiz-Montiel et al. 2013).

### 3.2 BH-ShaDe Features

BH-ShaDe can work in two different modes: interactive and automatic. In the interactive mode, it allows an interactive execution of three fixed shape grammars, intended to help students learn the concept of shape grammars. The first one is the toy example shown in Figure 1. The second one generates a very simple housing unit. The third grammar (Figure 2b) is applied to the shape in the canvas when the rules are loaded. The rules then add non-specialized spaces to the housing unit. This

grammar makes sense when the shape in the canvas is a housing unit generated with the automatic generation module described below.

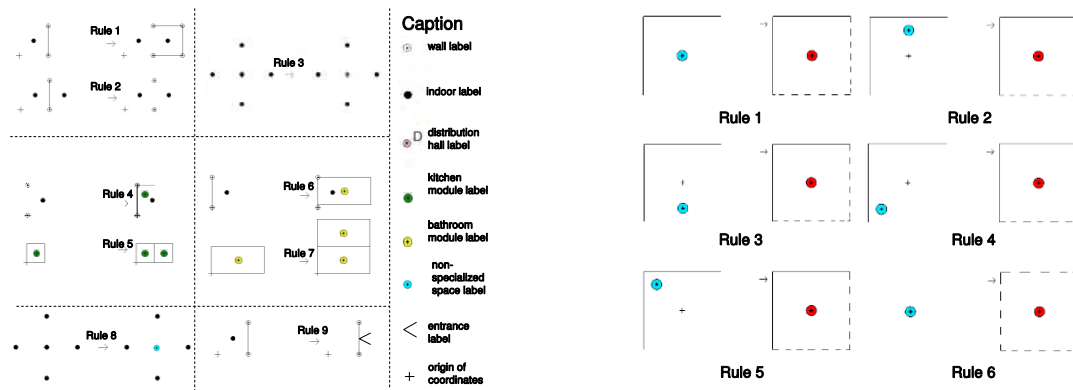


Figure 2. Shape grammars for the generation of a) basic house and b) non-specialized spaces

The automatic mode allows students to obtain housing units schemes according to Montaner and Muxi's guideline. These schemes are automatically generated by the computer, using the shape grammar shown in Figure 2a (that is hidden to students). In the automatic generation module, students just need to specify the desired number of schemes and then the tool will generate them.

### 3.3 BH-ShaDe Architecture and Interface

In this subsection we describe the architecture of BH-ShaDe and its interface. In Figure 3 we can see the different modules that interact in order to provide students with the aforementioned features.

BH-ShaDe is built on top of SketchUp (SketchUp, 2013), hence in the bottom of Figure 3 we can see some SketchUp-related modules. Our tool communicates with SketchUp by means of an Application Programming Interface (API). Immediately on top of this API module, we can see a *Shape Grammars Module* that encapsulates the shapes, the rules and the arithmetic for manipulating shapes. On the top, we can find BH-ShaDe interface, that mainly interacts with the two principal modules of BH-ShaDe: *the Interactive Generation Module* and *the Automatic Generation Module*.

*The Interactive Generation Module* deals with the interactive application of shape grammars by means of a general subshape detection algorithm. This algorithm is very powerful as it can detect possible application of rules of any general shape grammar. With the result of this algorithm the Search Algorithm finds a concrete rule application that satisfies the constraints (if present).

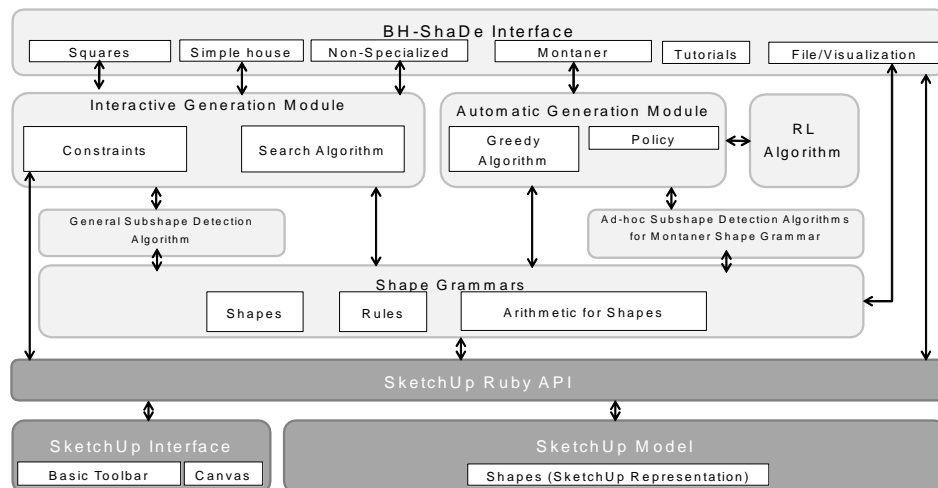


Figure 3. Architecture of BH-ShaDe

*The Automatic Generation Module* applies the shape grammar in Figure 2a by means of an ad-hoc subshape detection algorithm that only works with this shape grammar, but is much faster than



the general algorithm. With the result of this algorithm, the Greedy Algorithm chooses the best rule application with the help of the policy generated by the Reinforcement Learning (RL) algorithm. As we explained before, the policies inform about which rule applications lead to solutions that provide the best adjustment to Montaner and Muxi's guideline. BH-ShaDe interface is built on top of SketchUp interface, as depicted in Figure 4. Shape grammars and the results of successive applications of rules (according to the user's choices or to the automatic generation module) are also shown in the interface.

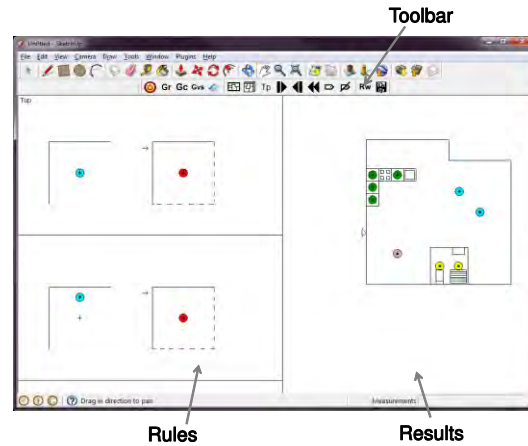


Figure 4. Screenshot of BH-ShaDe interface.

#### 4. The Experiment

In this section we describe the experiment and its settings. The evaluation was performed with three groups of students enrolled in the subject *Architectural Projects VII*, which is taught in the seventh semester of the Architecture Degree of the University of Málaga. In total, 78 students participated in the experiment. Next we will describe the task they had to perform.

First, each student executed the grammar in Figure 2a to automatically generate a basic house. Then, they interactively separated the non-specialized spaces (i.e., placed the walls) using the shape grammar in Figure 2b. The students were then divided in groups of three members. Each group had then 3 schemes, that had been developed by each of their members, partially in automatic mode (the basic house), and partially interactively (walls). This procedure could have continued so students had a large enough collection of basic houses to use in their projects. However, the generation of each scheme consumed some time that was not useful in our overall goal of generating starting points that supported students. Therefore, we decided to use the automatic generation module of BH-ShaDe to automatically generate a further 24 schemes for each group, resulting in a total of 27 schemes per group.

To promote discussion and reflection among the students, these 3-member groups were joined in larger groups of nine students. Each one of these larger groups had then 81 unique schemes that they had to classify according to the following criteria: A (optimal), B (adequate), C (some modifications needed), D (problematic) and E (absurd). Once the schemes had been classified, they had to select the most suitable for different kinds of groupings: row-houses, apartment blocks, galleries, single-family houses. Based on these selections they had to develop a complete architectural project, proposing single-family housing solutions, both in 3D and 2D. The students presented their final projects in the classroom, and the teachers commented and evaluated them.

Finally, the students completed a small survey. The survey was designed as 11 Likert items, relative to four different topics. The students had to evaluate their degree of agreement with each sentence (from 1 -low- to 6 -high-). We have used the more suitable methodology (Jamieson, 2004) to analyze nominal Likert items: mode, median, inter-quartile range and nominal levels of disagree (degree of agreement of 1, 2 and 3) vs. agree (degree of agreement of 4, 5 and 6).

Additionally, the survey included two free-text items where the students could identify the strong and weak points of the software. We have analyzed these free-text items according to the *constant comparative method* (Strauss and Corbin, 1998), a methodology based on *grounded theory*

(Glaser and Strauss, 1967). In the first step, each student's response is decomposed in the ideas it expresses (*answers*). Then these answers are divided into *categories*. In the *phenomenological reduction phase*, the categories are grouped by subject (*themes*). Finally, in the *triangulation phase*, examples of *supporting quotes* are provided. The main advantage of using this methodology is that the ideas expressed in student's answers emerge from the analysis of the sentences, and are not pre-conceived by researchers. Therefore this analysis complements the results obtained in Likert-type surveys.

## 5. Results

In this section we will present the results obtained in the experiment. They have been organized into different subsections: student's survey, teacher's opinion and student's final projects. Finally, the last subsection is devoted to a global discussion in light of these three sources of evidence.

### 5.1 Student survey

As aforementioned, 78 students answered the survey. Results are summarized in Table 1, while Table 2 and 3 summarize the results of the two free text items (using the constant comparative method).

Table 1: Results of Likert items.

|   | 1 | 2  | 3  | 4  | 5  | 6  | MEDIAN | MODE | (Q <sub>1</sub> ,Q <sub>3</sub> ) | Don't agree | Agree  |
|---|---|----|----|----|----|----|--------|------|-----------------------------------|-------------|--------|
| <b>About the software tool...</b>                   |   |    |    |    |    |    |        |      |                                   |             |        |
| 1. I quickly learned how to use the tool            | 0 | 3  | 4  | 3  | 41 | 27 | 5      | 5    | (5,6)                             | 8,97%       | 91,03% |
| 2. It was easy for me to use the tool               | 0 | 0  | 2  | 10 | 32 | 34 | 5      | 6    | (5,6)                             | 2,56%       | 97,44% |
| 3. The user interface is intuitive                  | 1 | 3  | 12 | 30 | 20 | 12 | 4      | 4    | (4,5)                             | 20,51%      | 79,49% |
| 4. The tool worked quick enough                     | 1 | 4  | 17 | 24 | 22 | 10 | 4      | 4    | (3,5)                             | 28,21%      | 71,79% |
| 5. The tutorial was easy to follow and useful       | 1 | 3  | 8  | 11 | 36 | 19 | 5      | 5    | (4,5)                             | 15,38%      | 84,62% |
| <b>About the schemes proposed by the tool...</b>    |   |    |    |    |    |    |        |      |                                   |             |        |
| 6. The schemes can be helpful in the design process | 4 | 12 | 17 | 27 | 14 | 4  | 4      | 4    | (3,4)                             | 42,31%      | 57,69% |
| 7. The schemes can provide good starting points     | 2 | 9  | 8  | 25 | 29 | 5  | 4      | 5    | (4,5)                             | 24,36%      | 75,64% |
| 8. The schemes were interesting                     | 3 | 7  | 19 | 24 | 21 | 4  | 4      | 4    | (3,5)                             | 37,18%      | 62,82% |
| <b>About this practice...</b>                       |   |    |    |    |    |    |        |      |                                   |             |        |
| 9. All in one, it was interesting                   | 3 | 5  | 7  | 27 | 29 | 7  | 4      | 5    | (4,5)                             | 19,23%      | 80,77% |
| 10. I think that the methodology used was suitable  | 1 | 3  | 15 | 26 | 25 | 8  | 4      | 4    | (4,5)                             | 24,36%      | 75,64% |
| 11. It was rewarding to work in groups              | 1 | 3  | 12 | 13 | 26 | 23 | 5      | 5    | (4,6)                             | 20,51%      | 79,49% |

Table 2: Categories, themes and supporting quotes for positive aspects.

|                       | CATEGORIES  |            |           | THEMES  | EXAMPLES OF SUPPORTING QUOTES  |
|-----------------------|---|------------|-----------|---|--|
|                       | Name  | N° answers | % answers |   |  |
| 135 different answers | Diversity   | 26         | 19,26%    | ASPECTS RELATIVE TO QUALITY OF SOLUTIONS (25,18%) | "Great variety of alternative solutions"<br>"What I liked most about this practice is that I could develop a feasible project"<br>"The tool provides a great variety of schemes, some of them present little annex spaces that could be grouped generating unexpected solutions"   |
|                       | Validity  | 6          | 4,44%     |   |  |
|                       | Versatility for groupings   | 2          | 1,48%     |   |  |
|                       | Usability   | 3          | 2,22%     | ASPECTS RELATIVE TO THE SOFTWARE TOOL (11,85%)    | "The tool was easy to use"<br>"The tool generated the schemes quickly and I could take advantage of some of them"<br>"Being able to use new computational methods for architectural design based on randomness"  |
|                       | Efficiency  | 10         | 7,41%     |   |  |
|                       | Possibility of using software tools in the design process           | 3          | 2,22%     | TEAMWORK (14,82%)                                 | "Working in groups and new relationships with other students"<br>"Debates in the group about what is desirable or not in architectural design"   |
|                       | Possibility of working in groups                                    | 10         | 7,41%     |   |  |
|                       | Processes of selection/reflection carried out in the working groups | 10         | 7,41%     | STARTING POINTS (48,15%)                          | "The tool provides a degree of randomness that would be otherwise difficult to include in a project"<br>"Little annex spaces that appear accidentally can be used to generate diverse groupings"<br>"Being able to have an starting point instead of a blank page"<br>"The tool generates schemes that you would not think of" |
|                       | Randomness  | 9          | 6,67%     |   |  |
|                       | Happy accidents or bugs   | 3          | 2,22%     |   |  |
|                       | Provides starting points  | 41         | 30,37%    |   |  |
|                       | Overcoming preconceived solutions                                   | 12         | 8,89%     |   |  |

**Table 3: Categories, themes and supporting quotes for aspects to be improved.**

|                       |   |    |        |   |  |
|-----------------------|---|----|--------|---|--|
| 102 different answers | Software capabilities for edition                                 | 9  | 8,82%  | ASPECTS RELATIVE TO THE SOFTWARE TOOL (12,74 %)     | "The user should be able to modify some aspects of the schemes generated"<br>"A more intuitive interface"  |
|                       | Usability (interface)   | 4  | 3,92   |   |  |
|                       | Shape grammar should include additional criteria                  | 20 | 19,61% | ASPECTS RELATIVE TO SHAPE GRAMMARS (21,56%)         | "Shape grammars should include additional architectural criteria"<br>"To fully exploit the tool, the user should be able to define his/her own shape grammars"   |
|                       | Possibility to include user-defined shape grammars                | 2  | 1,96%  |   |  |
|                       | Overlapping of non-specialized spaces                             | 11 | 10,78% | ASPECTS RELATIVE TO DISTRIBUTION OF SPACES (17,64%) | "Overlapping of non-specialized spaces should be avoided"<br>"Some kitchen modules are inaccessible"<br>"The tool should not generate residual spaces"<br>"The location of the entrance door near to the kitchen constrains the variety of the solutions"<br>"Better distribution of spaces"<br>"Wet zones should be contiguous" |
|                       | Bad distribution of kitchen furniture                             | 3  | 2,94%  |   |  |
|                       | Residual spaces   | 10 | 9,8%   |   |  |
|                       | Better location of doors  | 12 | 11,76% |   |  |
|                       | Better distribution of spaces                                     | 3  | 2,94%  |   |  |
|                       | Better placement of wet zones                                     | 10 | 9,80%  |   |  |
|                       | Excess of randomness  | 9  | 8,82%  | ASPECTS RELATIVE TO THE SOLUTIONS (48,03%)          | "The randomness of the tool should be controlled"<br>"Greater variety of schemes generated"<br>"Other parameters should be considered (environment, social aspects, etc.)"   |
|                       | Poor variety of solutions   | 7  | 6,86%  |   |  |
|                       | Additional criteria should be considered (not only architectural) | 2  | 1,96%  |   |  |

As shown in Table 2 and 3, there were 135 different answers for the positive aspects, and 102 for aspects to be improved. From these answers, researchers established a total of 12 and 13 categories, respectively. Two independent researchers assigned quotes to categories. The inter-rater agreement between those two researchers was computed using the *iota* measure (Janson and Olsson, 2001). We obtained *iota* values of 0.707 and 0.898 (a value of 1 represents perfect agreement), which indicates a quite good agreement. Through a negotiation process between the two researches, answers were definitely assigned to categories. The final step of the triangulation process is the *interpretation* of the supporting quotes. In our case, this interpretation will be done in section 5.4, in which we use all the information available to establish some conclusions.

## 5.2 Teacher's opinion

Three architecture teachers participated in the experiment. One of them was a member of our research team, while the other two did not have previous knowledge of shape grammars or about the tool. We developed a small survey for these two teachers, which had four open questions. For space reasons we do not include their complete answer, but a brief summary of the more relevant information.

It seems that what the teachers liked most of this experience was the possibility to use this kind of tool and learn about shape grammars, together with the interdisciplinary work carried out by the research team and the fact that the tool can provide an unlimited number of schemes, and therefore expedite the design process. Overall, they said that the students had done a great job, and that the more interesting projects emerged from the accidental elements, like the little annex spaces generated in some of the automatic solutions presented by the software tool. More concretely, they said that... *"The tool expedited the design process. The most interesting projects have emerged from accidental elements, like annex spaces or errors. Initially, they seemed not to have any practical use, but finally they have served to encourage the clustering of the dwellings, and have provided support so the students could freely use their imagination. We do believe the tool has accelerated this kind of discoveries"*.

They also pointed out that the use of tool has provided an excellent exercise of analysis and reflection. The students have learned in a practical way that their preconceived ideas are not always the best ones. *"Having 81 housing plan floors automatically generated by the tool, so they could be discussed and selected by the groups of students, has been an excellent exercise about analysis/reflection, which is usually easier to carry out in other people's work than in our own designs. At the same time, the program generates such a wide variety of schemes that accidents occurred randomly, giving birth to what at first sight could be considered as undesirable forms, which finally generated the most interesting projects. Students have therefore learned in a practical way that their preconceived ideas are not always the more appropriate solutions"*.

As for possible improvements, they mentioned that it would be useful to include more architectural criteria in the shape grammars defined. *"In relation to the tool and its use in this particular*

activity, we think that it would be desirable to extend the number of variables to be taken into account in the shape grammar”.

### 5.3 Students final project

In the last session of the experiment, groups of students presented their final projects. Each group presented A1 sheets with the 81 schemes, evaluated from A (no changes needed) to E (the scheme is absurd). In total, there were 9 groups of 81 schemes. The distribution of the percentage of schemes classified according to the different grades (both among those produced by the students and among those generated automatically by BH-ShaDe) is shown in Figure 5.

In their presentations, the students stated that they had held very productive discussions to agree about criteria to classify schemes (recall that teachers also thought that this discussion/reflection process had been very productive). To this respect, some groups had established more demanding criteria than others. The teachers pointed out that some of them had discarded useful schemes for irrelevant reasons, such as a poor positioning of some elements (door, kitchen/bath furniture) or the superposition of non-specialized spaces. The high number of schemes classified with D and E can be explained by the fact that the students considered criteria (circulation, ventilation, light distribution or grouping of wet zones) not accounted in the guideline used by the tool.

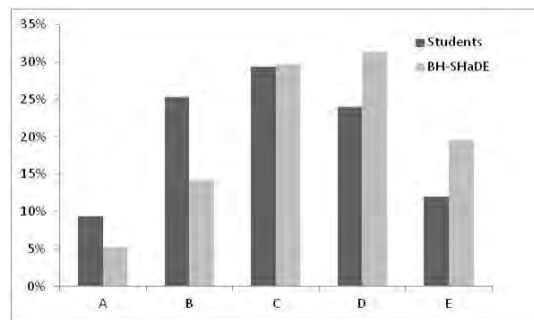


Figure 5. Distribution of the total percentage of schemes of each type (A to E)

From the schemes classified with A or B, each group selected four or five as the basis to create more complex structures. They explored different kinds of groupings: single-family houses, apartment blocks, galleries, etc.

There were many interesting projects, for illustration purposes we will show two of them (selected by the teachers as illustrative for different criteria). The teachers selected the first project as representative of those that emerged from starting points that contained accidental elements (and finally gave birth to creative solutions). This group used one of the schemes generated by the computer classified with A (upper left corner of the Figure 6). The scheme had two small corridors next to non-specialized spaces, and they decided to use these two corridors as terraces to generate an octahedron tower. The second project was chosen because it illustrated a nearly feasible solution (in teacher’s words, it seemed nearly pre-conceived). The students selected this scheme (right of the Figure 6 and also rated with A) because it has a good distribution of the so-called wet zones (kitchen and bathroom). In this way, once the schemes are grouped, wet zones occupy the central part of the building.

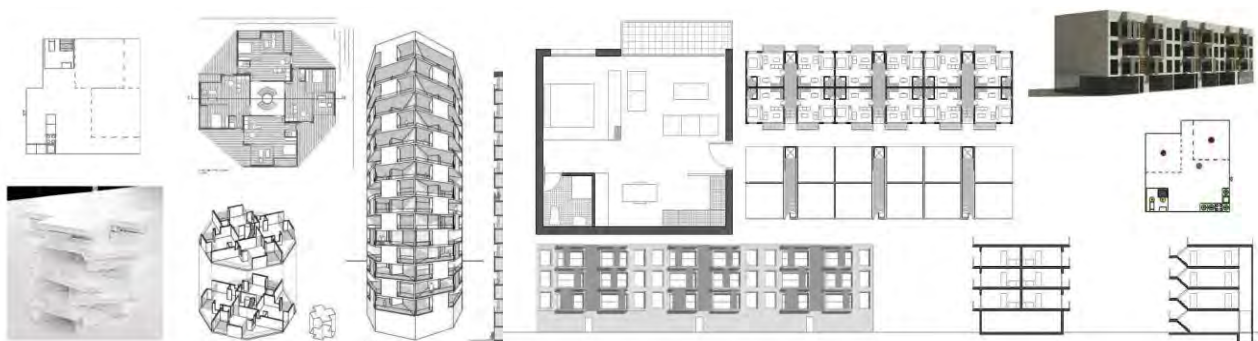


Figure 6. Examples of student’s projects: a) Octagonal tower and b) Gallery

## 5.4 Discussion

In this subsection we will use the results presented in sections 5.1, 5.2 and 5.3 to analyze to what extent the starting points provided by BH-Shade have been useful for the students in the early stages of their design projects.

With respect to this question, probably the more useful Likert items are items number 6, 7 and 8. In particular, item number 7 is very relevant, and we can see that 75,64% of the students agree that *“The schemes provided by the tool can provide good starting points”*. In addition, the students seem to agree that *“The schemes were interesting”* (62,82%), and that *“The schemes can be helpful in the design process”* (57,69%). This same conclusion can be reached from the analysis of the positive aspects of the first free-text item. Indeed, the theme *“Starting Points”* spontaneously emerged from student answers, being mentioned by 48,15% of the students, and specifically 30,37% of them mentioned that *“The tool provides good starting points”*. In this theme, other aspect mentioned by 8,89% of the students was the possibility of overcoming preconceived solutions. Teacher's feedback also seems to support this conclusion, because they said that *“However, the most interesting projects have emerged from accidental elements like annex spaces or errors”*. In fact, and according to their experience, *“the designs of the clusters of schemes obtained using traditional methods are usually more rigid and less creative than the ones generated with the tool”*.

Continuing with the positive aspects of the tool, the next more frequently mentioned theme in the survey was *“Aspects relative to the quality of solutions”* (25,28%), and in particular, the category *“Diversity”* (19,26%). As for the teachers, they declared that *“the program generates such high variety of schemes that accidents occurred randomly, giving birth to what at first sight could be considered as undesirable forms, but finally generate the most interesting projects”*. With respect to the tool, the students emphasized (7,41%) its *“Efficiency”* (also the teachers said *“The tool expedited the design”*).

All in one we think that, according to both the teachers and the students, the stronger point of BH-ShaDe is its capability to generate an unlimited number of diverse, feasible, random and suggestive starting points for novice designers.

With respect to aspects to be improved (and focusing our discussion in the quality of the starting points provided), the most frequently mentioned theme was *“Aspects relative to distribution of spaces”* (48,03%), and specifically the categories *“Better location of doors”* (11,76%), *“Overlapping of non-specialized spaces”* (10,78%), or *“Better placement of wet zones”* (9,8%). Next more frequently mentioned theme was *“Aspects relative to Shape grammars”* (21,56%), in particular, the category *“Shape grammars should include additional criteria”* (19,61%). Overall, it seems that both the teachers and the students think that the inclusion of additional architectural criteria (circulation, ventilation, illumination, grouping of wet zones...) could improve the quality of the solutions provided. Finally, and in relation with the overall quality of the starting points, Figure 5 shows that the students gave higher scores to their own designs than to those generated automatically by the tool. This suggests that future versions of the tool should offer a bigger degree of interactivity, allowing the user a greater control in the design of the initial scheme.

## 6. Conclusions and Future Work

In this paper, we have presented BH-ShaDe, an educational software tool that has been designed to help architectural students in early stages of design, by providing them with starting points for the design of residential projects. The tool is based on intelligent techniques, namely shape grammars and reinforcement learning.

In order to determine the usefulness of the tool we have conducted an experiment in the Architecture School of the University of Málaga. 78 students and three teachers participated in this experiment, which basically consisted in using BH-ShaDe to provide students with interactively and automatically generated schemes to help students to learn how to design dwellings and develop residential projects. Results of the experiment show that both the teachers and the students considered that the schemes provided by the tool were suitable, diverse and useful as starting points, and they had helped the students to develop creative and feasible solutions. Even in some cases, the schemes generated by the tool gave birth to more flexible and innovative projects than those generated with traditional methods.

Regarding future work, the more immediate step is to take into account the results of this study to improve the software tool. Some examples of these possible improvements are: increasing the degree of interactivity of the tool to allow users a greater control of the design process, or including additional architectural criteria in the shape grammar, to improve the quality of the starting points. Finally, we think that the approach exemplified in this work could be used in other design domains as support for the learning process.

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# From Tutoring to Cognitive Rehabilitation: Exploiting CBM to Support Memory Training

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**Abstract:** Constraint-Based Modeling (CBM) is an effective student modeling approach which has been used successfully in a wide range of instructional domains. Within the Intelligent Computer Tutoring Group (ICTG), we have developed numerous constraint-based tutors and demonstrated their effectiveness in real courses. In this paper, however, we discuss how we use CBM in the area of cognitive rehabilitation after stroke. Our computer-based treatment is aimed at improving prospective memory. Participants are first trained on how to use visual imagery and then practice in a Virtual Reality (VR) environment. We present how we use constraints to track the participant's progress when performing tasks in the VR environment.

**Keywords:** constraint-based modeling, prospective memory, virtual reality environment

## 1. Introduction

Constraint-Based Modeling was originally proposed by Ohlsson (1992) as a way to overcome problems with student modeling. Since 1995, when the work on the first constraint-based tutor started, we have developed numerous tutors using CBM at ICTG (Mitrovic, 2012). Our early work focused on showing that CBM was an effective way of modeling domains and student knowledge. In order to develop SQL-Tutor, we proposed a number of extensions to CBM, including a way to develop long-term student models, the distinction between syntax and semantic constraints, and the use of ideal solutions in order to deal with multiple correct solutions (Mitrovic, 1998; Mitrovic & Ohlsson, 1999).

Many other constraint-based tutors followed after SQL-Tutor: some teach other design tasks, such as EER-Tutor (Suraweera & Mitrovic, 2004; Zakharov, Mitrovic & Ohlsson, 2005), UML class diagrams (Baghaei, Mitrovic & Irwin, 2007) and Java (Holland, Mitrovic & Martin, 2009). In addition to these design tasks which are all ill-defined (Mitrovic & Weerasinghe, 2009), we have also developed tutors that teach well-defined tasks, like NORMIT in the area of data normalization (Mitrovic, 2005), thermodynamics (Mitrovic et al., 2011), capital investment decision making (Mitrovic et al., 2009) and oil palm plantations management (Amalathas, Mitrovic & Ravan, 2012). We have investigated various types of long-term student models ranging from overlays to probabilistic ones (Mayo & Mitrovic, 2001), and investigated the effectiveness of various teaching strategies (Mitrovic, Ohlsson & Barrow, 2012; Mathews & Mitrovic, 2007; Weerasinghe et al., 2011; Najjar & Mitrovic, 2013). Over the years, our research focus expanded to other research challenges. We extended CBM to represent and support meta-cognitive skills such as self-assessment (Mitrovic & Martin, 2007) and self-explanation (Mitrovic, 2005; Weerasinghe & Mitrovic, 2006). We also developed COLLECT-UML which supports pairs of students working together and provides feedback on both problem solving and collaboration (Baghaei, Mitrovic & Irwin, 2007). We investigated affective modeling (Zakharov, Mitrovic & Johnston, 2008), and the use of data mining and eye-tracking to improve our ITSs (Elmadani, Mathews & Mitrovic, 2012; Mathews et al., 2012; Elmadani, Mitrovic & Weerasinghe, 2013).

We have also developed ASPIRE<sup>1</sup>, a general authoring tool and deployment system for constraint-based tutors (Mitrovic et al., 2009). Many tutors have been developed in ASPIRE, by

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<sup>1</sup> <http://aspire.cosc.canterbury.ac.nz/>

members of ICTG and researchers all over the world. CBM is now a thoroughly tested and widely used methodology; is not used solely by ICTG, but also by various groups of researchers worldwide – see e.g. (Rosatelli & Self, 2004; Riccucci et al., 2005; Petry & Rosatelli, 2006; Mills & Dalgarno, 2007; Siddappa & Manjunath, 2008, Menzel, 2006; Oh et al., 2009, Galvez, Conejo & Guzman, 2013; Le & Menzel, 2009; Roll, Alevén & Koedinger, 2010).

In our current project, however, we use CBM in a completely different situation. Since 2011, we have been developing computer-based training for improving prospective memory in stroke patients. People with brain injury (including stroke) have severely impaired prospective memory in comparison to healthy people (Mathias & Mansfield, 2005; Brooks et al., 2004). Prospective memory, or remembering to perform actions in the future, is of crucial importance for everyday life (Titov & Knight, 2000). Prospective memory failure can interfere with independent living, as it can result in forgetting to take medication, switch off the stove or missing doctor's appointments. It is a complex cognitive ability, which requires dynamic coordination of multiple cognitive abilities: spatial navigation, retrospective memory, attention and executive functioning (Knight & Titov, 2009).

We start by presenting related work in Section 2. Section 3 presents the treatment we devised: the visual imagery training, the VR environment and the constraints we developed to track the user's behavior in the VR environment. In Section 3, we also briefly present the evaluation study we are currently conducting. We conclude the paper with a discussion of future work.

## 2. Related Work

Stroke is the second leading cause of death<sup>2</sup> and a major contributor to disability. Cognitive impairment plays a crucial role in determining the broader outcomes of a stroke survivor (Barker-Collo et al., 2009). The extent of impairment affects aspects of daily functioning, and often necessitates constant care. Customised rehabilitation is required but is labor-intensive and expensive (Lee et al., 2010). Rehabilitation outcomes are disproportionate in many countries; for example, in New Zealand lower outcomes are achieved in low socio-economic, Māori, and Pasifika areas due to a lack of resources (Dyall et al., 2008; Ministry of Health, 2002).

Prospective memory is defined as the ability to remember future intentions (Ellis & Kvavilashvili, 2000). There are two critical aspects of PM: it is closely related to retrospective memory (remembering what was learnt and experienced previously), as it is necessary to know what the task is (e.g. taking medication at 3pm) in order to actually perform the task. The other aspect is the retrieval of the intention at the time appropriate for the action. There is a distinction between event- and time-based prospective tasks. In the case of a time-based task, a certain action needs to be performed at a certain time (e.g. having a doctor's appointment at 4pm). In event-based tasks, an action needs to be performed when a certain event happens (like asking a friend a question when we see them next time).

To be able to perform a task in the future, a person needs to know the task, a level of intention and a cue. Cues are prompts that help people remember the tasks to be performed in the future. When a person perceives a cue, it delivers the information that was previously associated with the cue to the consciousness, and the person remembers the task. Previous research indicates that cues help a person's memory as it reinforces the intention to execute a task (Gollwitzer, 1996).

Prospective memory is very difficult to assess using neuropsychological tests as conventional tests consist of simple, abstracted activities that are very different from real-world tasks. In order to assess prospective memory, it is necessary to obtain information about how a patient functions in everyday life, which is difficult to achieve in laboratory settings. Research shows that scores from neuropsychological tests often cannot be translated to conclusions about the level impairment and therefore rehabilitation goals because many conventional tests lack ecological validity (i.e. similarity with real life) (Knight, & Titov, 2009). It is therefore necessary to replace such tests with tasks that mirror real-world activities. However, assessing patients in real-world situations entails logistic problems and is not achievable in rehabilitation units (Brooks et al., 2004).

In the last decade, many research projects have used Virtual Reality (VR) in neuroscience research and therapy (Bohil, Alicea & Biocca, 2011), ranging from the use of VR for assessing cognitive abilities, over neuro- and motor rehabilitation to psychotherapy, such as treatment of phobias.

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<sup>2</sup> <http://who.int/mediacentre/factsheets/fs310/en/>



VR environments are computer-generated environments that simulate real-life situations and allow users to interact with them. They provide rich, multisensory simulations with a high degree of control and rich interaction modalities. They can also have a high level of ecological validity. VR has been used for assessment of prospective memory in patients with traumatic brain injury (TBI) (Knight & Titov, 2009) and stroke patients (Brooks et al., 2004). VR is suited for prospective memory as it supports complex, dynamic environments that require coordination of many cognitive abilities. VR environments are convenient and safe for patients. Non-immersive, PC-based environments have been used more than the immersive ones, which require special hardware (such as head-mounted displays) and therefore are more expensive and induce more anxiety in patients than PC-based ones.

Although there has been some research done on how to assess PM, there is very little available on rehabilitation strategies for PM. Yip and Man (2013) involved 37 participants in 12 sessions (held twice a week) of prospective memory training using non-immersive VR. The participants were asked to perform a set of event- and time-based prospective memory tasks in parallel with an ongoing task, all performed in a virtual convenience store. The prospective memory training was based on remedial and process approaches. The remedial approach provides repetitive exercise within the VR environment. The process approach, on the other hand, aims to support multiple facets of prospective memory, and supports encoding of intention, retention and performance interval and recognition of cues. Participants were given a list of four shopping items they needed to memorize, and their recall was tested before entering the VR environment, where they needed to perform the tasks. The VR training showed significant improvement in participants' immediate recall of PM tasks, performance on both time- and event-based tasks as well as ongoing tasks, and also a significant improvement in self-efficacy.

### **3. Our Approach to Prospective Memory Training**

The primary goal of our project is to develop an effective PM treatment that could be used by the stroke survivors without the input of clinicians. Our approach combines the use of visual imagery and practice in VR environments. We developed a treatment based on visual imagery, and a VR environment in which the patient will be able to improve their prospective memory. We start by describing the visual imagery training, and then present the VR environment, constraints used in the VR environment, and the evaluation study.

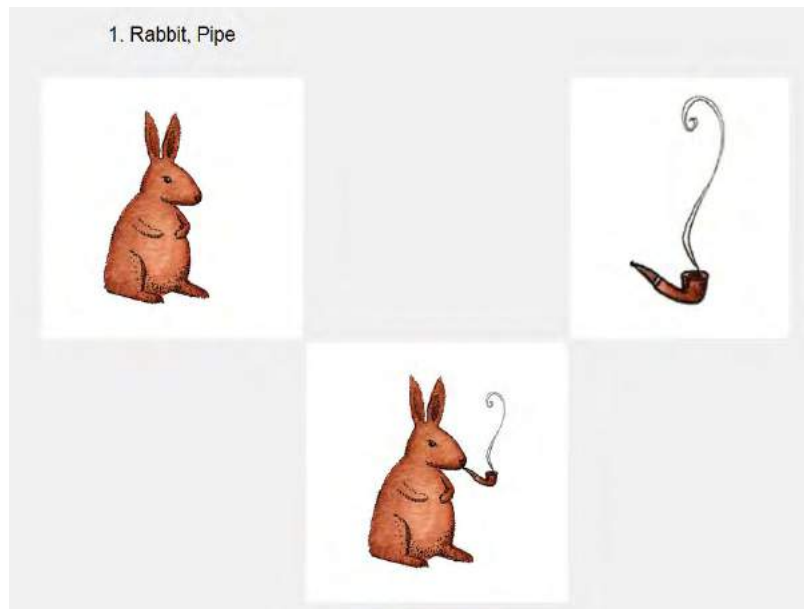
#### *3.1 Visual Imagery Training*

Visual imagery is a technique in which the participant forms a visualization of a given word. The same strategy can also be used to make a visualization of a pair of words, by linking the words and making the visualization as unusual as possible to make it more memorable. Previous work (Lewinsohn, Danaher & Kikel, 1977) has shown that visual imagery improves retrospective memory. McDaniel and Einstein (1992) showed that PM performance improved when participants were given pictures of targets, or when participants formed mental images of cues.

The idea behind the visual imagery training is to teach participants to remember a list of tasks with their associated cues using visual imagery as a mnemonic strategy. The training is presented on a computer in the form of a set of sequential pages. Pages contain recorded voice messages that participants can hear, images, video, written text, buttons to navigate to the previous and next pages, and a replay button. Sometimes participants are asked to interact with the page (e.g. during testing). On such pages, buttons are provided for the user to record the answers.

In the first phase of training, participants are introduced to visual mnemonics by being shown how to form mental images in order to remember a list of paired words. The user is presented with pairs of words and taken through creating the image for each pair. For example, for the pair (*rabbit, pipe*), the participant is first shown pictures of a rabbit and a pipe, and they listen to the recording of the following text: *Look at the image displayed of a rabbit. Imagine its bristly fur and its long ears wriggling. Really focus on it, like it's right there in front of you. Now look at the picture of a pipe. Imagine this in your mind. Smoke is coming out of the pipe, giving off a smoky smell. Imagine grasping the pipe, and feeling it. The pipe feels round and smooth in your hands. The more senses you use, the more memorable the image will be.*

The following training page (illustrated in Figure 1) shows the two previously shown pictures of a rabbit and a pipe, and also the combined picture, and plays the recording of this text: *Now that you have imagined the two images individually, we are going to visually link them together, which will help you to remember them. This technique of visually linking them together will allow you to recall the individual words in the future. So, what I want you to do right now is to imagine the rabbit smoking the pipe, like it is in the third image. Close your eyes and really think about it. The rabbit is puffing away and more and more smoke is coming out. In your mind, imagine the rabbit taking the pipe out and blowing a smoke ring and then putting it back in its mouth. What a silly rabbit! Ok, now open your eyes. Now that you've done this, the image of the rabbit smoking the pipe should be firmly in your memory, so that if we gave you the image of a rabbit, you would immediately think of it smoking a pipe, which will lead you to the second word: pipe!*



**Figure 1:** The screenshot of the training for the paired words *rabbit* and *pipe*

The audio instruction is designed to be as descriptive as possible in order to better aid the user's visualisation. The user is encouraged to mentally add to the presented images, personalizing them and making them more concrete. After presenting the initial three pairs of words, the user is tested by presenting one word from the pair and asking them to record the other paired word. Next, the user is presented five pairs at once, which he/she needs to visualize, and then the user is quizzed on them.

In the next phase, the training is modified by removing the combined picture, and asking the user to generate his/her own combined image. In the third phase, the training becomes even more demanding, as the user needs to visualize both given words as well as to generate the combination picture. The later phases provide the user with example tasks and show how, for each example task, the context could be related to the items to be done. The user is taught that each task consists of either object-action pairs or time-action pairs. An object-action pair is where some action is required when a certain object is encountered. A time-action pair is when some action is required at a particular time. An example of an object-action pair was then given: "Tell Laura about tomorrow's weather when you meet her next". The object in the pair is Laura and the action is to tell her about tomorrow's weather. Using this pair, a corresponding visual mnemonic could be made; for example, seeing Laura being swept up and carried by a tornado or the sun shining brightly out of Laura's head. Participants are taught that the more concrete (using real places, real people, real things, or real time) and more detailed a visual mnemonic was, the more personal and real it would be, and thus more memorable. The user is taught that the more silly or humorous a visual mnemonic was, the more memorable it would be.

In the last phase, the user is given lists of tasks to memorize, and then completes four problems. Each problem consists of watching a video containing the given tasks. During the video, when the user identifies the cue for a task, he/she needs to stop the video and record the action that corresponds to the cue, before carrying on with the video. They cannot rewind the video to enter in missed tasks.

### 3.2 VR Environment

We have developed a VR environment using the Unity game engine, in which the participants need to perform a given set of time- or event-based tasks. The VR environment represents a house with common household objects, and a garden. Figure 2 shows two scenes from the environment. The user is given a problem, which consists of several PM tasks they need to visualize first, and then perform in the VR environment. As discussed earlier, some tasks are time-based and the user is able to view a clock whenever they choose. The user is able to carry out a number of actions on a variety of objects such as a radio or a washing machine.



Figure 2: Two scenes from the VR environment

The tasks vary in complexity: the ones in early sessions consist of a cue and a single action, such as *Turn on the TV at 6pm*. In later sessions, the user will be given more complex tasks, such as *When the oven timer beeps, take the cake out of the oven and put it on the dining table*. To perform an action, the user needs to select the object first, and then to specify the action from a menu. The screenshot in Figure 3 shows a situation when the user is interacting with the oven. The selected object (oven in this case) is highlighted in red, and the user is given a menu listing the actions that can be performed on the object. In this particular situation, the user wants to take the cake out. Some tasks, such as taking the cake out of the oven, involve other objects, which are added to the inventory. Other tasks require inventory items to be collected beforehand. Consider the task *Take the white dress and iron it*. The first step involves collecting the inventory item *white dress*, while the second step involves operating the iron. The user is able to view their inventory at any time. The problems range in complexity: the initial ones contain only three simple tasks, and they become more complex as the user practices in the environment.



Figure 3: Two scenes from the kitchen

In order to be able to track the progress of the user, the system maintains the list of active tasks. Tasks should only be attempted from a point known as 'cue discovery'. Time-based tasks become active several minutes before the stated time. For example, if the task is *Turn on the radio at 6.00pm*, the user

can start to move towards the radio a few minutes earlier in preparation. Event-based cues only begin when the stated event occurs. Consider the task: *Bring in the washing when it starts raining*. For this task, the user has no way of knowing when it is going to rain, and so they should not begin the task before the cue is discovered.

For every task, there is a finite amount of time for which the task can be completed before it becomes obsolete or impossible. However, this alone is not the only factor in determining which tasks are more important. Some tasks, such as turning off the stove, have worse outcomes for failing to complete than other tasks do, such as turning on the TV. Each task therefore has a priority level, which is an integer from 0 to 5, with 5 representing the highest priority. Tasks with a level 5 priority are tasks with a very real chance of injury or household damage if they are not completed on time. A typical priority 5 task is *When the timer beeps, turn off the stove top*. By contrast, a priority 0 task may be: *When you are finished all other tasks, watch television*. From cue discovery, the user has a fixed time to complete the task before it becomes obsolete.

### 3.3 Using CBM for PM Training

We have developed a set of constraints that enable us to evaluate the participant's actions and provide feedback. As originally proposed by Ohlsson (1992), each constraint has two components: a relevance condition and a satisfaction condition. The relevance condition specifies features of situations for which the constraint is relevant, while the satisfaction condition details what must be true for the constraint to be satisfied. A constraint can be described as: *If <relevance condition> is true, then <satisfaction condition> had better also be true, otherwise something has gone wrong*. If a constraint is violated, the user needs some means of knowing that he/she has made a mistake, and they need to know what needs to be done differently next time. This is the role of feedback: it informs the user on what tasks need to be performed, and what objects need to be interacted with.

We have developed 15 constraints to track the user's progress within the VR environment. The constraints deal with navigation, prioritization of tasks, selection of objects to perform actions on, remembering/selecting actions to be performed and general skills of interacting with VR (such as selecting objects, selecting items from the menu or crouching). In order to be able to specify relevance and satisfaction conditions, we have defined a set of functions and predicates. For example, the *OnRouteTo* predicate takes the current position of the user (i.e. the room the user is currently in), the target position needed in order to perform the current task, and returns *True* if the current position is on a path to the target position. An example of a constraint where one object is required to perform action on another is:

*If the user has selected an action for Object X which requires Object Y,  
Then Object Y should be in the inventory.*

Each constraint contains three feedback messages. When a constraint is violated for the first time, the user will be given a general message, in order to remind them that they have missed something. For example, if the user is going in the opposite direction from the target destination, he/she will be given feedback "*You're going the wrong way!*" If the user continues down the wrong path, the feedback for to the second violation of the same constraint becomes more specific: "*Perhaps you should be going to the [goalRoom]*" ([goalRoom] is a function which returns the position for the current task). This culminates on their third violation of the constraint with "*You should be going to the [goalRoom] and use the [goalObjects]*". This is the bottom-out feedback which instructs the user what to do. Figure 4 illustrates a situation when the user tried to put a white dress on the clothes line, but forgot to collect the dress beforehand.

Three constraints check whether the user is working on the correct task. Tasks with only one minute left should be done before tasks with more than one minute left, even if that task with more than one minute left is of higher priority. In this way the user can still complete all the tasks. It is also important to bear in mind that higher priority tasks will reach the point of only having one minute left a lot sooner than a lower priority task. If there are multiple tasks with less than one minute left, the user should choose the highest priority one. The next threshold is at five minutes. Users must do tasks with less than five minutes left before they attempt tasks with more than five minutes left. As discussed in the previous section, tasks are first stratified according to time left into less than one minute, less than five

minutes, more than five minutes. From there they are ranked according to priority. If any tasks have equal time strata and priority, they can be done in any order, otherwise the user must pick the top one.



**Figure 4:** A screenshot showing feedback from a violated constraint

In addition to the feedback being displayed during the session, the user can also press the H key for more help. If the user has had a message displayed in the last 30 seconds, this message is displayed again to remind them of what they were doing wrong. Otherwise the default message is displayed. If there are no tasks left to do, the default feedback informs them of this. Otherwise it gives them increasingly specific hints as to what they should be doing.

In our previous work with ITSs, constraints are evaluated when the student submits the solution, therefore requiring feedback from the system. The timing of constraint evaluation in the VR environment differs from this: there is no time when the user explicitly requires feedback. On the contrary, the system needs to be able to evaluate constraints when appropriate. The constraints that deal with task prioritization are evaluated at intervals of 0.5s. Other constraints are evaluated in the appropriate contexts: for example, navigation constraints are evaluated every time the user changes room, while constraints that deal with objects are evaluated when the user selects an object or an action.

We have conducted a case study with a stroke survivor, who used the VR environment for 30 minutes. The participant could interact with the environment, and the case study identified a few usability issues and further improvements to the timing and duration of feedback. We then had a domain expert interact with the system. The domain expert explored the virtual environment completing a number of tasks. The domain expert was able to compare the feedback generated by constraints with the feedback they expected from the system. All constraints were satisfied or violated as expected, and these results were recorded faithfully by the user model. At some points, the feedback actually led to the domain expert making more errors. In such situations, the user was alerted that they should be doing one of several tasks, and told all the tasks currently available. When the user completed the lowest priority of these tasks, they violated the constraint that they should be doing the most high priority tasks. This led to the recommendation that feedback messages should only suggest the single most important task at the current time. The findings were then used to improve the constraint set and the system.

### 3.4 Evaluation Study

We are currently conducting an evaluation study of our computerized treatment with stroke patients. The study consists of ten sessions. In session 1, the participants will be tested to determine the level of cognitive functioning by performing a battery of cognitive tests, including the digit span test, the CAMPROMPT test of PM and the visual imagery questionnaire. Throughout the study, the participants are asked to keep a diary of their activities, and note PM tasks they have managed or failed to complete in their everyday activities. The diary will be discussed at the beginning of each session.

The second session is scheduled 4 weeks after the first session, so that it is possible to track the PM skills after this initial period. Starting from the second session, there are two one-hour-long sessions per week, for four weeks. The participant undergoes visual imagery training (discussed in Section 3.1) in sessions 2-4, followed by videos in sessions 5 and 6. In sessions 4 and 5, the participant is also introduced to the VR environment so that they can become familiar with it and also get used to using the joystick. The next stage of the study (sessions 6-9) is practice in the VR environment. The participant will be given 3-4 problems per session. At the end of session 9, the participant will again undergo the PM assessment. This assessment will allow us to measure the effectiveness of the treatment. Finally, the last session will be held after 4 weeks, and will consist of repeated assessment of the participant's PM. We will then analyze the results to determine whether the expected improvement in PM skills holds over the 4 weeks since session 9.

## 4. Conclusions and Future Work

In previous research, constraint-based modeling has been used to develop domain and student models in intelligent tutoring systems. CBM has been proven to be an effective student modeling approach that is applicable in a wide range of instructional domains. In this paper, we describe how we have used CBM in order to track the user's prospective memory. We have presented a computer-based treatment for improving prospective memory for stroke survivors. Our treatment consists of training users on how to use visual imagery to improve their memorization skills. Later on, participants practice using visual imagery by interacting with videos and a VR environment.

The contribution of this research is in extending constraint-based modeling from modeling and supporting cognitive skills to modeling and supporting prospective memory skills. We have developed a constraint set that allows us to track the user's behavior in the VR environment. The constraints identify whether the user is prioritizing the tasks correctly, whether there are any problems with navigation, identifying cues (time or event ones), interacting with objects and specifying actions. The pilot study performed with one stroke survivor was promising. Three domain experts have interacted with the VR environment and expressed satisfaction with the feedback the system provides. We are currently conducting a full study, aiming to have a group of 20 stroke patients to undergo all the phases of our treatment.

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# Ontological Descriptions of Statistical Models for Sharing Knowledge of Academic Emotions

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**Abstract:** Many studies have been conducted during the last two decades examining learner reactions within e-learning environments. In an effort to assist learners in their scholastic activities, these studies have attempted to understand learner mental states by analyzing participants' facial images, eye movements, and other physiological indices and data. To add to this growing body of research, we have been developing IMS (Intelligent Mentoring System) which performs automatic mentoring by using an ITS (Intelligent Tutoring System) to scaffold learning activities and an ontology to provide a specification of learner's models. To identify learner mental states, the ontology operates based on theoretical and data-driven knowledge of emotions. In this study, we use statistical models to examine constructs of emotions evaluated in previous psychological studies, and then produce a construct of academic boredom.

**Keywords:** Ontology, academic emotions, academic boredom, constructs

## 1. Introduction

During the last two decades, studies have been conducted that examine semiconscious behaviors of learners participating in e-learning environments by observing and analyzing facial images, eye movements, and other physiological indices. Analysis of data obtained from such examinations enables researchers to understand various mental states of learners, such as that of "confidence" and "confusion" (Arroyo et al., 2009; Muldner et al., 2009). In addition, studies have employed the intelligent tutoring system to evaluate the structural features of the knowledge learners possess. As a result of these studies, researchers have developed an intelligent mentoring system (IMS) that supports learning based on the various aspects of mental states and knowledge (Kojima et al., 2012; Muramatsu et al., 2012; Muramatsu et al., 2013). One of its main characteristics is diagnostic function of learner model considering mental states of learners. Because mental states can instantly change in a short activity (e.g., solving of a single problem), IMS is required to monitor learners at all time and give feedback based on diagnosis. The IMS provides integrative learning-support including real-time estimation of learners' mental states and selection of ways to support learners, in addition to diagnosis of learners' knowledge structures and determination of teaching strategies provided by ITS (Intelligent Tutoring System). In the IMS, data from interactions between users and the system are captured according to two levels of cognitive activity: high-level interactions (HLI) and low-level interactions (LLI). HLI examine a user's explicit awareness of scholastic activities and illustrates it by means of a data resource that employs large grain samples. By contrast, LLI examine user's diffuse awareness to a limited extent and illustrates it by means of a data resource that uses much smaller grain samples.

Muramatsu et al. (2012) developed an ontology that provides descriptions of the relationships among LLI resources and the mental states of learners. These descriptions are based on specific tasks performed by learners, which are independent of the knowledge structures examined within specific domains which they learn about. Muramatsu et al. (2013) expanded the ontological descriptions pertaining to mental states based on concepts of academic emotions (Pekrun et al. 2002) and the control-value theory (Pekrun 2006). These descriptions help to clarify relationships between academic emotions and subjective attributes that perform the role of subjective control or value in accordance with the control-value theory. Their ontology effectively illustrates how academic emotions are formed during co-occurrence of control and value, and it has helped researchers interpret learners' mental states based on LLI resources in the IMS. However, the descriptions provide insufficient detail to identify

subcategories of attributes that perform a role of control or value in practical settings. The subcategories derive from experiments that measure emotions using rating scales and statistical analyses of the measured data. To implement the IMS, ontological descriptions about academic emotions should include both data-driven and theoretical knowledge. The academic emotions are student's emotions experienced in academic settings such as class-related, learning-related and test-related situations (e.g. boredom experienced in classroom instruction, enjoyment of learning and test anxiety).

This study makes a conceptualization of statistical models such as the factor analysis model used in psychological research. Specifically, we describe the structure of rating scales that express psychological attributes as representations, and specify relationships among variables that represent the psychological attributes in statistical models. Finally, we demonstrate ontological descriptions in constructs of academic emotions.

## 2. Emotions in Academic Settings

In the field of psychology, learner emotions, specifically within the context of classroom instruction and achievement, are referred to as academic emotions (Pekrun et al., 2002). Emotions related to achievement are defined as achievement emotions and are measured by using the achievement emotions questionnaire (Pekrun et al., 2011). This questionnaire consists of scales related to nine emotions: enjoyment, boredom, anger, hope, anxiety, hopelessness, pride, relief, and shame. These nine emotions can be subdivided into two types according to their object focus: (1) activity emotions, which pertain to ongoing achievement-related activities, and (2) outcome emotions, which concern the outcomes of these activities. Enjoyment, boredom, and anger constitute activity emotions. The outcome emotions include *prospective* outcome emotions such as hope, anxiety, and hopelessness, as well as *retrospective* outcome emotions such as pride, relief, and shame.

Academic emotions are explained by referring to the control-value theory proposed by Pekrun (2006). This theory describes emotions as sets of interrelated psychological processes composed primarily of affective, cognitive, motivational, and physiological dimensions (Pekrun et al., 2011). The theory appraises the subjective control and subjective value. The appraisal of subjective control relates to perceived control of achievement-related actions and outcomes. By contrast, the appraisal of subjective value pertains to the subjective importance of achievement-related activities and outcomes.

In e-learning environments, learning materials such as multiple-choice tests are considered as "object focuses," and activity emotions such as enjoyment, boredom, and anger can arise in such settings. For example, when a learner's mental states are estimated as "interesting" and "comprehending," enjoyment is expected to be the academic emotion experienced. In this situation, the quality of "interesting" has a subjective value, which includes a quality value of positive or negative, because subjective evaluation on the quality of "interesting" correlates to a positive/negative affection (Acee et al., 2010). However, when an activity involves a learning material that lacks incentive value, whether positive or negative, boredom is the expected result. The incentive value of an activity may depend on the control that is perceived by the learner (Pekrun, 2006).

According to research on the construct of academic boredom, a learner's perceptions of boredom also represent a situation-dependent construct (Acee et al., 2010). Specifically, over-challenging situations lead learners to either "task-focused" or "self-focused" boredom, while under-challenging situations lead to more general boredom. In the research of Acee et al., the academic boredom scale (ABS) was used to measure learners' emotions. The ten items in ABS (ABS-10) consist of unipolar scales that correspond to ten psychological attributes, which are listed as follows: "want something else," "tired of activity," "impatient," "frustrated/annoyed," "apathetic," "nothing to do," "activity dull," "repetitive," "wonder why doing this," and "useless/unimportant." As a result of a factor analysis of data related to under-challenging situations, all items in the ABS-10 scale were correlated to general boredom. By contrast, a factor analysis of data related to over-challenging situations correlated five psychological attributes ("want something else," "tired of activity," "impatient," "frustrated/annoyed," and "apathetic") to self-focused boredom. The other five attributes ("nothing to do," "activity dull," "repetitive," "wonder why doing this," and "useless/unimportant") were correlated to task-focused boredom. Because the variables derived from these factor analyses yield psychosocial attributes

measured through the use of rating scales, the relationships among them provide a construct of academic emotions and their subcategories.

### 3. Method for Ontology Development

#### 3.1 Role Concept

Ontological engineering is a field of computer science that supports the systematic description of knowledge. From this knowledge-based perspective, "ontology is defined as a theory (system) of concepts/vocabulary used as building blocks of an information processing system (Mizoguchi et al., 1995)." In Hozo<sup>1</sup> ontology editor which is one of ontology development environment, each node represents a whole concept and contains slots that represent part-of or attribute-of relations (Fig. 1).

Hozo helps describe role concepts wherein a role depends on the contents of each whole concept. For example, a teacher's role is played only in the context of school. Every slot thus has a role within a whole concept that implies a context. In the context, a class of instances that can play a role is defined by a class constraint and is called a role holder (Kozaki et al., 2000). In this way, the role concept distinguishes between concepts within different contexts. Inherited role holders and class constraints imported from other ontologies are shown in the right half of Figure 1.

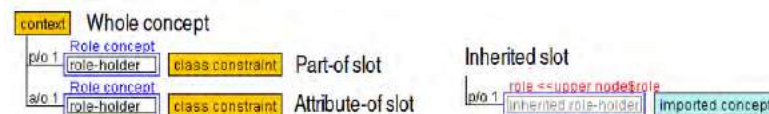


Figure 1. Legend.

#### 3.2 Top-level Ontology

Mizoguchi (2010) constructed a top-level ontology based on the role concept theory known as “yet another more advanced top-level ontology” (YAMATO<sup>2</sup>). Based on YAMATO, an entity is divided into three classes: physical, abstract, and semi-abstract. Although instances of a physical class require 3D space and time to exist, instances of an abstract class require neither. Instances of a semi-abstract class require only time to exist, and the class contains mind, representation, content, and a representation form.

Representations such as novels, poems, paintings, music, and symbols are distinguished from their propositions and forms of representation (Mizoguchi, 2004). A class of representation is further divided into primitive representation and composite representation. The composite representation has one or more part-of slots which indicates that a subsidiary role is played by a representation. The representation contains part-of slots that indicate a content role played by a proposition and a form role played by a representation form. The proposition is divided into two classes: representation-primary and representation-secondary. For example, “content of a piece of music” and “content of a novel” are examples of the former and “content of a fact recognized by a human” is an example of latter. These classes necessarily depend on their representation. However, instances of a representation-secondary class, such as facts, data, and thoughts, indicate original content that should be represented. For example, a fact designated as an event exists before it can be recognized and expressed as a representation. In this sense, the process of human recognition, which necessarily includes sensations and perceptions, belong to the representation-secondary class.

The main features of YAMATO are definitions of qualities and quantities, their representations, and descriptions of their interrelationships in other top-level ontologies. Attributes of entities are represented as qualities comprised of quality values. A quality value is divided into a class of “categorical” and a quantity contains a quantitative quantity and a qualitative quantity. A quality is divided into a property and generic quality, with the property being an abstraction of the generic quality

<sup>1</sup> <http://www.hozo.jp>

<sup>2</sup> [http://www.ei.sanken.osaka-u.ac.jp/hozo/onto\\_library/upperOnto.htm](http://www.ei.sanken.osaka-u.ac.jp/hozo/onto_library/upperOnto.htm)

but possessing a quality value. The generic quality is divided into intrinsic generic quality and accidental generic quality. A subclass of intrinsic generic quality is basic generic quality, which contains quantitative generic quality and qualitative generic quality.

In YAMATO, a representation of a quality is distinguished from a real quality which exists with an entity. Therefore, representations of qualities and quantities are defined as transformations of real quality through an “action to measure.” The measure contains a part-of slot that indicates a “result” role played by a primitive representation. A quality measurement is defined as a role-holder performed by a proposition in a content role subplot of the result role slot. Through measurements, data are approximation of real qualities and a quality value representing a true value is independent of any measurements. Therefore, representations of a quality must be distinct from representations of a quality obtained through measurements (Masuya et al., 2011).

## 4. Ontological Descriptions

### 4.1 Subjective Measurement

In psychometric methods that use rating scales, subjective evaluations of emotions are often expressed as points on a scale. The *rating scale* and *point on rating scale* are displayed in Figure 2. A point on the rating scale has a form slot that is filled by a *word* or *pictogram* and contains an additional slot in which a number represents a scale marking. The rating scale is a composite representation comprised of multiple points. Two points are considered *anchor* role-holders in which a *pole* subplot indicates a perceptual large or small point.

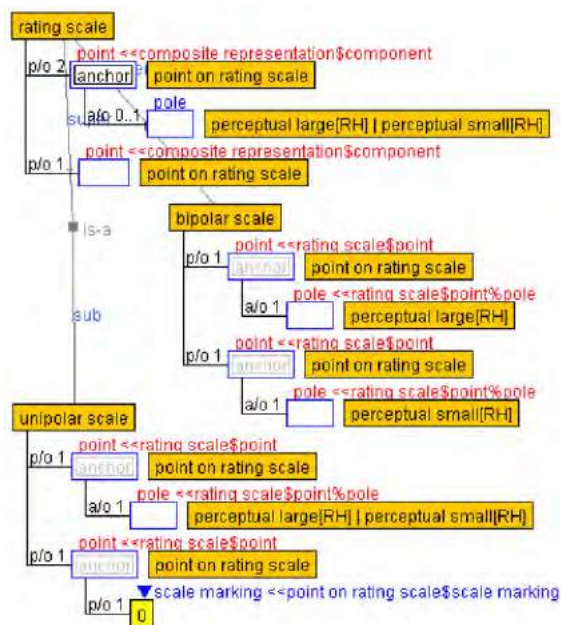


Figure 2. Rating Scale and its Points.

Semantic differential scales contain adjective pairs that represent perceptual qualities, each of which indicates large or small perceptual quality values. Thus, the relationship of magnitude among perceptual quality values can be defined through the rating scale. Furthermore, *unipolar* and *bipolar scales*, defined as subclasses of the rating scale, contain unipolar and bipolar perceptual qualities, respectively.

### 4.2 Statistical Models

To show relationships between measured data of emotions in subjective ways, statistical models are often adopted in psychological research. In this study, we employed unique mathematical models as well as mathematical and quality data expressions (Fig. 3) in the composite representation in

YAMATO. The *mathematical model* contains a *mathematical expression* slot inherited from the *composite* and *quality data* slot. Each role of the slots employs a mathematical expression and *quality data representation*. In the mathematical model, the content of the quality data is defined as a *modeled attribute value*, while the mathematical expression is composed of multiple *variables* inherited from the *component* slot and *constant* slot. The variable role contains a representation and coefficient performed by a number defined as a subplot.

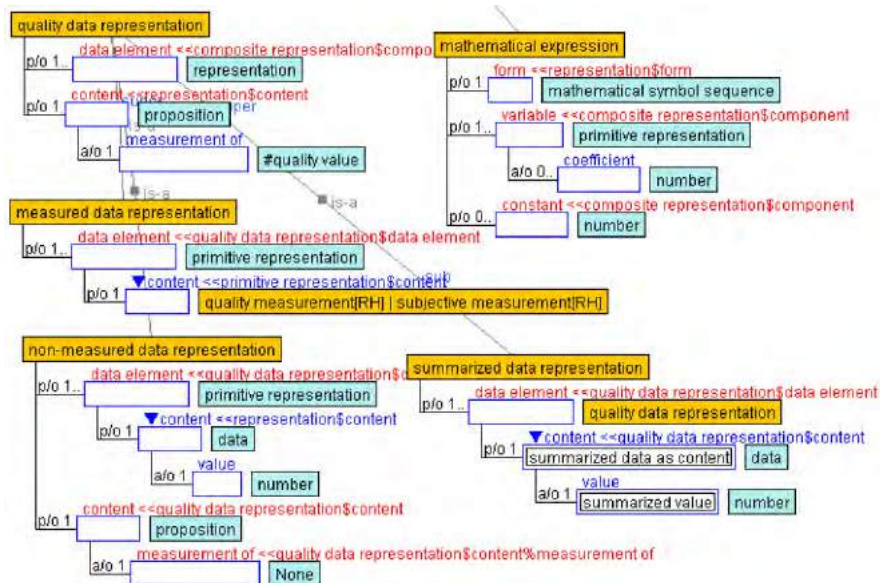


Figure 3. Mathematical Model and its Components.

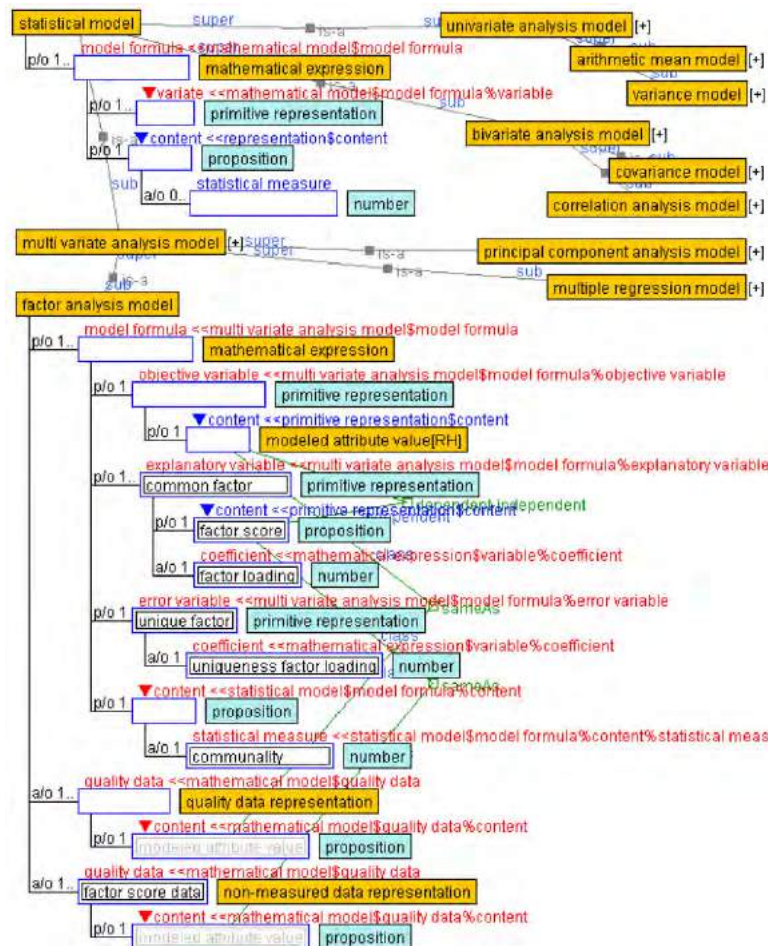


Figure 4. Classes of Statistical Models.

The quality data representation contains multiple *data element* role slots performed by other representations. The content role slot is performed by the data and the *measurement of* the subplot indicates the derivation. The quality data representation is divided into *measured data representation*, *non-measured data representation*, and *summarized data representation*. In the measured data representation, the content is performed by the quality measurement or subjective measurement, which indicates quality value as a proposition. However, the content of the non-measured data representation such as factor scores and principle component scores exists only in mathematical models. The summarized data representation is composed of data elements played recursively by the quality data representation, and its content is regarded as *summarized data as content*, which represents a summarized value such as an average.

Figure 4 displays the hierarchy of statistical models and their subclasses. The statistical model is divided into a *univariate analysis model*, *bivariate analysis model*, and *multivariate analysis model* by cardinality of the quality data representation slot. The univariate and bivariate analysis models employ summary statistics such as arithmetic mean, variance, covariance, and correlation. Multivariate analyses such as multiple regression, factor analysis, and principle component analysis are defined as subclasses of the multivariate analysis model. Objective and explanatory variables are described in a *model formula* slot and have a “dependent-independent” link to indicate their correspondences. The data to be assigned to the variables is described by a “same as” link between the content slots of variables and the data representations.

## 5. Discussion and Conclusion

In this section, we discuss the validity and utility of the ontological descriptions discussed in the previous section through a demonstration of the construct of academic boredom. The results of a factor analysis conducted by Acee et al. (2010) indicate that academic boredom is comprised of multidimensional and situation-dependent constructs. First, some items on the ABS-36 are correlated to negative and positive values. Second, all items on the ABS-10 are correlated to general boredom in under-challenging situations. The ABS-10 consists of ten items representing ten psychological attributes: “want something else,” “tired of activity,” “impatient,” “frustrated/annoyed,” “apathetic,” “nothing to do,” “activity dull,” “repetitive,” “wonder why doing this,” and “useless/unimportant.” Third, in over-challenging situations, five psychological attributes (“want something else,” “tired of activity,” “impatient,” “frustrated/annoyed,” and “apathetic”) are correlated to self-focused boredom, whereas the remaining five attributes (“nothing to do,” “activity dull,” “repetitive,” “wonder why doing this,” “useless/unimportant”) are correlated to task-focused boredom.

This construct of academic boredom is represented in Figure 5 and, as a subclass of the factor analysis model, is further defined in Figure 4. Model formulae given in mathematical expressions (Fig. 3) are defined as *Negative Affect-related Expression* and *Positive Affect-related Expression* role holders, which indicate relations between object variables and factors. The object variables contain a content slot used by a *modeled attribute value*, which is defined as a proposition of a quality data representation (Fig. 3). This means that the modeled attribute value refers to a quality value measured with a rating scale (Fig. 2). Therefore, correlations between some items of the academic boredom scale and negative/positive values are adequately described.

The constructs of boredom in under- and over-challenging situations are represented in Figure 5. In the *Construct of Academic Boredom in Under-challenging situation*, the modeled attribute value that is correlated to the *General Boredom Factor* refers to a quality value measured with a rating scale. Types of qualities are specified by the role player in the *measurement of* role slot. For example, a quality measured by the ABS-10 such as “want something else,” “tired of activity,” or “impatient” can play the role. Similarly, modeled attribute values in the *Construct of Academic Boredom in Over-challenging situation* also refer to qualities measured by the ABS-10.

This study conceptualized the three features of the boredom construct derived from the factor analysis conducted by Acee et al. (2010). However, two issues remain. First, qualities measured by items in the ABS lack sophistication. Second, the construct of academic boredom is uncertainly positioned in the description of statistical models. In this study, we provided an adequate description of relationships between modeled attribute values and quality values measured with rating scales.

However, we did not address modeled values described by the rating scales, a topic that we hope to examine in the future. Furthermore, we offered tentative descriptions of the constructs of academic boredom and positioned them in the statistical models. The concepts related to these constructs fundamentally differ from general statistical models. In other words, the constructs should be conceived in ways similar to learner models, for example. We addressed these unresolved matters in this study.

Our ontology will enable researchers to better interpret their results and share their findings. The descriptions we provide of constructs of academic boredom can help researchers acquire knowledge about associations between academic emotions and psychological attributes. Because the descriptions provided in the current study derives from only single study, their capability and range of application are confined to a construct of the academic boredom from a viewpoint of a few researchers. However, basic forms of statistical models which represent the constructs of academic emotions are common in psychology. Thus the current study just proposed the descriptions as a framework of the knowledge sharing on academic emotions. In future work, we extend our descriptions of constructs to include various academic emotions studied in educational psychology, and conduct practical assessments of their validity and utility through an implementation of IMS.

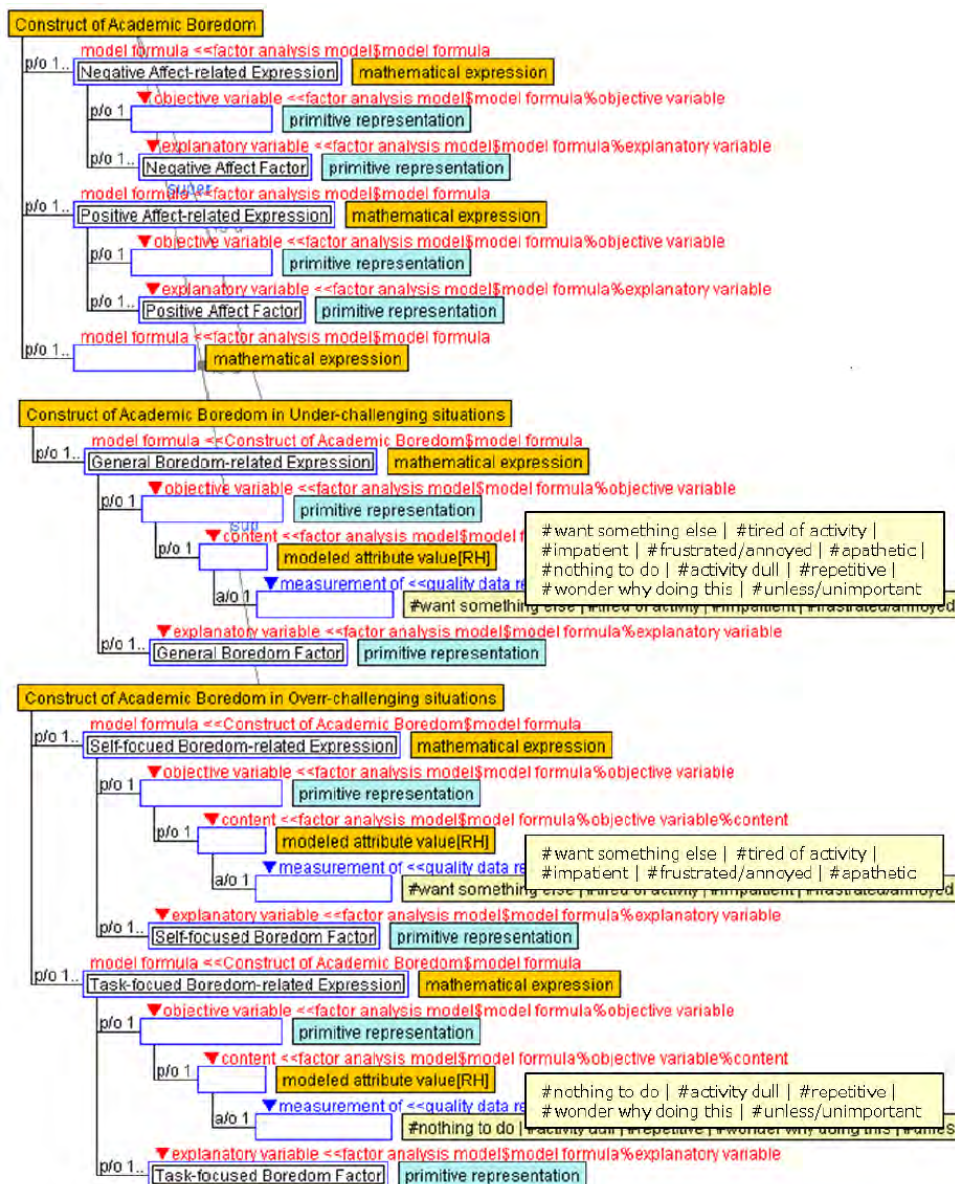


Figure 5. Construct of Academic Boredom.

## Acknowledgements

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# Scaffolding for Self-overcoming of Impasse by Using Problem Simplification

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**Abstract:** As a support for learners who failed to solve a problem, teaching the way to solve the problem is a general method. However, in order to realize active learning, it is a desirable way to let learners overcome the impasse of the problem solving by themselves. Because it is usually difficult for the learners to do it by themselves, we have proposed “problem simplification” that is a way to find a simplified problem that is included in the original problem from the viewpoint of problem solving. If the simplified problem can be solved by the learner, the difference between the simplified one and the original one is the origin of the impasse. To make clear the origin of the impasse is feasible scaffolding for self-overcoming of impasse. In this paper, firstly we propose a framework to define simplification of problems in elementary mechanics in high school. Then, it is introduced a support system for self-overcoming of impasse of problem solving using the problem simplification targeting elementary mechanics. We also report a practical use of this system in classes of a technical high school.

**Keywords:** Problem Simplification, Self-overcoming, Impasse, elementary mechanics

## 1. Introduction

Problem exercise is an indispensable step in learning of physics, mathematics and so on. When a learner engages in the problem exercise, the learner usually has enough knowledge to solve the problems in the exercise. However, the learner often fails to solve a problem because it is difficult for the learner to use knowledge adequately to solve the problem. In such case, to explain how to solve the problem is a standard method in usual teaching. This method is effective to let the learner solve the problem. However, because the learner often accepts the way to solve the problem passively, it is not effective as learning. In order to use failure of problem solving as an opportunity of learning, it is desirable to let the learner to overcome the failure or impasse of the problem solving by him/herself (Polya, 1945; Perkinson, 1984). In this paper, targeting elementary physics, we propose “problem simplification” to support a learner to overcome his/her impasse in problem solving by him/herself.

Even if a learner cannot solve a problem in an exercise, the learner usually has almost enough knowledge to solve the problem. Then, a few elements including the problem often cause the difficulty for the learner to solve it. In such case, it is possible to expect that the learner can solve a problem generated by deleting the elements in the original problem by him/herself. If the simplified problem is solved, it is possible to specify the cause of the difficulty for the learner as the difference between the original problem and the simplified problem. When a learner to engage in a new and difficult problem, it has been confirmed that to make clear the difference between the difference between the new problem and the problems that have been already solved is a promising way (Sheiter and Gerjets, 2002; Sheiter and Gerjets, 2003). Therefore, in the case of impasse of problem-solving, we assumed that such simplified problems are useful to overcome the impasse in solving the original problem. If the learner can solve the original problem after solving the simplified problem, the learner was supported but didn't teach the way to solve the original problem. So, we call this process “self-overcoming of Impasse”.

In order to use the simplified problem in problem exercise, however, it is necessary to generate the simplified problem from the original one. Therefore, in this research, we define “problem simplification”. Simplified problems used in the process should be included in the original problem from the view point of problem solving. The definition of the simplification is carried out based on

Microworld Graph describing simplification-complication relations between physical situations (Horiguchi and Hirashima, 2005; Horiguchi and Hirashima, 2009).

We have already implemented a system that support a learner in impasse of problem solving by using problem simplification targeting physics of high school. Because the system is implemented on tablet PC, it is possible to use the system in a usual classroom. We have already conducted practical use of the system in physics class in a technical high school. 130 students in three classes were used the system in one class time (45 minutes). Almost of them could use the system smoothly and we found behavior of self-overcoming of impasse from more than half of them. Also to other students, we could find focused their weak points.

This paper describes description of each problem and relations between problems in Section 2. The problem simplification supporting for Self-overcoming of impasse is explained in Section 3. This paper also reports a practical use of this system in classes of a technical high school and its results in Section 4.

## 2. Derivative Problem

As shown in Figure 1, previous research has defined the elementary mechanics problem as “situation” and “solution” (Okawachi, Ueno and Hirashima, 2012). Problems defined based on the situation, and the situation has attributes, such as gravitational acceleration and mass, and operational relations which is the relationship among attributes. The solution is defined by connecting attributes given in a problem sentence by means of operational relations defined in the situation. We call it solution structure (Hirashima, Kashihara and Toyoda, 1995). This is a tree structure composed of input attributes which are leaf nodes, output attribute which is a root node, derived attributes which are the others nodes, formula nodes which connect their attributes, and edges. Input attributes is attributes explicitly given in a problem sentence (blue nodes in Figure 1), output attribute is attribute which learners should seek by connecting input attributes (red node in Figure 1), and derived attributes is attributes which learners acquired in the middle of solving the problem (green nodes in Figure 1). How to the read solution structure in Figure 1 is that firstly “Gy” (gravitation of block A in vertical direction) is derived from “m” (mass of the object) and “g” (acceleration of the gravity) which are input attributes, using formula node “gravitation of block A (vertical)”, then “N” (normal force) is derived from “Gy” using formula node “normal force”, then “f” (dynamic friction) is derived from input attribute “μ” and derived attribute “N” using formula node “dynamic friction”, and lastly output attribute “Fx” (resultant of block A in parallel on the surface) derived from derived attribute “f” and input attribute “Tx” using formula node “resultant of block A (parallel on the surface)”.

We call the problem which has relevance from a viewpoint of the situation or the solution, "derivative problem" (Okawachi, Ueno and Hirashima, 2012). Automatic generation function of the formalized derivative problems had already been developed in the previous research. In the following subsections, the two types of derivative problems are explained.

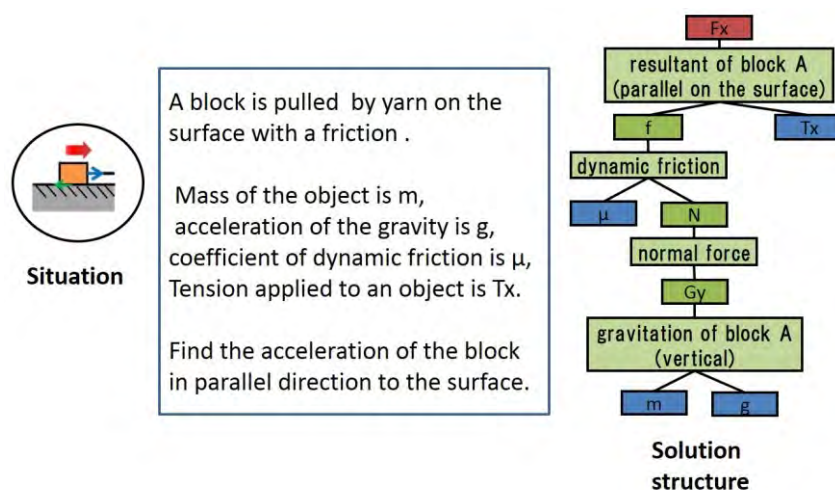


Figure 1. Problem and Solution Structure.

## *2.1 Specialized/Generalized Problem*

A specialized problem is generated by specialized a certain attribute, such as an angle of inclination and friction coefficient, which the situation of a certain problem has. This problem has simpler situation than original problem has. The specialization is making a certain attribute into a specific value. The solution of the specialized problem does not change from the solution of the original problem. Therefore, this problem is included by the original problem from the viewpoint of problem solving, so if learners can solve the original problem, they can inevitably solve the specialized problem.

A generalized problem is generated by adding a certain attribute to the situation of a certain problem. This problem has more complex situation than original problem has. The generalization is the opposite of specialization. The generalized problem includes the original problem from the viewpoint of problem solving, so if learners cannot solve the original problem, they cannot inevitably solve the generalized problem.

We use a model called a micro world graph for transition of the situation. This graph is comprehensively described situations which are derived from a certain situation (Hirashima, et al, 1994; Horiguchi and Hirashima, 2009).

## *2.2 Partialized /Expanded Problem*

A partialized problem has a part of solution structure of a certain problem as a solution of this problem. This problem is generated by making derived attribute input attribute, or derived attribute output attribute. Thus, extracting a part of solution is called the partialization. The partialized problem is included by the original problem from the viewpoint of problem solving, so if learners can solve the original problem, they can inevitably solve partialized problem.

An expanded problem is generated by making input attribute derived attribute, or output attribute derived attribute. The expansion is the opposite of partialization. The expanded problem includes the original problem from the viewpoint of problem solving, so if learners cannot solve the original problem, they cannot inevitably solve expanded problem.

# **3. Problem Simplification Strategy**

## *3.1 A Summary of Problem Simplification Strategy*

One of a purpose of the problem exercises is finding where learners reach an impasse in problem solving. For this purpose, when learners cannot solve a certain problem, they need to recognize the origin of the impasse. In order to have learners recognize it, let us use the following idea. Considering a problem structurally, the problem is made by complicating “a situation” or “a solution” of the simplest problem derivatively. Therefore, more complex problem includes simpler problem from the viewpoint of problem solving, and if learners can solve more complex problem, they inevitably can solve simpler problem. According to this idea, we can consider that problems are made hierarchically. We call this idea “Derivative Establishment Model of the Problem”.

Considering problems as things with such relationship, we can say that when a learner cannot solve a certain problem, he/she cannot solve the part in this problem, not the entire. Taking a difference between problem which a learner cannot solve and simpler problem which a learner can solve, this difference is the origin of the impasse in solving the problem which a learner cannot solve and the part which they should overcome. Based on this idea, if learners cannot solve a certain problem, the problem is simplified until they find a problem which they can solve. After they find the problem which they can solve, taking a difference between the original problem which they couldn't solve and the simplified problem which they could solve, they can recognize the origin of the impasse in solving the original problem. We call this strategy “Problem Simplification Strategy”. Although it is difficult for learners to consider combining the simplified problem and the difference as learners return to the original problem from the simplified problem, they can easily recognize their origin of the impasse, comparing to usual exercise. We assume that learners may overcome their impasse of the original problem which they

couldn't solve by themselves without some teaching activities, by tackling the problem with their being conscious of their origin of the impasse and recognizing the relationship of the problems, because learners usually have enough knowledge to solve the problems in the exercise. On the other hand, if they cannot overcome their impasse of original problem, they lead to efficient learning by learning again focusing on their origin of the impasse.

"The Problem Simplification Strategy" has two functions which get learners to recognize the difference between the problem which they couldn't solve and the problem which they could solve. One is "the Difference Extract Function", and the other is "the Difference Connect Problem". We describes these functions in 3.2 and 3.3.

### *3.2 Difference Extract Function*

In problem simplification strategy, the learning environment sets learners simpler problem by only one step when they cannot solve a problem. If they can solve the simpler problem, they tackle again the original problem by only one step. Since the simplified problem which a learner could solve and original problem which a learner couldn't solve have strong relationship, they are expected to tackle the original problem using simplified problem. However, for this purpose, they need to recognize the relationship of the problems. Therefore, by lining up the simplified problem which a learner could solve and the original problem which a learner couldn't solve and highlighting difference between those, the learning environment has learners be conscious of the difference. This function is called "a Difference Extract Function". By using this function, the learners may be able to be not only aware of difference between the simplified problem which they could solve and the original problem which they couldn't solve, but also may be able to solve the original problem by using simplified problem.

### *3.3 Difference Connect Problem*

We can assume that there are learners who cannot overcome the impasse in solving the original problem, even if they use "a Difference Extract Function". In this case, the learning environment set them "a Difference Connect Problem". This problem is a problem which connects the simplified problem which they could solve and the original problem which they couldn't solve.

It is assumed that a problem which a learner couldn't solve has a part which they cannot solve somewhere in a solution. Because the difference connect problem has such part as a solution of this problem, this problem is a problem which connects a solution of problem which a learner could solve and a solution of problem which a learner couldn't solve. The solution of this problem is generated by taking the difference of the solution of problem which a learner could solve and problem which a learner couldn't solve, i.e., solution structure of problem which a learner could solve and problem which a learner couldn't solve. Although the difference connect problem is one of a partialized problem, unlike usual partialization, partialization in generating the difference connect problem is performed so as to focus on the part which they cannot solve in a solution. We assume that if learners recognize where the part as their origin of the impasse is and connect this part and problem which they could solve, they can solve problem which they couldn't solve. If learners cannot overcome their impasse in solving problem which they couldn't solve through "Difference Extract Function", the learning environment sets them "a Difference Connect Problem".

If learners cannot solve "a difference connect problem", this problem is specialized/ partialized based on "Problem Simplification Strategy". By repeating this, they can find the part which they cannot solve more appropriately.

There are three kinds of the difference connect problem as follows. In case the relation between problem which a learner could solve and problem which a learner couldn't solve is partialization and expansion, the difference connect problem is (1) a problem whose solution is lost by partialization (Figure2). In case the relation between problem which a learner could solve and problem which a learner couldn't solve is specialization and generalization, the difference connect problem is (2) a problem which have learners derive attribute omitted by specialization (Figure3 (a)), and (3) a problem which have learners use operational relation changed by specialization (Figure3 (b)).

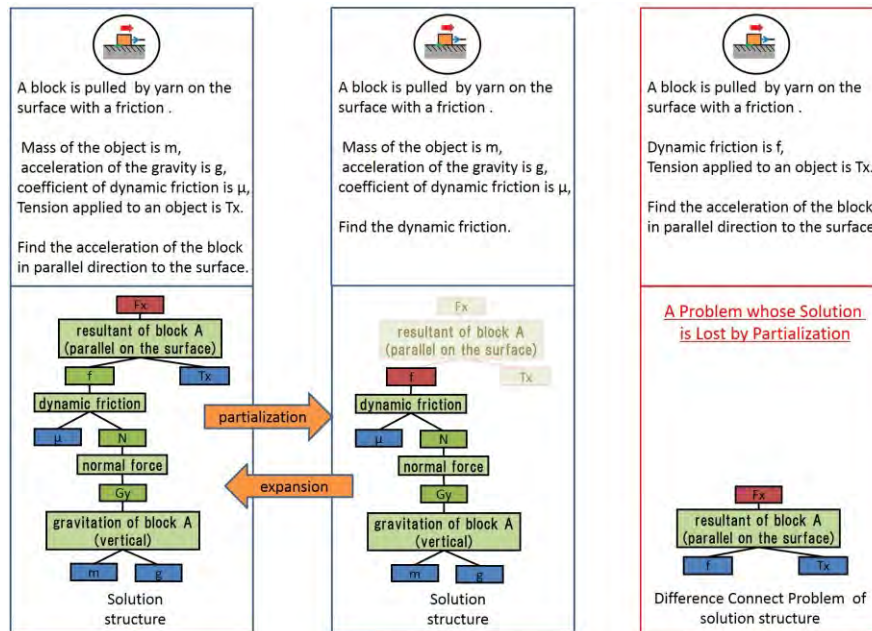


Figure 2. A Difference Connect Problem in Case the Relation between Problem which A Learner could solve and Problem which A Learner couldn't solve is Partialization and Expansion.

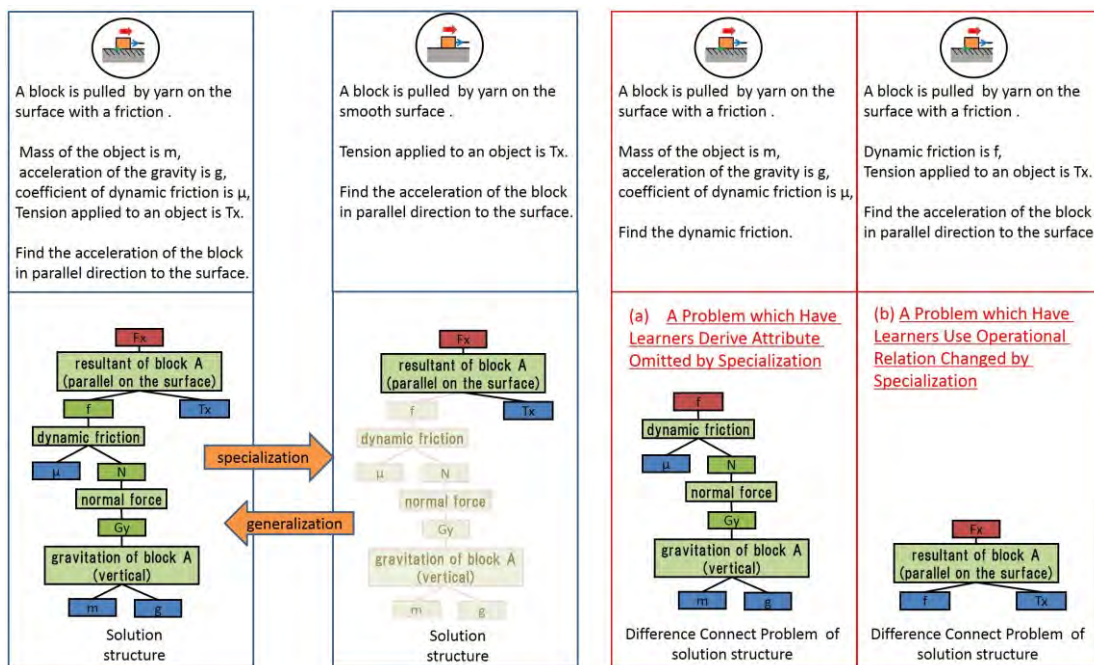


Figure 3. Difference Connect Problems in Case the Relation between Problem which A Learner could solve and Problem which A Learner couldn't solve is Specialization and Generalization.

### 3.4 Support System for Self-overcoming of Impasse

We had created support system for the self-overcoming of impasse. This system is a system which performs a problem exercise that a natural situation for taking the difference into consideration by “Problem Simplification Strategy”. This system has first problems and can automatically generate simplified problems. This system is implemented on a tablet PC that excels in carrying and been able to use anywhere, taking it into consideration that this system is used at actual schools.

Firstly, learners select a first problem prepared by this system which they should tackle. It is desirable that this problem be a little difficult for the learners. If they cannot solve this problem, they can systematically simplify (specialized/partialized) this problem by only one step based on “Problem

Simplification Strategy”. And so, if they can solve simplified problem, the difference extract function get them to pay attention to a difference between problem which a learner could solve and problem which a learner couldn’t solve. This difference is the origin of the impasse in solving problem and this system specifies this difference. Then, they tackle again the original problem which a learner couldn’t solve and aim to overcome an impasse of solving the problem by only one step. Then, if they cannot solve the original problem once more, this system sets them “a Difference Connect Problem”. If they can solve this problem, they tackle again the original problem. If they cannot solve “the Difference Connect Problem”, they can simplify (specialized/partialized) this problem based on “Problem Simplification Strategy”. Repeating this flow, this system encourages learners to learn with them considering the difference between problems.

On this system,

- (1) If learners cannot solve a certain problem, this problem is simplified.
- (2) After learners can solve simplified problem, through “a Difference Extract Function” or “a Difference Connect Problem”, they tackle the original problem.
- (3) Learners can solve the original problem.

While the above a series of activities, this system only sets learners problems, not teaching how to solve. Furthermore, since learners overcome the problem which they could not solve once, when such activity has been seen, it is assumed that the self-overcoming of impasse has been done.

#### 4. Practical Using Targeting National Collage Students

##### 4.1 A Purpose and Method of Practical Using

We had used the system in class of dynamics at National Collage in a period. This purpose is that we confirm, from a questionnaire and a log, whether “a Problem Simplification Strategy” used by this system is valid support for the self-overcoming of impasse in actual school or not.

The subjects are freshmen of National College of maritime technology. They are 130 people in three classes. A method of practical using is as following;

- (1) operation explanation of a system (10 minutes)
- (2) system exercise (20 minutes)
- (3) post-questionnaire (10 minutes)

The post-questionnaire is shown in Table 1.

We prepare three problems as first problems. These problems are checked by learners’ teacher and are got his assent.

Table 1: The post-questionnaire for learners.

| No.  | Question   |
|------|--|
| (1)  | Do you like mechanics?   |
| (2)  | Are you good at mechanics?   |
| (3)  | Do you think that this exercise is useful for learning of mechanics?   |
| (4)  | Solving the problem which was set after answering correctly, did you use the problem which you could solve as a reference?     |
| (5)  | Was the problem that was set after making a mistake easier than the problem you mistake?                                       |
| (6)  | Was solving the problem that was set after making a mistake useful for solving the problem you made a mistake?                 |
| (7)  | What was especially a good point of this system, you comparing this system with exercise books that you have used in the past? |
| (8)  | Did it make your motivation to tackle the problem exercise increase that you can select the problem to solve next?             |
| (9)  | Were you easy to use this system?  |
| (10) | Did using this system make your impression of the mechanics better?  |
| (11) | Do you want to go on such exercises in the future?   |

## 4.2 A Result

We used 103 persons' data as valid data, excluding the subjects who cannot be identified from the log and who have a defect in a questionnaire. The result of post-questionnaire is shown in Figure 4. For each item, we treated "I think so very much" and "I think so" as a positive opinion, and "I do not think so" and "I do not think so much" as a negative opinion. We done sign test for each item. This result is that there is no significant difference in question No.10, a significant difference in No.9 ( $p < 0.05$ ), and there are significant difference in the others ( $p < 0.01$ ). In question No.7, there are 33 learners who described contents that they grasp the intent of the exercise. Except the question No.10, questions are positive opinions about this system and are statistically significant. About the question No.10, considering many learners feel reluctant in learning mechanics and this practical using is in only a period, we can interpret this result that about 40 percent of the learners had changed the impression of mechanics by using of this system as not a negative result for this exercise.

Counting the log in valid data, the total number of problems which this system set is 2432. 360 of these are problems which learners could solve, 1899 of these are problems which they couldn't solve, and remaining 173 problems are problems which were not marked because of the time-out and which had a system trouble before marking. And so, there were 53 kinds of problem which the learners had tackled. The average time in which learners tackled a problem was 46.98 seconds ( $SD = 82.25$ ). There are 23.61 problems which a learner had tackled ( $SD = 13.09$ ). We can say that learners can tackle many problems. This is because, we assume, how to tackle one problem depends on learners, e.g. tackling the same problem repeatedly or simplifying problem which they cannot solve. In addition, we assume that the average time in which learners tackled a problem is slightly short because of not taking time so much while resolving a problem which they couldn't solve. Besides, we assume that three first problems prepared by us are the problems of suitable difficulty for learners because they cannot solve all first problems.

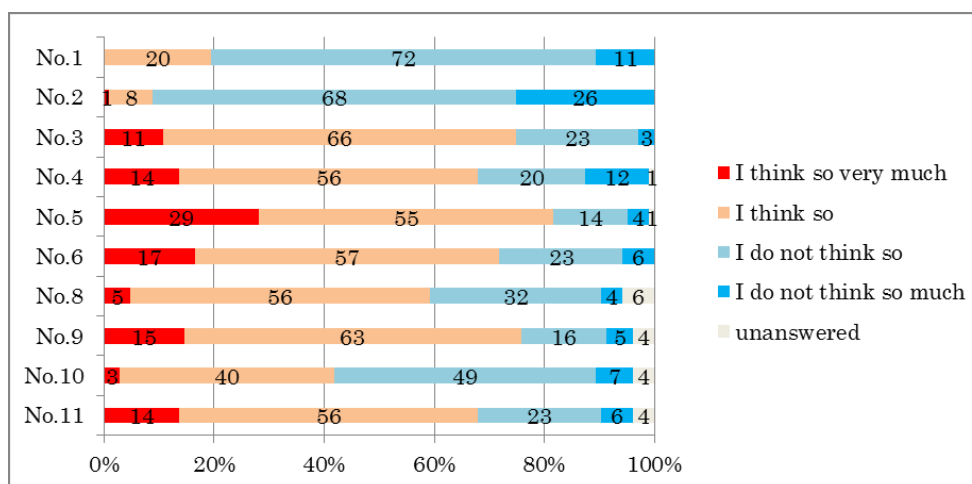


Figure 4. The Result of Post-questionnaire.

## 4.3 A Learners' Type Classification

We classify a learner's behavior by these features from log data. We call learners who had done the self-overcoming of impasse in "Problem Simplification Strategy" "learners having done the self-overcoming of impasse", learners who had recognized their challenge by finding problem which they can solve "learners having revealed a challenge", and learners who hadn't solved any problems "learners not having solved any problem". Each learner's distribution is shown in Table 2.

There are 29.42 problems which a learner in "learners having done the self-overcoming of impasse" had tackled ( $SD = 11.22$ ). (The breakdown of this is as follows; the average number of problems which he/she could solve is 5.29 ( $SD = 2.87$ ). The average number of problems which he/she couldn't solve is 22.37 ( $SD = 9.56$ ). The rest are problems which were not marked because of the time-out and which had a system trouble before marking.) The average time in which learners tackled a

problem was 38.14 seconds ( $SD = 60.52$ ). There were 6.65 kinds of problem which the learners had tackled ( $SD = 2.61$ ). The ratio of these learners is 60%, and they are learners who had done the self-overcoming of impasse as defined in this research. Because this system only set learners problems in this problem exercise, we assume that their solving problem which they couldn't solve is that they could do the self-overcoming of impasse. Since the 60 % of whole learners could do such activity, we assume that the expected effect of support for the self-overcoming of impasse using "Problem Simplification Strategy" is demonstrated. The number of problems which "learners having done the self-overcoming of impasse" had tackled is also more than one of the other learner groups.

There are 19.86 problems which a learner in "learners having revealed a challenge" had tackled ( $SD = 11.03$ ). (The breakdown of this is as follows; the average number of problems which he/she could solve is 1.60 ( $SD = 0.92$ ). The average number of problems which he/she couldn't solve is 16.34 ( $SD = 9.73$ ). The rest are problems which were not marked because of the time-out and which had a system trouble before marking.) The average time in which learners tackled a problem was 58.45 seconds ( $SD = 82.33$ ). There were 6.34 kinds of problem which the learners had tackled ( $SD = 2.66$ ). The ratio of these learners is a little over 20%. Because these learners couldn't do the self-overcoming of impasse, the average number of problems which they could solve for them is less than one for "learners having done the self-overcoming of impasse". Since "Learners having revealed a challenge" could solve a certain problem, it can be said that they have knowledge required to solve this problem and can use it. Then, it can be said that the difference between problem which they could solve and problem which they couldn't solve is the challenge to be overcome for the learners, and besides, this challenge for the learners have been elicited. We can't suggest that it is effective for the learners to overcome this point by using our system clearly because our system doesn't teach them how to overcome the challenge for them. However, we suggest that the problem exercise using "Problem Simplification Strategy" is useful for these subjects in order to clarify the challenge. Also, we insist that it is important to expand the functions which teach them directly so that they overcome their challenge as necessary.

There are 9.47 problems which a learner in "learners not having solved any problem" had tackled ( $SD = 7.24$ ). (The breakdown of this is as follows; the average number of problems which he/she couldn't solve is 8.31 ( $SD = 6.59$ ). The rest are problems which were not marked because of the time-out and which had a system trouble before marking.) The average time in which learners tackled a problem was 111.43 seconds ( $SD = 185.83$ ). There were 3.36 kinds of problem which the learners had tackled ( $SD = 1.49$ ). The ratio of these learners is a little under 20%. We can consider them as students which don't have the basic knowledge of mechanics. "Problem Simplification Strategy" has the aims of the promotion of understanding the relationship between problems for the student with the knowledge required to solve this problem. "Learners not having solved any problem" must have been taught the knowledge required to solve this problem by classes. However, we can presume that they don't have the knowledge or they cannot use the knowledge for solving problems. Therefore, we can't suggest that it is valid for them to perform this problem exercise. However, we suggest that it is indirectly valid for them to perform this problem exercise because of suggesting that they need a method of learning other than problem exercise. Although outside the scope of this research, it is also important to teach such learners when we consider the overall support of learning of mechanics. Besides, we can consider that we can integrate teaching such learners with our problem exercise with an affinity.

From the above, we confirmed the self-overcoming of impasse through this practical using. However, we still haven't demonstrated a learning effect of this strategy. So, we need to confirm it in the future issue.

Table 2: A Learners' Type Classification.

| A learners' type classification.                    | The number of people | The ratio of the whole |
|---|----------------------|------------------------|
| Learners having done the self-overcoming of impasse | 61                   | 59.22%                 |
| Learners having revealed a challenge                | 23                   | 22.33%                 |
| learners not having solved any problem              | 19                   | 18.45%                 |



## 5. Conclusion and Future Issues

In this paper, we suggest “Problem Simplification Strategy” as support for the self-overcoming of impasse. This is a way to aim to do the self-overcoming of impasse by learner’s dividing a problem into the part that can be solved and not solved. We designed and developed support system for the self-overcoming of impasse implemented this strategy. Besides, we had done a practical use of this system in classes of a technical high school. This result shows that this strategy can use as problem exercise and is valid as support for the self-overcoming of impasse because the ratio of “learners having done the self-overcoming of impasse” is 60%. Our main future works are (1) verification of the learning effect of the scaffolding with problem simplification by comparing with the usual problem exercise and (2) design of a fading method of the scaffolding.

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# An Examination of Affect and its Relationship with Learning among Students using SimStudent

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**Abstract:** The goal of this paper was to examine affect-related factors and its relationship with student learning while tutoring an agent called SimStudent. These affect-related factors are the negativity of student self-explanations, the incidence and persistence of student affective states. Secondary school students who were part of this study were asked to teach their SimStudents solve algebra equations and make them pass all the quizzes. Results revealed that students failed to learn which led us to investigate other factors that could have attributed to this failure. Although the non-negatively valenced self-explanations did not have significant relationships with the students' learning gains, the self-explanations were helpful in terms of mathematical content and they generally exhibited positive attitudes when giving the self-explanations. Students also tended to perform better with higher levels of good confusion. Higher levels of boredom were associated with poorer learning. Boredom and confusion were the most persistent but both did not have significant relationships with student learning. Though the negative correlations of the negative self-explanations, incidence and persistence of boredom vis-à-vis learning were not significant, the findings imply that negativity is linked to students' poor performance.

**Keywords:** Affect, SimStudent, learning by teaching, self-explanation

## 1. Introduction

SimStudent is an algebra-solving teachable agent that learns problem-solving skills from examples (Matsuda et al., 2011; Carlson, Matsuda, Koedinger & Rose, 2012). A student, who acts as the tutor, gives a problem in a form of mathematical equations with variables which a SimStudent tries to solve one step a time (Matsuda et al., 2012c). Researchers have used SimStudent to investigate learning and the factors that affect learning, e.g. competition (Matsuda et al., 2013), meta-cognitive help (Matsuda et al., 2014), deep vs. shallow learning (Matsuda et al., 2012c), quality of self-explanations (Matsuda et al., 2012a) and others. This paper investigates the relationship between affect and learning among students using SimStudent.

Affect refers to a positive or negative mental state coupled with some combination of physiological arousal, cognitive evaluation, and behavioral expression (Picard, 2000). Affect is interesting because its role is encompassing; be it in decision-making, in perception, in human interaction, or in human intelligence (Picard, 2000). There is an interplay between affect and learning and this claim is supported by recent reports made by affective neuroscience and psychology which suggest that human affect and emotional experience are important as they can influence how humans learn (Ahn & Picard, 2005).

In this paper, we narrate a SimStudent deployment that failed to help students learn. We then examine the relationship between student achievement and the following affect-related factors: *negativity of student self-explanations, incidence of student affective states, and persistence of student affective states.*

## 2. SimStudent

SimStudent is a teachable agent that helps students learn linear equation problem-solving skills by teaching (Matsuda et al., 2011). It has been tested and redesigned several times, resulting in insights regarding the effects of learning by teaching and related cognitive theories to explain when and how students learn by teaching (Matsuda et al., 2012a; Matsuda et al., 2012b; Matsuda et al., 2013).

SimStudent is a synthetic pedagogical agent that acts as a peer learner. It learns procedural skills from examples. SimStudent attempts to solve a problem given by the student one step at a time. If SimStudent cannot perform a step correctly, it asks the student for a hint. To respond to this request, the student has to demonstrate the step.

This study used the self-explanation version of SimStudent, where the SimStudents ask their tutors to provide explanations for their tutoring decisions, e.g. “*Why should I do this problem?*” or “*But I tried that move earlier. Why doesn’t it work now?*” Students could choose a response from a drop-down list or create freeform responses. SimStudents do not understand these self-explanations. It was included in this version to see the effect of self-explanation for tutor learning.

## 3. Methods

### 3.1 Participants

The study took place in one high school in Davao City, Philippines. Two (2) first year high school (Grade 7) sections with an average of 36 students per class were enlisted in this study. All students were taking an algebra class. There were 72 study participants in all with ages ranging from 12 to 14. The average age of the participants was 13.5 years old.

### 3.2 Structure of the study

The actual experiment was comprised of one session designed for the SimStudent orientation and pre-test, three 60-minute sessions for the actual use of SimStudent in the computer laboratory, and one session for post-test and debriefing.

When students used the software, they tutored their SimStudents in solving equations with variables on both sides. They were informed that their goal was to help their SimStudents pass all four (4) sections of the quiz.

### 3.3 Measures

There were three types of data collected during the experiment: written test data, system logs, and human observations. Students took pre- and post-test before and after the intervention. Three versions of isomorphic tests, tests A, B, and C, were randomly used to counterbalance the test differences in the pre- and post-tests. The test was divided into five parts. Parts 1, 3, and 5 constituted procedural knowledge while parts 2 and 4 constituted conceptual knowledge. We only used the procedural test scores as the learning outcome measure for the current analysis.

The system automatically logged all of the participants’ activities including problems tutored, feedback provided, steps performed, examples reviewed, hints requested, and quiz attempts.

Finally, human observers noted students’ affect and behavior as they used SimStudent. Observers followed the Baker-Rodrigo Observation Method Protocol (BROMP) 1.0 (Ocumpaugh, Baker & Rodrigo, 2012). The behaviors of interest were *On Task*, *Giving/Receiving Answers*, *Other On Task Conversation*, *Off Task Conversation*, *Off Task Solitary*, *Inactive* and *Gaming* while the affective states were *Boredom*, *Confusion*, *Delight*, *Surprise*, *Flow*, *Frustration*, and *Neutral*.

$$\text{Normalized gain} = \frac{\% \text{Post-test score} - \% \text{Pre-test score}}{1 - \% \text{Pre-test score}} \quad (1)$$

#### 4. Student achievement

Of the 72 participants, only 50 had complete test scores and log data. The analysis that follows is limited to this subset.

As already mentioned earlier, this deployment of SimStudent failed to help students learn. The mean scores of the procedural skill test and their standard deviations are shown in Table 1. The result of the pre-test and the post-test showed that the students did not learn from SimStudent. The average normalized gain was -0.18. Students did not have any classroom instructions between the pre-test and post-test.

**Table 1. Mean Test Scores  $\pm$  SD for Pre-test and Post-Test**

| Pre-test (%)      | Post-test (%)     |
|-------------------|-------------------|
| 37.63 $\pm$ 10.67 | 35.58 $\pm$ 11.38 |

With  $p=0.42$ , the difference between the pre-test and post-test of the students was not statistically significant.

#### 5. Affect-related factors and their relationships with student learning

In this section, we examine several affect-related factors and their relationship with learning. These include the poor quality of student self-explanations, negative attitudes towards SimStudent, and negative affective states.

##### 5.1 Valence of Self-explanations

There is evidence that self-constructed explanations could be an effective way to facilitate learning because the students are able to reflect in the process when they work out the examples themselves based on prior knowledge (Chi, 1996; Matsuda et al., 2012a). Occasionally, SimStudent asked the students what, how, and why questions. Students made their responses by typing their answers or instructions on the given placeholder.

Students' self-explanation responses to SimStudent were classified into 8 categories using a Self-Explanation Coding Manual by Carnegie Mellon University. Eight (8) (N1, N2,..., N8) different codes were used to classify the type of explanation. Table 2 shows the coding scheme along with the summary of the results of the self-explanations.

**Table 2. Coding Scheme for Classifying Self-Explanations**

| Code | Description  | Total | %     |
|------|--|-------|-------|
| N1   | The input must include a math concept-oriented explanation why the student entered the problem, why SimStudent's performance was wrong, or why the student did a particular demonstration. | 53    | 11.57 |
| N2   | The input only provides a math-related explanation of how to solve the problem.  | 259   | 56.55 |
| N3   | The input blames SimStudent for an incorrect action on the current problem solving process.  | 10    | 2.18  |
| N4   | The input is related to math but is vague and abstract. It does not include a math-concept-oriented justification for the student's action.  | 26    | 5.68  |
| N5   | The input is an admission on the part of the student that he/she made a mistake.   | 1     | 0.22  |
| N6   | The input is an admission on the part of the student that he/she does not know the answer to SimStudent's question.  | 5     | 1.09  |
| N7   | The input does not address SimStudent's question or the input is just a number.  | 104   | 22.71 |
| N8   | The input does not fit into the other categories.  | 0     | 0     |

| Code | Description  | Total | %   |
|------|--------------|-------|-----|
|      | <b>Total</b> | 458   | 100 |

Two coders independently labeled 651 self-explanations based on the coding scheme. Inter-rater reliability was acceptable with Cohen's Kappa=0.66. The 651 self-explanations were produced by 50 students who completed the pre-test and post-test. Four hundred fifty-eight (458) self-explanations were retained after discarding the disagreements between coders.

We computed for the percentage of helpful self-explanations per student using the following formula:

$$(N1+N2)/ \text{TotalLabels} \quad (2)$$

Helpful self-explanations are students' explanations that were found appropriate in terms of mathematical content.

The percentages of helpful self-explanations were correlated with the individual learning gain of the students. We found that there was no correlation between the helpfulness of self-explanations and learning ( $r=0.04$ ;  $p=0.94$ )

Was there perhaps a link between the emotional valence of the self-explanations and learning? In other words, could students' positive or negative attitudes towards SimStudent be related to the students' skills in math? Working independently, two coders labeled the 651 self-explanations for valence. A self-explanation was labeled as negative if it manifested negative emotions like anger, fear, and frustration (e.g. shouting at the tutee by typing in all caps like "*I DON'T KNOW HOW, I'M NOT GOOD IN MATH*", using exclamatory marks LIKE "*multiply 3!!!*", not answering, giving irrelevant answers like "*loser*", and the like). A self-explanation was labeled non-negative if it was polite, patient or neutral (e.g. "*You shall subtract 2 in both sides*", "*Yes, transfer 6 to the right side*", "*yes*", "*no*"). Inter-rater reliability was acceptably high, with Cohen's Kappa=0.78

After discarding the disagreement between coders, 554 self-explanations labeled for valence remained. Sixteen percent (16%) (89 out of 554) of the total self-explanations had negative valence. On the other hand, eighty-four (84%) (465 out of 554) had positive valence.

The percentages of self-explanations labeled as negative valence were correlated with the learning gains of the students. We found a low negative correlation between negative self-explanations and learning ( $r=-0.27$ ) however the correlation was not significant ( $p=0.56$ ).

## 5.2 The incidence of boredom and confusion

Is it possible that poor learning gains were related to the incidence and persistence of confusion or boredom? Both confusion and boredom are interesting as previous studies have shown their relationship to learning (Baker, D'Mello, Rodrigo & Graesser, 2010; D'Mello & Graesser, 2012). Confusion has a positive and negative dimension. It has been found that positive or good confusion can motivate learners to exert more effort to learn while negative or bad confusion can cause learners to give up and disengage from a learning task (D'Mello & Graesser, 2012). Boredom has been found to lead to poor learning gains (Rodrigo et al., 2009; Baker, D'Mello, Rodrigo & Graesser, 2010) and non-productive learner behaviors like gaming the system (Baker, D'Mello, Rodrigo & Graesser, 2010).

As mentioned earlier, 72 students participated in this experiment. For every ten of these students, one pair of affect observers used the Baker-Rodrigo Observation Protocol Method (BROMP) to note the affective states of the students. Unfortunately, only one pair of coders had an acceptable inter-rater agreement, with Cohen's Kappa=0.77. Data from three students was excluded because they had no pre- or post-tests. Hence, for this section, data from only 7 students was included.

With a total of 78 observations, the average for each of the affective state per student was computed to determine the incidence of the affective states. This was further averaged across all seven (7) students and the computed average boredom affect was 13.31% (SD=0.06) while the average confusion affect was 6.57% (SD=0.04).

Learning gains and boredom had a moderate negative correlation ( $r=-0.61$ ) but this relationship was not significant ( $p=0.14$ ). Similarly, learning gains and confusion were moderately correlated ( $r=0.54$ ) but the relationship was not significant ( $p=0.21$ ). Although not statistically significant, the directionality of the correlations was interesting. Students who tend to be confused tend to do better on the post-test, while students who are bored tend to do worse.

The positive correlation of confusion and learning gains implies that students may have experienced a good form of confusion.

### 5.3 Persistence of boredom and confusion

Finally, we tried to determine whether the persistence of affective states was related at all to learning gains. We computed each affective state's transition likelihood metric  $L$  (D'Mello, et al., 2005), which is statistically equivalent to Cohen's Kappa.

$L$  is computed as follows:

$$L = \frac{\Pr(NEXT | PREV) - \Pr(NEXT)}{(1 - \Pr(NEXT))} \quad (4)$$

The  $L$  value for each student was computed for a given transition, followed by the mean and the standard error across students. Using the two-tailed test for one sample, we can then determine if a given transition is significantly more likely than chance (chance = 0), given the base frequency of the next state.

Both boredom-boredom and confusion-confusion transitions were not significant (Table 4).

Table 4. L-Values and SD for Confusion and Boredom

| Affective State | L-Value | Standard Deviation | p    |
|-----------------|---------|--------------------|------|
| Boredom         | 0.11    | 0.22               | 0.34 |
| Confusion       | 0.02    | 0.14               | 0.99 |

The  $L$  values of boredom and confusion were correlated with the learning gains of the students. The results showed that there was a moderate negative correlation between boredom and the learning gains however the relationship was not significant ( $r=-0.46$ ,  $p=0.28$ ). The relationship between confusion-confusion and learning gains was practically zero and not significant ( $r = -0.01$   $p=0.98$ ).

## 6. Summary of Contributions, Limitations, and Future Work

The goal of this paper was to investigate the relationship between student learning gains and affect-related factors. Since student pre-test and post-test scores were not significantly different, we attempted to examine some of the factors that may be related to students' failure to learn. We first examined the quality of students' self-explanations. Majority of the students' self-explanations were helpful in terms of mathematical content. Sixty-nine (69%) of the total self-explanations deliberately instructed SimStudent how to solve the algebra equations. However, the percentages of helpful self-explanations were not significantly correlated with the students' learning gains.

We then examined the valence of the self-explanations. The large majority of self-explanations (84%) were non-negative, i.e. students generally gave helpful, constructive advice. The percentages of negatively valenced self-explanations and learning gains were negatively correlated but the relationship was not significant.

We examined whether certain affective states were related to students' lack of achievement. Although the correlations were not significant, student confusion tended to be correlated with performance while boredom tended to be correlated with poorer learning.

Finally, we examined first whether certain affective states persisted and whether there was a relationship between the student achievement and the persistence of the boredom and confusion. We found that boredom and confusion tended to persist, although the persistence of these affective states was not significant. There were also no significant relationships between persistent boredom and learning gains as well as persistent confusion and learning gains.

Though none of the correlations were significant, the overall trend of the findings imply that negativity goes with poor performance. Negative self-explanations, incidence of boredom, and the persistence of boredom were negatively correlated with the students' learning gains.

For future work, additional, reliable human observations would be very helpful.

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# An Exploratory Analysis of Confusion Among Students Using Newton's Playground

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**Abstract:** We investigated the interplay between confusion and in-game behavior among students using Newton's Playground (NP), a computer game for physics. We gathered data from 48 public high school students in the Philippines. Upon analyzing quantitative field observations and interaction logs generated by NP, we found that confusion among students was negatively correlated with earning a gold badge (solving a problem with objects under par), positively correlated with earning a silver badge (solving a problem with objects over par), and positively correlated with stacking (drawing numerous small objects to reach the objective), a form of gaming the system.

**Keywords:** Confusion, student affect, Newton's Playground, learning, in-game behavior

## 1. Introduction

In recent years, researchers have been investigating the state of confusion among learners using intelligent tutoring systems. Confusion, or cognitive disequilibrium, is defined as the uncertainty about what to do next (D'Mello et al., 2005). It occurs when a student encounters stimuli or experiences that fail to meet expectation (D'Mello, Lehman, Pekrun, & Graesser, 2014) and plays an important role in the learning process because cognitive disequilibrium "has a high likelihood of activating conscious, effortful cognitive deliberation, questions and inquiry that aim to restore cognitive equilibrium (Craig, Graesser, Sullins, & Gholson, 2004; D'Mello et al., 2008)." Confusion is actually useful when it spurs learners to exert effort deliberately and purposefully to resolve cognitive conflict. If the learners are successful, they return to a state of flow – complete immersion and focus upon the system (Csikszentmihalyi, 1990). However, confusion may also be negative. If unresolved, confusion can lead to frustration or boredom, and students may decide to disengage from the learning task altogether (D'Mello & Graesser, 2012). Previous studies have shown confusion to correlate positively with learning gains (Craig et al., 2004; D'Mello et al., 2014). Extended periods of confusion, however, were associated with negative learning outcomes (Lee, Rodrigo, Baker, Sugay, Coronel, 2011).

This study explores student in-game events that may be indicative of student confusion within Newton's Playground (NP, described in detail in Section 2), a computer game for physics. NP requires the player to guide a green ball to a red balloon by drawing simple machines on the screen with colored markers controlled by the mouse. The software has been used previously for stealth assessment of creativity, persistence, and conceptual physics understanding (Shute & Ventura, 2013). The studies found significant improvement in terms of conceptual physics understanding among students that played the game, depending on how engaged they were (or how many levels they attempted to play) during gameplay (see Shute, Ventura, & Kim, 2013). Additional studies are using Newton's Playground to examine the relationship between student affect, in-game behavior, and



mastery of physics concepts. This exploratory study examines human observations alongside logged student-software interactions to determine what in-game events correlate with student confusion.

## 2. Study population, system, and data collection methodology

### 2.1 Participant Profile

We conducted a study to measure the relationship between a variety of affective and cognitive variables. Data was gathered from 60 eighth grade public school students in Quezon City, Philippines. Students ranged in age from 13 to 16. As of 2011, the school had 1,976 students, predominantly Filipino, and 66 teachers. Of the participants, 31% were male and 69% were female. Participants were asked to rate how frequently they played video games and watched television on a scale of 1 (not at all) to 7 (everyday, for more than 3 hours), and the resulting average frequency of gameplay is 3.2 (in between a few times a month, and a few times a week), and the resulting average frequency of watching television is 5.9 (in between everyday, but for less than 1 hour, and everyday, for 1-3 hours). Participants were asked for their most frequent grade on assignments, and on a scale of 0 (F) to 4 (A), the average most frequent grade of the participants is 3.1 (B).

### 2.2 The Software

Newton's Playground (NP) is a computer game for physics patterned after Crayon Physics Deluxe. It was designed to help secondary school students understand qualitative physics (Shute & Ventura, 2013). Qualitative physics is a nonverbal conceptual understanding of how the physical world operates, along the lines of Newtonian physics. Qualitative physics is characterized by an implicit understanding of Newton's three laws: balance, mass, and conservation and transfer of momentum, gravity, and potential and kinetic energy (Shute et al., 2013).

NP is a two-dimensional computer-based game that requires the player to guide a green ball to a red balloon. Two example levels are shown in Figure 1, the level on the left requiring a pendulum, and the level on the right requiring a lever. The player uses the mouse to nudge the ball to the left and right (if the surface is flat), but the primary way to move the ball is by drawing or creating simple machines on the screen with the mouse and colored markers. The objects come to life once the object is drawn. Everything obeys the basic rules of physics relating to gravity and Newton's three laws of motion (Shute et al., 2013).

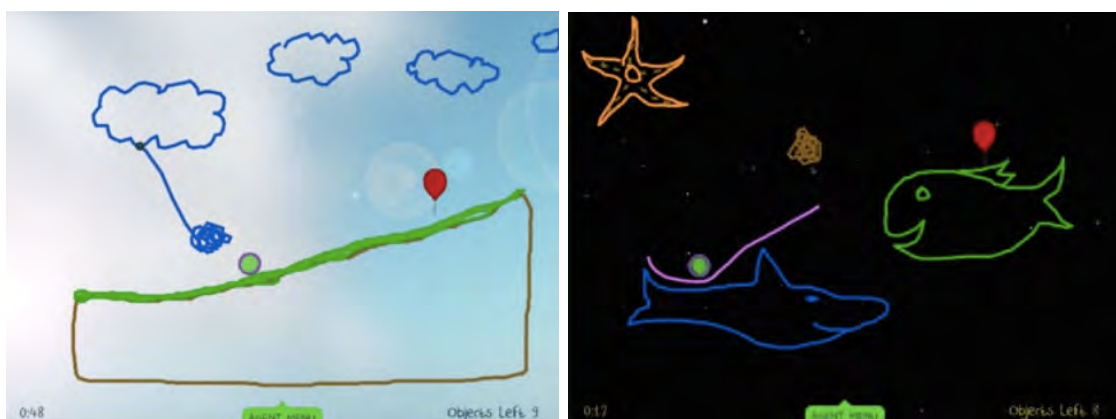


Figure 1. Examples of Newton's Playground levels.

The 74 levels in NP require the player to solve the problems via drawing different simple machines, representing agents of force and motion: inclined plane/ramps, levers, pendulums, and springboards. Again, all solutions are drawn with colored markers using the mouse. A ramp is any line drawn that helps to guide a ball in motion. A ramp is useful when a ball must travel over a hole. A lever rotates around a fixed point, usually called a fulcrum or pivot point. Levers are useful when a player wants to move the ball vertically. A swinging pendulum directs an impulse tangent to its

direction of motion. The pendulum is useful when the player wants to exert a horizontal force. A springboard (or diving board) stores elastic potential energy provided by a falling weight. Springboards are useful when the player wants to move the ball vertically.

*Gold badges versus silver badges.* Some levels in NP have multiple solutions, which means a player can solve the level using different agents. Gold badges are awarded when a player solves a problem “under par;” that is, under a limit set for a specific solution. For example, a level may be solved using a ramp, with a par of 1 object, or a lever, with a par of 3 objects. If a player solves the level with more objects than par, he receives a silver badge. Gold badges suggest that the player has mastered the agent relevant to the given level. Silver means the player may not have fully mastered the agent yet.

*Stacking.* During pilot testing, Shute et al. (2013) reported that it was possible to game the system to succeed without using the target knowledge (Baker, Corbett, Koedinger, & Roll, 2006) by drawing many tiny objects that stack up, propelling the ball upward until it reaches the target. This behavior is called stacking. The log files capture stacking actions on levels where the player did this (Shute et al., 2013).

### 2.3 *The Interaction Logs*

We collected two types of data during the study: interaction logs and human observations. During gameplay, NP automatically generates log files. Each level a student plays creates a corresponding log file, which tracks every interaction the student has with the game in terms of particular counts and times for selected features of gameplay. These features include but are not limited to:

- Time spent on the level in seconds,
- Number of in-level restarts,
- Number of objects drawn in a solution attempt,
- Whether the level was ultimately solved,
- Whether or not the player earned a gold or silver badge, and
- Whether or not a player was stacking, a form of gaming the system – the systematic misuse of system features to advance through the learning materials without learning the content (Baker et al., 2006) – within Newton’s Playground

Each of these variables provides useful information about students’ gameplay behaviors, which can then be used to make inferences about how well they are doing in the game (Shute et al., 2013).

### 2.4 *The Observation Protocol*

The Baker-Rodrigo-Ocupaugh Monitoring Protocol (BROMP) is a protocol for quantitative field observations of student affect and behavior. BROMP is a holistic coding procedure that has been used in thousands of hours of field observations of students, from kindergarten to undergraduate populations. It has been used for several purposes, including to study the engagement of students participating in a range of classroom activities (both activities involving technology and more traditional classroom activities) and to obtain data for use in developing automated models of student engagement with Educational Data Mining (EDM) (Ocupaugh, Baker, & Rodrigo, 2012). Within BROMP, each student observation lasts 20 seconds, and the observers move from one student to the next in a round robin manner during the observation period.

The affective states observed within Newton’s Playground were concentration, confusion, frustration, boredom, happiness, delight, and curiosity. The behaviors observed were on-task, off-task, stacking, and a behavior called *without thinking fastidiously* (WTF), a behavior in which, despite a student’s interaction with the software, “their actions appear to have no relationship to the intended learning task (Wixon, Baker, Gobert, Ocupaugh, & Bachmann, 2013).” The analysis of the behaviors, however, is outside this paper’s scope.

The inter-coder reliability for affect was acceptably high with a Cohen’s (1960) Kappa of 0.67. The typical threshold for certifying a coder in the use of BROMP is 0.6, established across dozens of studies as well as the previous affective computing literature.

## 2.5 Procedure

Before playing Newton's Playground, students completed a 16-item multiple-choice pretest for 20 minutes. Students were then assigned a computer on which they would play NP. Students played the game for two hours, during which, two trained observers used BROMP to code student affect and behavior. A total of 36 observations per participant per observer were collected. Videos of participants' faces were also recorded during gameplay. After completing the two hours of gameplay, participants completed a 16-point multiple-choice posttest for 20 minutes. The pretest and posttest were designed to assess knowledge of physics concepts, and has been used in previous studies involving Newton's Playground (Shute et al., 2013).

The pretest and posttest scores were tabulated and averaged. Students scored an average of 6.02 out of 16 in the pretest, and 6.02 out of 16 in the posttest. While these results suggest that NP did not seem to help increase knowledge of physics concepts, the researchers noticed that students were answering the posttest hurriedly. The posttest scores may thus not reflect an accurate knowledge assessment. It is important to note, however, that significant pretest-to-posttest improvements were reported in three previous studies that also used NP. Students in these studies used NP for longer periods of time.

## 3. The Relationship between Student Confusion and In-game Events

In order to investigate how students mastered content in Newton's Playground, we made use of the interaction logs recorded during gameplay to analyze student performance. Of the 60 participants, data from 12 students were lost because of faulty data capture and corrupted log files. Only 48 students had complete observations and logs. The analysis that follows is limited to these students.

The BROMP observations were tabulated, and the percentage of each affective state per student was calculated. Boredom, confusion, and frustration were three of the more commonly observed affective states, besides concentration.

All interaction logs were passed through a parser to arrange log events in tab-delimited text files. These text files were then run through a filter to get per student, per level, per attempt summaries, such as total time spent, total number of restarts, total number of objects drawn, etc. Finally, the information was collapsed to form per student vectors that summarized the students' entire interactions with the game. Each vector included the following attributes, which are indicative of mastery:

- Gold badge – percentage of level attempts solved, earning the student a gold badge
- Silver badge – percentage of level attempts solved, earning the student a silver badge
- Stacking – percentage of level attempts wherein a student was flagged for stacking

These three attributes, among about thirty other gameplay features, were correlated with the percentage of confusion, based on the human observations. Because the number of tests introduces the possibility of false discoveries, Storey's adjustment was used as a post-hoc control. Storey's translates the p-value to a q-value, which represents the probability that the finding was a false discovery. Among the results, earning a silver badge was positively correlated with confusion, while earning a gold badge was negatively correlated, and stacking was positively correlated with confusion. Table 1 shows their correlations, p-values, and q-values. Note that the findings were still significant even after the post-hoc correction was applied.

Table 1: Correlations between student interaction and confusion, their p-values, and q-values.

|             | Silver badges | Gold badges | Stacking |
|-------------|---------------|-------------|----------|
| Correlation | 0.32          | -0.29       | 0.31     |
| p-value     | 0.03          | 0.04        | 0.03     |
| q-value     | 0.02          | 0.03        | 0.03     |

The opposite relationship between gold and silver badges and confusion is interesting. Recall that solving a level under par earns a player a gold badge, while solving a level with more objects than par, no matter how many are drawn, earns the student a silver badge. As mentioned earlier, earning a

gold badge is indicative of mastery of the four agents being used in the game. Mastery of these agents goes beyond knowing what agents to use, as in many cases, different agents can be used to solve the same level. Mastery also entails proper execution of the drawing, and being able to keep the number of objects under par. A player has to be very precise in his understanding of various aspects of the agents (e.g. how massive an object must be and from what height it must be dropped onto a springboard in order to propel the ball towards the target) Students who have mastered the agents do not have to experiment for prolonged periods of time with drawing different objects to see which agents will propel the ball closer to the balloon.

If a student has not yet mastered the agents, however, he may end up making more guesses, experimenting by drawing different objects until the ball reaches the balloon, and ends up earning a silver badge. Understanding the solution could help the student gain mastery of the agents, but finding a solution merely by chance may contribute to making him even more confused.

The other interesting observation was the positive correlation between confusion and stacking, which, as mentioned earlier, is a form of gaming the system within NP, a behavior associated with negative affect. Previous studies have found confusion to have no significant effect on gaming the system (Baker, D’Mello, Rodrigo, & Graesser, 2010). This correlation, however, suggests that the more confused a student is, the more likely he is to stack. Stacking indicates a lack of mastery of the physics agents.

#### **4. Conclusions and Future Work**

In this study, we attempted to identify in-game events that may relate to confusion among students playing Newton’s Playground. Students played NP for two hours while two BROMP coders labeled student affect and behavior. These observations were then analyzed alongside NP interaction logs. In our analysis, we found that confusion was negatively correlated with earning a gold badge but positively correlated with earning a silver badge, and that stacking and confusion are positively correlated. This implies that, within our population, students who are confused lack of mastery of physics concepts. They solve problems inefficiently, using more objects than necessary. On the other hand, students who develop mastery of physics concepts are able to solve the NP problems with an optimal number of objects.

This study is the first of many analyses done on the data set, and is part of a bigger investigation. As such, there are several next steps to take from this work. One avenue is to disambiguate good and bad confusion, and find what student behaviors are indicative of each. Learning benefits can be derived from episodes of good confusion (D’Mello & Graesser, 2011). Bad confusion, on the other hand, has no pedagogical value (D’Mello & Graesser, 2011).

It would also be interesting to explore how student boredom manifests itself within NP. Boredom is defined as an “unpleasant, transient affective state in which the individual feels a pervasive lack of interest in and difficulty concentrating on the current activity” (Fisher, 1993). Boredom has been associated with poorer learning (e.g. Craig et al., 2004) and problem behaviors, such as gaming the system (e.g. Baker et al., 2010).

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# Evaluation of Difficulty Estimation for Learning Materials Recommendation

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**Abstract:** The popular technology for the information recommendation of books or web pages is based on taste information from many users, but it is important to be based on difficulty and proficiency for the recommendation of learning materials. We have developed an algorithm to estimate difficulty of learning materials and proficiency of learners, for recommendation considering difficulty of learning materials. The algorithm uses only a bipartite learner-material graph that consists of the reader relations with materials and learners. In this paper, we describe how to make an accurate data to evaluate the estimated difficulty, and report about the result that evaluated the precision of our proposed algorithm.

**Keywords:** Personalized recommendation, learning materials, difficulty estimation

## 1. Introduction

Most of mainstream information recommendation systems use content-based filtering or collaborative filtering based on the past behaviors of users, and may use hybrid filtering that redeems their defects and capitalizes on their respective strengths. Both the filters are based on taste information from many users. In recommendation for learning materials, the recommender systems that based on taste information of users might recommend the materials too difficult to a user. They might recommend the materials too easy adversely. The recommender system for learning materials desires to recommend the materials that have suitable difficulty for users. Therefore we propose new filtering based on difficulty of learning materials and proficiency of users. As you can see in figure 1, we propose also a recommender system that adopts pipelined hybrid filtering. Our proposed system recommends the learning materials suitable for proficiency of users after having narrowed down candidate materials by users' taste information.

## 2. Related Work

Durand, Belacel and LaPlante (2013) proposed a learning path recommendation algorithm using graph theory based model. This approach focuses on ways to search for potential learning paths. We suggest that a new and good learning material would be hard to be recommended by affected by old learning paths. Ghauth and Abdullar (2010) and Guo, Erdt and Lee (2013) proposed a learning materials recommendation algorithm based on difficulty of materials. Their recommender systems ask to learners to specify a difficulty level. Among other examples, there is a difficulty based recommender system for recommending games on mobile phones (Skocir et al., 2012).

## 3. Algorithm to Estimate Difficulty and Proficiency

### 3.1 Summary of Estimation Algorithm

Our algorithm does not use contents of learning materials at all. It only use the reading relations that denote who read which materials. The reading relations are expressed in bipartite graph like figure 2, and we call it a learner-material graph. Even if learning materials may be acquired no contents, this algorithm can make it a target of recommendation by combining with collaborative filtering like figure 1 because it can estimate difficulty and proficiency without using the contents of the learning

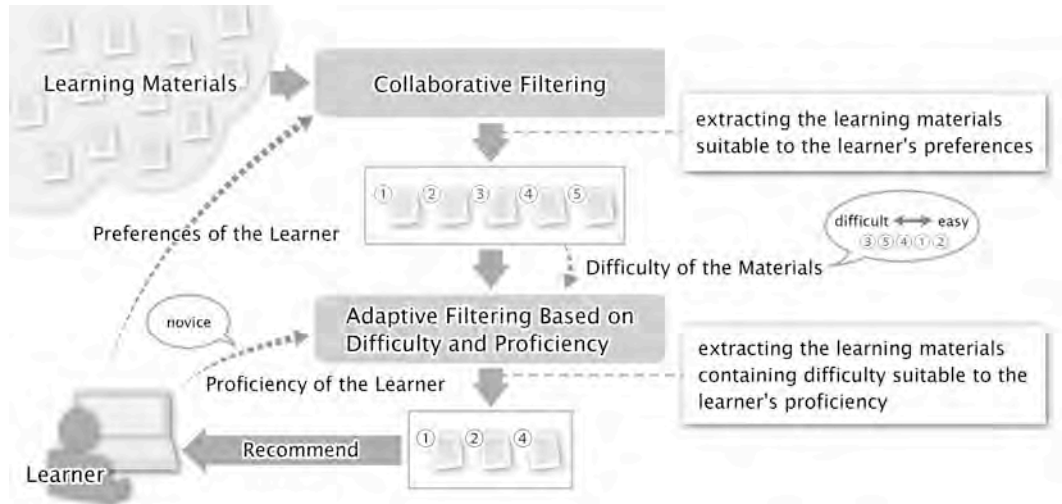


Figure 1. A Proposed Recommender System that Adopts Pipelined Hybrid Filtering.

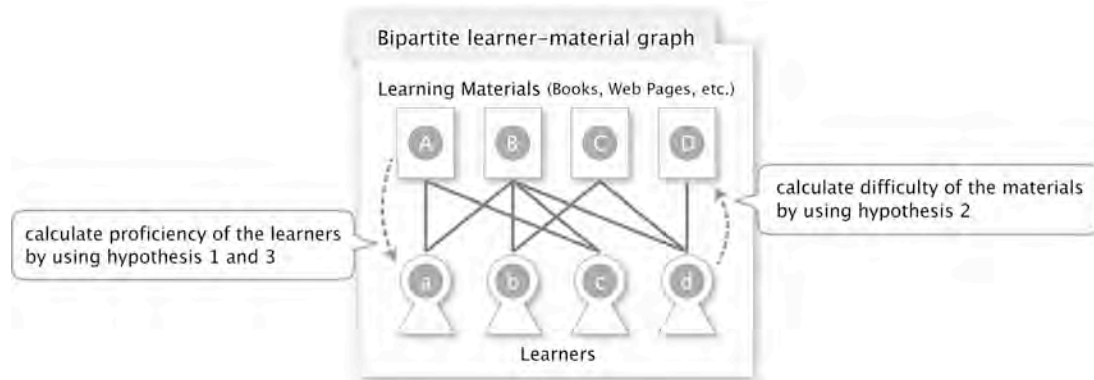


Figure 2. To Estimate Difficulty and Proficiency Using Learner-Material Graph.

materials. One of feature of this algorithm is to be able to simultaneously estimate difficulty of learning materials and proficiency of learners, but the estimation algorithms based on contents can estimate only difficulty. In addition, this algorithm is similar to PageRank (Page, Brin, Motwani and Winograd, 1999) and HITS (Kleinberg, 1999) that are popular webpage ranking algorithms, in concept to use a link structure of the graph network. The elemental algorithm performs based on the following hypotheses.

- Hypothesis 1: A learner reading a lot of learning materials of a domain should know a lot about the domain.
- Hypothesis 2: A learning material read by learners that have much knowledge should be difficult, and a material read by learners that do not know a lot should be easy.
- Hypothesis 3: A learner reading difficult learning materials should know a lot, and a learner reading easy materials should not have much knowledge.

At first, proficiency of learners is estimated by hypothesis 1. Next, based on hypothesis 2, difficulty of learning materials is calculated from proficiency of the learners. Then proficiency is recalculated from difficulty of the materials by hypothesis 3. Hypothesis 2 and 3 are influenced by each other. The calculations based on hypothesis 2 and 3 are repeated until the calculation result converges.

Hypothesis 1 and 3 are expressed as:

$$p_u = \sum_{i \in I_u} \dot{d}_i \quad (1)$$

where  $p_u$  is proficiency of the learner  $u$  and  $\dot{d}_i$  is normalized difficulty of the learning material  $i$  and  $I_u$  is a set of learning materials read by the learner  $u$ . The initial value of  $\dot{d}_i$  is 0.5. The difficulty value  $d_i$  of hypothesis 2 is written as:

$$d_i = \sum_{u \in U_i} (\dot{p}_u - 0.5) \quad (2)$$

where  $\dot{p}_u$  is normalized proficiency of the learner  $u$  and  $U_i$  is a set of learners who read the material  $i$ . The normalization values of  $\dot{d}_i$  and  $\dot{p}_u$  are found by dividing the deviation value by 100.

### 3.2 Improve of the Algorithm

We will define difficulty of learning materials and proficiency of learners before we describe an improved algorithm. The premise to estimate difficulty of learning materials and proficiency of learners is for recommending the learning materials. Therefore, in this study, we define the term “difficulty of a learning material” as presupposed knowledge quantity necessary to get most knowledge with the learning material, and define the term “proficiency of a user” as knowledge quantity that the user has about the domain of the learning materials and the associated domain.

The obtained values of difficulty and proficiency from elemental algorithm are relativity, and then there are not the direct relations in each other's values. Therefore the values are hard to be handled to recommend learning materials, because the value of difficulty of the learning material suitable for a learner who has a proficiency value is unclear. In addition, the elemental algorithm does not consider the order of that a learner read learning materials. The algorithm improved from elemental algorithm considers the order and estimates how learners acquire knowledge, for improvement of precision. Specifically we add hypothesis 4 and revise hypothesis 2 and 3 because a learner that has much knowledge might read an easy material.

- Hypothesis 4: A learning material read by expert learners while they are beginners should be easy.
- Hypothesis 2': A learning material read by learners that have much knowledge should be difficult.
- Hypothesis 3': A learner reading difficult learning materials should know a lot.

Furthermore, the improved algorithm makes it clear that the difficulty value of the learning material suitable for a learner is near to the proficiency value of the learner because the improved algorithm uses a same unit of the values of difficulty and proficiency by changing methods of calculation and normalization. Figure 3 and 4 show the difference of the estimation methods between

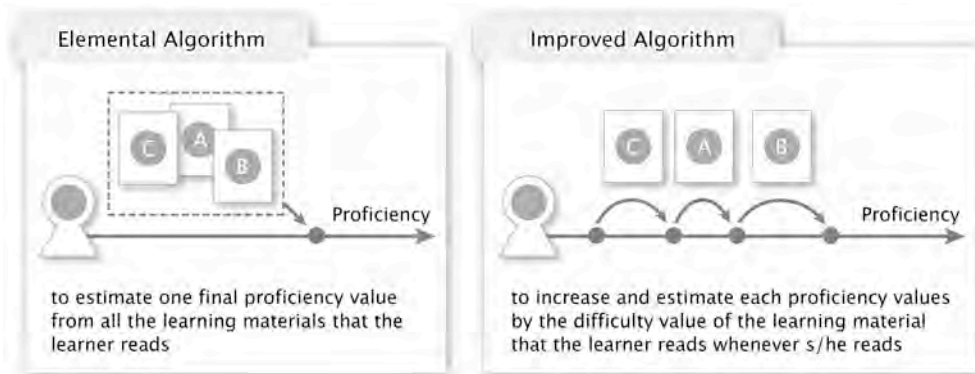


Figure 3. The Difference of the Methods for Proficiency Estimation.

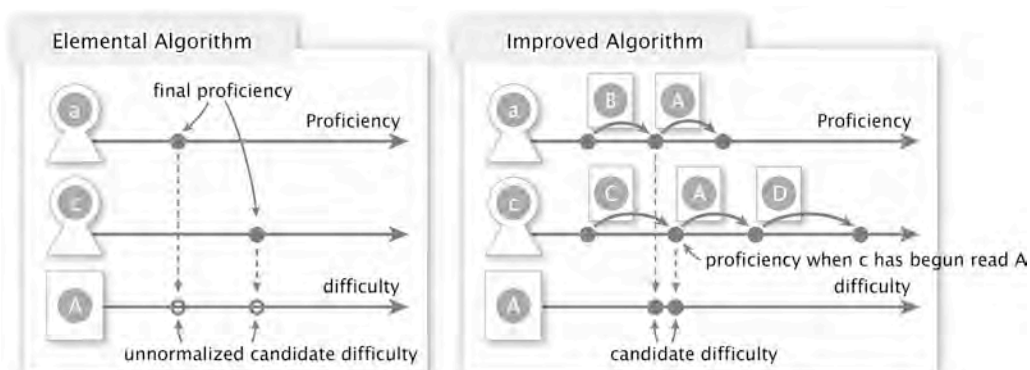


Figure 4. The Difference of the Methods for Difficulty Estimation.



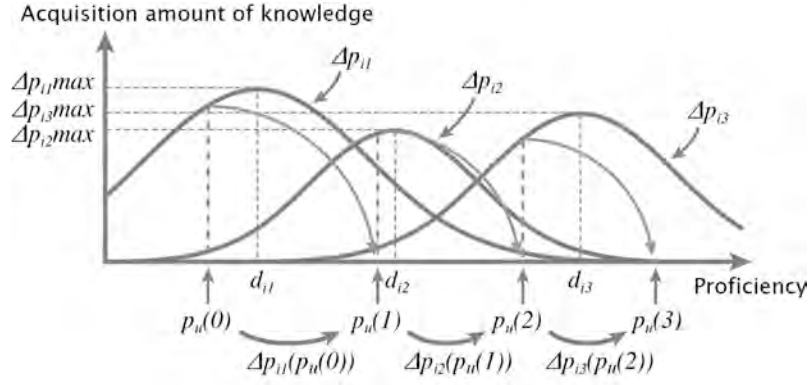


Figure 5. The Amount of Knowledge Acquired by Learner  $u$

elemental algorithm and improved algorithm. The improved algorithm estimates the amount of knowledge acquired by the learner that reads a learning material. We describe the flows of estimation of the amount of acquisition knowledge by using figure 5. Learner  $u$  acquires knowledge from initial proficiency  $p_u(0)$  to  $p_u(3)$ , when the learner reads in order of learning material  $i1$ ,  $i2$ ,  $i3$ .  $p_u(n)$  is the proficiency value of learner  $u$  after having read the  $n$ -th learning material.  $\Delta p_i$  as the amount of knowledge acquired by reading learning material  $i$  depends on  $p_u$  at that time:

$$\Delta p_i = \Delta p_i \max \cdot \sigma_i^{-(p_u - d_i) / \Delta p_i \max} \quad (3)$$

where  $\Delta p_i \max$  is the height of the curve and  $\sigma_i$  is the width of the curve. For example, quantity of knowledge  $\Delta p_{i1}(p_u(0))$  is slightly lower than  $\Delta p_i \max$  because  $p_u(0)$  is lower than  $d_{i1}$ , and then  $p_u(1)$  is given by  $p_u(1) = p_u(0) + \Delta d_{p1}(p_u(0))$ . The initial value of proficiency  $p_u(0)$  is tentatively the difficulty value of the learning material that is read by  $u$  at the beginning in this study. However,  $p_u(0)$  is the difficulty value of the next learning material if the next material is easy than first material. Therefore, although  $p_u(0)$  is lower than  $d_{i1}$  in figure 5,  $p_u(0)$  is  $d_{i1}$  accurately. Maximum quantity of acquirable knowledge  $\Delta p_i \max$  and a spread of target scope  $\sigma_i$  are tentatively unity values, although the calculation methods of them are under consideration. As you can see in figure 4, a learning material gets some candidate difficulty values from the learners who read it. Most learners should have proficiency higher than or comparable with the difficulty value  $d_i$ , because  $d_i$  means quantity of knowledge necessary to read learning material  $i$ . Therefore, in this study,  $d_i$  is tentatively the middle value with the minimum and the median of the proficiency values of each learners.

#### 4. Evaluation of Difficulty Estimation

We evaluated precision improvement between the elemental algorithm and the improved algorithm. The evaluation of estimation precision is relative evaluation. We compared the order of values estimated by the algorithm with the order of accurate data. We gathered and created the learner-material graph that represents the relations between web pages written about programming language C and the users that bookmarked them from social bookmark site ‘‘Hatena Bookmark’’ (<http://b.hatena.ne.jp/>) that is famous in Japan. The learners of the graph are the bookmark users, and the learning materials of the graph are the bookmarked web pages. Although our proposed algorithm is able to estimate not only difficulty of learning materials but also proficiency of learners, we evaluated only difficulty estimation because it is impossible to appreciate accurate proficiency of the bookmark site users. We would like to evaluate the learner proficiency estimation of our algorithm by letting the subject, whose accurate proficiency is known, use the bookmark site in the long term.

##### 4.1 Accurate Difficulty Values of Learning Materials for Comparing with Estimated Data

We extracted the partial graph from the learner-material graph at random because to get accurate values of difficulty of all-bookmarked pages increases in cost. A scale of the learner-material network

is 6,079 learners, 16,016 materials and 40,145 bookmarks. Their bookmarks have “C language” tag. We have decided the target page count of getting accurate value as 30 in consideration of workload of the subjects. We randomly selected 50 pages from the web pages that were bookmarked by over 30 users, because the pages may include inappropriate contents and have broken links. There were no pages including inappropriate contents, but 9 pages were not found or not available. Then we randomly reselected 30 pages from the 41 pages. All extracted web pages are technical contents about C programming and consist of blogs, news articles, reference pages, curated pages and so on.

We calculated accurate difficulty values from the results of the experiment evaluated by subjects that are learning C language. The subjects are 42 undergraduate students that learn information science, university freshmen are 13 people, second year students are 14 people and third year students are 15 people. The experiment was carried out in December 2013, and freshmen did not yet study a class of the C language at that point in time. Therefore we assume that the subjects consist of beginners and intermediate graders. The subjects firstly glanced through a web page for around 10 seconds and then evaluated in 5-point scale how much knew the contents of the page by oneself (Q1). The subjects secondly read the page and then evaluated in 4-point scale whether it was a useful page for oneself (Q2). The scales of Q1 are “not to know at all (0%)”, “know a little (25%)”, “know half (50%)”, “know most (75%)” and “know at all (100%)”. The scales of Q2 are “1) almost useless”, “2) useless a little”, “3) helpful a little”, “4) very helpful”. We confirmed that the self-evaluation of understanding became low as the young year students and the tendency of the frequency distribution of Q1 and Q2 became different, by analyzing the answers of all subjects for 30 pages. Therefore we calculated accurate difficulty values of learning materials from the answer data, using Item Response Theory (IRT). We used 1 parameter logistic model because we need only simple indicator of difficulty. The binary response data represents whether a subject is able to understand a learning material. Specifically, if answer in Q1 is 0% then the binary data is 0, but answer in Q2 also is 3) or 4) then it is 1. The probability of a correct response item  $j$  in the Rasch model is given by:

$$p_j(\theta) = \frac{1}{1 + \exp(-Da(\theta - b_j))} \quad (4)$$

where  $\theta$  is the standing on the underlying trait and  $b_j$  is the difficulty of item  $j$ . The variable  $a$  is the parameter of the logistic curve. We estimated accurate difficulty from the binary response data with rasch function of R software package “ltm” (Rizopoulos, 2006). Table 1 shows the difficulty values of the learning materials in descending order of difficulty.

## 4.2 Results

We evaluated difficulty rankings precision by comparing accurate difficulty ranking, and table 2 shows result of improved algorithm. We applied some measures such as NDPM (Yao, 1995) and Spearman's rank correlation. NDPM measure will give a perfect score of 0 when estimated ranking completely agrees with accurate ranking, and will give a worst score of 1 when reversed estimated ranking completely agrees with accurate ranking. A score of 0.5 represents that there is no correlation between estimated ranking and accurate ranking. The Spearman's rank correlation coefficient would be near 1 when estimated ranking and accurate ranking have positive correlation. -1 is a negative correlation and 0 is no correlation. Therefore, as you can see in table 3, the difficulty ranking estimated by improved algorithm is better than elemental algorithm. We implemented simple content-based algorithm for evaluation. This algorithm estimates difficulty of a web page from difficulty of terms and frequency of terms about C language in the page. We defined difficulty of terms from the page number of index of the best-known book (Kernighan and Ritchie, 1988) in

Table 1: Accurate difficulty values of the partial learning materials.

|            |       |       |       |       |       |       |       |       |       |       |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Label      | M1    | M2    | M3    | M4    | M5    | M6    | M7    | M8    | M9    | M10   |
| Difficulty | 1.19  | 0.71  | 0.49  | 0.39  | 0.19  | 0.00  | 0.00  | -0.31 | -0.41 | -0.41 |
| Label      | M11   | M12   | M13   | M14   | M15   | M16   | M17   | M18   | M19   | M20   |
| Difficulty | -0.51 | -0.61 | -0.61 | -0.94 | -1.32 | -1.32 | -1.47 | -1.62 | -1.80 | -1.80 |
| Label      | M21   | M22   | M23   | M24   | M25   | M26   | M27   | M28   | M29   | M30   |
| Difficulty | -2.00 | -2.00 | -2.23 | -2.23 | -2.51 | -2.51 | -2.51 | -2.51 | -2.89 | -3.51 |

Table 2: Estimated difficulty ranking and values with the improved algorithm.

|            |       |       |       |       |       |       |       |       |       |       |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Label      | M1    | M2    | M3    | M4    | M5    | M6    | M7    | M8    | M9    | M10   |
| Ranking    | 1     | 5     | 14    | 8     | 16    | 2     | 7     | 19    | 11    | 6     |
| Difficulty | 2.798 | 2.619 | 2.590 | 2.612 | 2.583 | 2.629 | 2.614 | 2.565 | 2.610 | 2.615 |
| Label      | M11   | M12   | M13   | M14   | M15   | M16   | M17   | M18   | M19   | M20   |
| Ranking    | 28    | 12    | 27    | 4     | 20    | 18    | 10    | 25    | 15    | 9     |
| Difficulty | 2.553 | 2.605 | 2.553 | 2.624 | 2.564 | 2.570 | 2.610 | 2.559 | 2.585 | 2.611 |
| Label      | M21   | M22   | M23   | M24   | M25   | M26   | M27   | M28   | M29   | M30   |
| Ranking    | 26    | 3     | 17    | 13    | 21    | 23    | 22    | 30    | 29    | 24    |
| Difficulty | 2.558 | 2.629 | 2.583 | 2.591 | 2.564 | 2.563 | 2.563 | 2.550 | 2.552 | 2.560 |

Table 3: Evaluation difficulty rankings by each ranking measures.

| Metrics                | Improved Algorithm | Elemental Algorithm | Content-Based Algorithm |
|------------------------|--------------------|---------------------|-------------------------|
| NDPM                   | 0.289              | 0.332               | 0.499                   |
| Spearman's Correlation | 0.576              | 0.468               | -0.07                   |

Japanese edition. We suppose that the reason to become worse estimation precision of content-based algorithm is that the algorithm is too simple.

## 5. Conclusions

We have described difficulty estimation algorithm to recommend learning materials. The evaluation result of difficulty estimation of our improved algorithm is better than elemental algorithm. We would like to improve the algorithm more and develop a learning material recommender system using the algorithm. Bookmark data of a social bookmark site is untrustworthy because a user may bookmark an unread page. We think that read pages should estimate difficulty and proficiency. Unread bookmarks are suitable to be re-recommended because a learner certainly has an interest in the bookmarked learning materials.

## Acknowledgements

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# Exploring Student Interactions with Tutorial Dialogues in a Substep-based Tutor

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**Abstract:** Understanding students' interactions with Intelligent Tutoring Systems (ITSs) allows us to improve the system as well as our pedagogical practices. Engaging students in tutorial dialogues is one of the strategies used by ITSs, which has been proven to improve learning significantly. This paper presents preliminary findings of a project that investigates how students interact with the tutorial dialogues in EER-Tutor using interaction videos in addition to eye-gaze data. We discuss some frequent misconceptions and behaviors student exhibited. Students usually focus on correcting one error at a time and then immediately submit their solutions to get feedback, thus not taking advantage of opportunities to reflect on what they have learnt. Based on the results, we identify several future directions of work on using eye-tracking for on-line adaptation.

**Keywords:** Substep-based Tutor, Tutorial Dialogues, Eye Tracking

## 1. Introduction

Studies of human one-on-one tutoring suggest that the student's behavior is a stronger predictor of learning gain than the tutor's behavior (Chi et al., 2001). Therefore, it would be beneficial to understand how students interact with ITSs. However, most evaluation studies involving ITSs focus on their effectiveness and do not explore student behavior deeper. In recent years, researchers have started analyzing student behaviors such as "gaming the system", or investigating how students attend to feedback (Baker et al., 2009; Conati, Jaques and Muir, 2013; Kim, Alevan & Dey, 2014).

We are interested in students' behavior while they solve problems in conceptual database modeling. EER-Tutor (Zakharov, Mitrovic & Ohlsson, 2005) is an ITS that teaches conceptual database design. We have enhanced EER-Tutor with tutorial dialogues (Weerasinghe, Mitrovic & Martin, 2009), which engage the student in discussing a mistake made. Tutorial dialogues help students learn relevant domain concepts as well as reflect on their errors. Many studies have shown the benefits of tutorial dialogues, such as (Evans & Michael, 2006; Graesser, 2011; Weerasinghe, Mitrovic & Martin, 2010).

Because we are mainly interested in the effect of dialogues on student behavior, we focus on students' actions following tutorial dialogues. For example, do students follow advice given in dialogues about how to correct errors? Verbal protocol analysis has been the dominant technique to analyze human tutoring. In this work, we analyzed student-system interaction videos and eye-tracking data. We describe our study and the version of EER-Tutor used in the following section. Section 3 presents the findings, while the final section presents our conclusions and future work.

## 2. Study

The interface of EER-Tutor (Figure 1) shows the problem statement at the top, the toolbox containing the components of the EER model, the drawing area on the left, and the feedback area on the right. Students' diagrams are checked for constraint violations on submission. The model for supporting tutorial dialogues is out of the scope of the current paper, and we refer the interested reader to (Weerasinghe, Mitrovic & Martin, 2009) for details. When a student makes one or more mistakes, s/he is presented with a tutorial dialogue. The problem statement, toolbar and drawing area are disabled but

visible for the duration of the dialogue, and the error is highlighted in red in the diagram. In the situation illustrated in Figure 1, the student has incorrectly modeled *facility* as a regular entity type, and EER-Tutor has highlighted it and provided a tutorial dialogue related to that error.

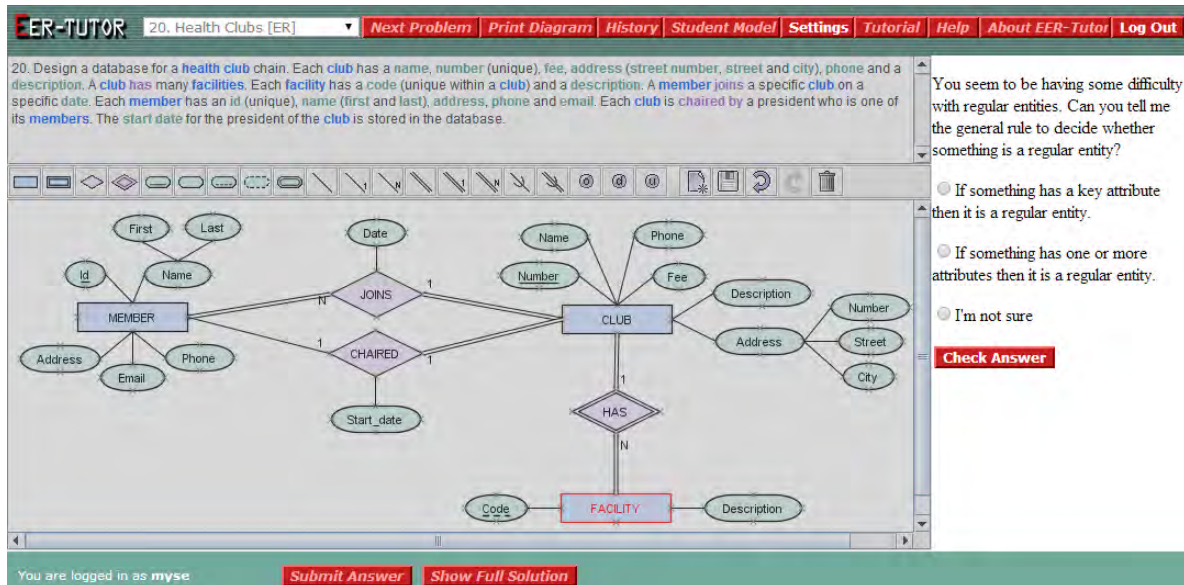


Figure 1. EER-Tutor interface after submission – the tutorial dialogue appears on the right

A dialogue consists of a sequence of questions, each with several possible answers. Such structure of tutorial dialogues allows multiple aspects of a single error to be discussed. The student answers by selecting an option, or asks for additional help (by selecting the “I’m not sure” option). Dialogues consist of the following prompt types:

- Conceptual (CO): discusses the relevant domain concept independently of the problem context. This is shown in Figure 1: the student has modeled *facility* as a regular instead of a weak entity type, so the conceptual prompt shown is asking about the basics of regular entities.
- Reflective (RE): aims to help students understand why their action is incorrect in the context of the current problem. For example, if the student answers the prompt in Figure 1 incorrectly, the RE prompt requires the student to specify why *facility* is not a regular entity type.
- Corrective action (CA): gives the student an opportunity to understand how to correct the error. For the error in Figure 1, the CA prompt is asking the student to specify the best way to model the *facility* and giving different options. Not all dialogues have this prompt type.
- Conceptual reinforcement (CR): allows the student to review the domain concept learnt. For the error in Figure 1, the CR prompt asks the student to identify the difference between a weak entity and a regular entity from the given options. Again, this is a problem-independent prompt.

The participants were 27 students enrolled in a database course at the University of Canterbury (9 females), aged from 18 to 50 years old (mean = 23.8, sd = 7.3). All participants had normal or corrected-to-normal vision. During the week prior to our study, the participants had used EER-Tutor in a regular lab session. Each participant was given a NZ\$20 voucher and took part in the study individually. One student was excluded because no eye-tracking data was collected

We used a version of EER-Tutor modified slightly to make eye tracking easier. A calibration phase with the eye tracker (Tobii TX300) was carried out at the beginning of the session. The participants could work on three problems and were free to move between problems. They were instructed to attempt all problems and to submit their solutions regularly. Each student was given 50 minutes to solve the problems. The mean session length was 49 minutes (sd = 3.1 min).

We have previously analyzed the difference in behavior between novices and advanced students on all three problems in (Elmadani, Mitrovic and Weerasinghe, 2013). In this paper, we focus on the first problem only (shown in Figure 1), and analyze the actions the students take immediately after tutorial dialogues. The mean time spent on the first problem is 16.1 minutes (sd = 8.7 min), with students making an average of 6.2 submissions (sd = 5.3). 17 students successfully completed the problem, three of whom had solved it previously and re-did it for the study.

We focused on the video segments beginning when the student submits his/her answer for the final dialogue prompt and ending when the student next submits their solution to the same problem, the session ends or the student switches to another problem. There were 111 such segments.

### 3. Findings

The completeness of the solutions at the point the students first asked for feedback varied. Nine participants submitted complete solutions as their first attempt (only one was error free). One student submitted a solution excluding connectors, participations, and cardinalities. This student may have wanted to check that s/he has the correct entities, relationships, and attributes before thinking about the associations between them. Relationship attributes were left out from otherwise complete solutions by four students, highlighting the concept's complexity.

We investigated the errors made when answering the final dialogue prompt, which represent common or deep misconceptions. These errors were made by more than one student, or made several times by the same student. There is a lack of understanding of the differences between regular and weak entity types, and related concepts. For example, each weak entity type must have exactly one identifying relationship type. Two participants mixed up which relationship type belonged with which entity type. Students also show misunderstanding about which key type belongs to which entity type.

The cardinality ratio of relationships is a similarly difficult concept. There were nine situations where students indicated that in order to determine the cardinality ratio of a relationship, you must ask how many instances of an entity participate with another entity. This is incorrect as you must think in terms of a single instance of the second entity. One student made this error four times (two of which were in consecutive dialogues but pertaining to separate errors), which suggests that the student was not applying the tutorial dialogue content beyond correcting the current error.

Participation is a concept related to the cardinality ratio, so students may confuse the two. Five students thought that when determining the participation of entities in a relationship type it was necessary to consider how many instances of an entity participate with a single instance of another entity. On the contrary, it is necessary to consider whether every instance of an entity participates in relationship instances. One student answered this prompt incorrectly twice despite being able to correct the participation the first time s/he saw the prompt. This indicates that s/he may be relying on the fact that there are two participation options and so just chose the other one to correct the error.

Once the student receives the final message of a dialogue, s/he can go back to editing the diagram. Regardless of whether the student reads or looks at that final message, the red error highlighting is almost always the next focus of attention. This visual cue is therefore beneficial to students as they are able to quickly locate the error and concentrate on its correction. In addition, for cases where there is no error highlighting on the diagram, the students fixate on the toolbar or problem statement straight away. This is consistent with the type of errors made, for example submitting a solution with a missing entity type and therefore searching for it in the problem statement.

There were 20 students who answered the final prompt correctly and fixed the error (in 60.4% of all segments). After the tutorial dialogue, the student is free to change the diagram. We identified several common patterns of changes done:

- *attempts\_fix*: the student addresses the error but incorrectly
- *fix*: the student corrects the error
- *check*: the student inspects his/her solution or rearranges diagram components
- *similar*: the student corrects a similar error
- *related*: the student makes related changes
- *other*: the student continues working on other parts of the solution
- *problem*: the student looks at the problem statement
- *wrong\_issue*: the student tries to fix the error by addressing the wrong issue

A correction is attempted in 93.7% of segments, with 82.0% of these fixes being correct (made by 22 students). There were seven segments during which the student did not attempt to correct the error but switched to a different problem instead. One participant did not understand the tutorial dialogue. After completing the dialogue, s/he examined the text of the problem and all components of the diagram, and then attempted creating another entity type which was not necessary. The participant was

clearly confused; s/he even looked at the other two problems before submitting the unchanged solution. This particular situation is illustrated in Figure 3 as a gaze plot generated by Tobii.

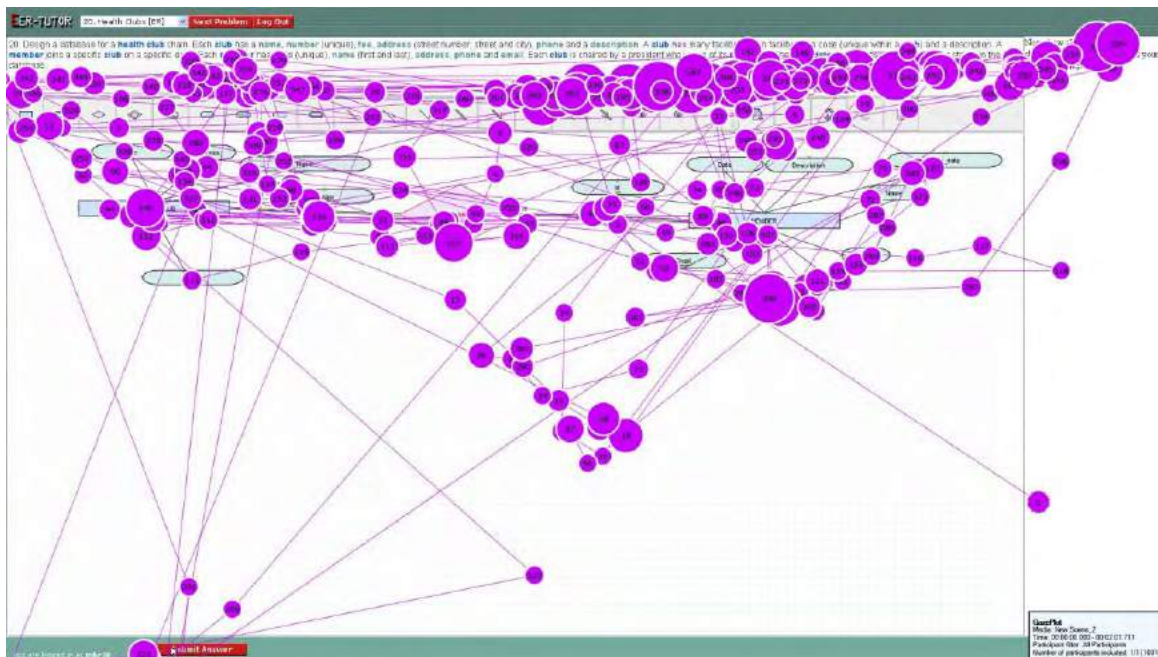


Figure 3. A gaze plot illustrating confusion

We also analyzed sequences of patterns following tutorial dialogues. There are 20 students who performed the *submit-fix-submit* sequence (row *a* in Table 1). That is, the student submitted his/her solution (*submit*), went through the tutorial dialogue, corrected the error (*fix*) and submitted the solution again (*submit*). A gaze plot illustrating this kind of situation is given in Figure 4. The student has submitted a solution with two mistakes, and received a dialogue about one of them. Upon completing the dialogue, the student quickly corrected their mistake, and submitted the modified solution for checking immediately. In this particular situation, there was another similar mistake in the solution, but the student has not taken the time to check the other parts of the solution.

Therefore, the dialogues may be encouraging shorter interaction sequences. Most participants addressed one error at a time and submitted their solutions to be checked immediately. With the exception of one student, students who solely followed this interaction pattern saw at most two multi-level dialogues (eight students in total). The next most frequent sequence (Table 1, row *d*) adds a single step, where the student checked his/her solution themselves before asking EER-Tutor for feedback. The other interaction patterns are shown in Table 1.

If the student has learnt from the dialogue, s/he should also be able to fix similar errors in the solution. This occurs in 7.2% of segments by six students (Table 1, rows *g*, *j*, *k*). These participants fixed the errors that are either the addition of missing constructs (relationship and cardinality) or correcting participation, cardinality or relationship type. Three of these students had also answered the final dialogue prompt correctly as well as fixing the error discussed in the dialogue (5.4% of segments).

If the student is reflecting on what s/he has learnt in a dialogue, s/he should be able to make related changes required. A related change is needed if the type of entity is changed for example, as the corresponding key and relationships would need modification. In 13.5% of segments, other related changes are required but these related changes are only made in 5.4% of segments (Table 1, rows *i* and *m*). Interestingly, there are no cases where a student fixed similar errors as well as made the required related changes. This is probably due to the relatively small number of components in this problem as there were limited opportunities to fix similar errors.

In 12.6% of segments, the student made further additions/deletions/changes to his/her solution prior to submission. These are situations in which the student continued to work on the problem or presumably decided to narrow the scope of his/her solution in order to focus on addressing the error discussed by the tutorial dialogue. 11 students demonstrated this behavior (Table 1, rows *e*, *h*, *i*, *k-m*).

There are cases where the student attempted to correct an error but did so by addressing the wrong issue (Table 1, rows *c* and *l*). One student, for example, had the wrong cardinality ratio but

changed the participation instead. A similar situation occurred where a student had the wrong relationship type and, despite answering the corrective action prompt correctly, changed the cardinality on one side of that relationship. In that situation, the student got the same dialogue again because the system selects the most frequent error. The student then addressed the error by removing the cardinality s/he just added and changed the participation for another relationship. It is not until the next submission that the student corrected the error, suggesting s/he finally focused on and/or understood the dialogue content. Another student had a missing relationship attribute and, instead of adding it, changed the relationship type. The tutorial dialogue explicitly mentioned that this relationship was modeled correctly and fixations appeared on the feedback area when this text is displayed. This suggests that the student may not have fully comprehended the dialogue.

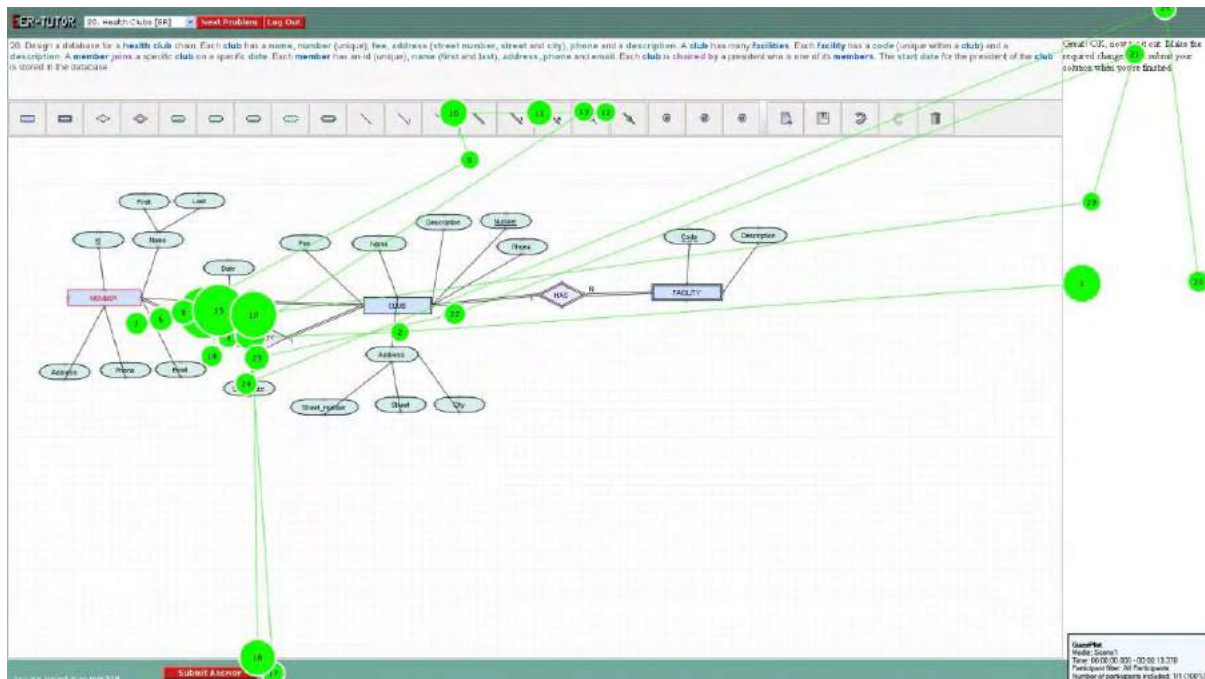


Figure 4. A gaze plot for the *fix* step of the *submit-fix-submit* sequence

Once the student has corrected or attempted to correct the error, ideally s/he should check the rest of the solution before submitting. Students inspected their solutions or rearranged diagram elements prior to submission in 19.8% of segments (Table 1, rows *d*, *h*, *j* and *m*). This kind of behavior was performed by 12 distinct students, at various stages of solution completion, ranging from one participant who checked the solution after each correction (two occasions in total) to a participant who checked the solution irregularly (after six out of 21 dialogues seen).

Table 1. Interaction sequences

|          | Pattern  | Segments | Distinct Students |
|----------|--|----------|-------------------|
| <i>a</i> | <i>submit - fix - submit</i>                           | 64       | 20                |
| <i>b</i> | <i>submit - attempts_fix - problem - submit</i>        | 1        | 1                 |
| <i>c</i> | <i>submit - attempts_fix - wrong_issue - submit</i>    | 2        | 1                 |
| <i>d</i> | <i>submit - fix - check - submit</i>                   | 16       | 9                 |
| <i>e</i> | <i>submit - fix - other - submit</i>                   | 6        | 4                 |
| <i>f</i> | <i>submit - fix - problem - submit</i>                 | 1        | 1                 |
| <i>g</i> | <i>submit - fix - similar - submit</i>                 | 5        | 3                 |
| <i>h</i> | <i>submit - attempts_fix - other - check - submit</i>  | 1        | 1                 |
| <i>i</i> | <i>submit - fix - related - other - submit</i>         | 3        | 3                 |
| <i>j</i> | <i>submit - fix - similar - check - submit</i>         | 2        | 2                 |
| <i>k</i> | <i>submit - fix - similar - other - submit</i>         | 1        | 1                 |
| <i>l</i> | <i>submit - fix - wrong_issue - other - submit</i>     | 1        | 1                 |
| <i>m</i> | <i>submit - fix - related - other - check - submit</i> | 1        | 1                 |



Following the submission of a correct solution, EER-Tutor gives a final feedback message: “That’s correct, well done!” From the eye-tracking data, we noticed that 59% of students who completed the problem read the feedback message whereas 24% only briefly looked in its direction. We had expected students to reflect on their correct solutions, but only 18% of students looked at and/or moved the cursor around the canvas or problem statement.

#### 4. Conclusions and Future Work

Understanding students’ interactions with an ITS allows us to improve the systems as well as our pedagogical practices. We presented a study in which we investigated how students interact with tutorial dialogues in EER-Tutor, using eye-tracking data. When a student submits a solution for checking, EER-Tutor selects an error to be discussed via a tutorial dialogue. We analysed the effect of the dialogue on the student’s actions following the dialogue.

We found that most participants fixed the error discussed in the tutorial dialogue, and asked for feedback immediately. By focusing on the discussion of a single error, we may be encouraging this *submit-fix-submit* pattern. We also observed that students did not always reflect on their solutions after correcting the discussed error or successfully solving the problem. There are therefore opportunities for reflection that students do not take advantage of. If the system can identify the lack of reflection, (e.g. by identifying missed opportunities to improve the solution by fixing similar errors), the system can prompt the student to reflect and make these further changes. In addition, if the student demonstrates repeated behavior patterns, it may be beneficial to point out this behavior and to emphasize the importance of reflection. When analyzing the data from the study we also identified several minor improvements to the wording used in problems and dialogues used in the study.

Eye tracking provides a wealth of information which allows for further improvement of ITSs. We discussed a situation when the student did not understand a tutorial dialogue and was confused as the result. In such situations, the ITS could provide additional support, in the form of examples or additional explanations. Our future work will involve further studies of student behavior in EER-Tutor and enhancements to the system.

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# Gaze Analysis and Subjective Assessment of Learners Observing the Writing Process

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**Abstract:** We used subjective assessments from learners as well as eye trackers for gaze analysis to investigate and analyze differences between two cases: when learners were presented with a writing process, such as on a chalkboard, and when only the final results of writing were presented. The results indicate a relation between subjective learner assessment and gaze. More specifically, there were differences in gaze between learners who reported that watching the writing process was beneficial to learning and those who reported otherwise. We discuss the influences on understanding that result from showing the writing process and propose new ideas for presentation named “information push” and “information pull”.

**Keywords:** gaze, eye tracker, writing process, chalkboard, slide

## 1. Introduction

As a method of presenting information in class, the slide presentation or chalkboard is often used. Although slides have many benefits, not a small number of teachers and learners prefer classes with traditional chalkboards in preference to presentation slides (Yanagisawa & Fukuda, 2008), and many teachers use their experience, knowledge, and teaching skill to determine how a variety of information should be presented to learners.

One of the predominant features of the traditional methods of presenting information on a chalkboard is that learners watch information presentation as it is being written (Brown, 2012; Jones, et al., 1994). Research is currently being performed that focuses on such features to examine the benefits of presentations that incorporate representations of the writing process (Bandoh et al., 2002; Kurihara, 2006).

We consider that chalkboard presentation represents a visualization of the thought process, and thus is far richer in educational information than simple presentation of final results. Presentation slide has advanced features such as animations, but these features are simply methods for drawing attention or mechanically creating sequential divisions, and do not reflect the structure or thought process behind the object being displayed. Showing this process has meaning with regard to understanding, and is different from presentation of completed forms or mechanical step-by-step presentations.

We focused on learners' gaze as fundamental data for elucidating the benefits of presenting the writing process (Okazaki et al., 2013). For presentation materials, we selected prime factorization and geometric proofs as topics for experimental problems where displaying the writing process can be examined in relation with comprehension of the topic. We used subjective assessments from learners as well as eye trackers (a system for following the path of a person's gaze) (Duchowski, 2007; Ohno, Mukawa & Yoshikawa, 2002) for gaze analysis to investigate differences between the case where learners are presented with the writing process, such as writing on a chalkboard, and the case where only the final results of the writing are presented.

## 2. Methods

We used the following method to measure participants' gaze. Tobii T60 Eye Tracker was used to track gaze (Tobii T60 & T120 Eye Tracker, 2013). This eye tracking system is a standalone eye tracking unit integrated in a 17-inch TFT monitor. No sensors or other hardware elements are visible to distract the user. The system detects user's gaze by both bright and dark pupil tracking eye tracking technique with 60Hz data rate and typical 0.5 degrees accuracy.

Participant gaze was measured by the following method. There were 16 participants (12 men and 4 women). Experiments were performed over 4 days: November 22, November 29, December 3, and December 10, 2013.

Figure 1 shows the presentation stimuli, which comprised two prime factorization problems and two geometric proofs. Each problem was presented in two ways—a presentation that included the writing process and another that showed only the final results of writing—for a total of eight presentation patterns.

Presenting the writing process provides students with a focal point that learners' gaze can follow. A presentation that includes the writing process reproduces the thought process during problem solving, which likely serves to support comprehension. We created presentation stimuli using a presentation tool, HPT (Handwriting Presentation Tool), currently in development at our laboratory (Hosoki et al., 2011). This tool allows for reproduction of the writing process such as when writing on a chalkboard.

We used Tobii Studio for analysis of gaze data (Tobii Studio, 2013). We used gaze plots for dynamic analysis, and heat maps for static analysis.

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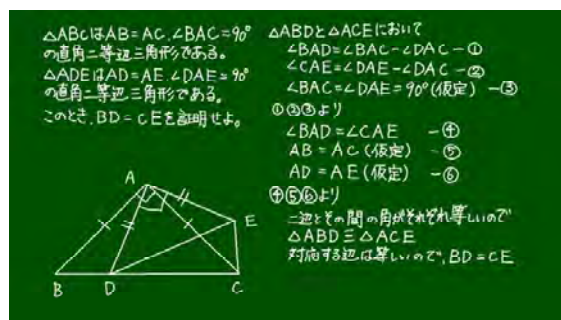
$$\begin{aligned}
 & a^2b + b^2 - ac - c^2 - 2b + 2c \\
 &= ab - ac + b^2 - c^2 - 2b + 2c \\
 &= a(b-c) + (b+c)(b-c) - 2(b-c) \\
 &= (b-c)(a+b+c-2)
 \end{aligned}$$

(a) Prime factorization 1

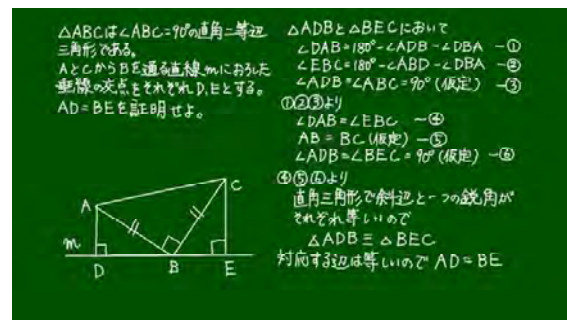
因数分解をしろ。

$$\begin{aligned}
 & a^2 - b(b+1) - a \\
 &= a^2 - b^2 - b - a \\
 &= a^2 - b^2 - (a+b) \\
 &= (a+b)(a-b) - (a+b) \\
 &= (a+b)(a-b-1)
 \end{aligned}$$

(b) Prime factorization 2



(c) Geometric proof 1



(d) Geometric proof 2

Figure 1. Presentation stimuli

## 3. Results

### 3.1 Comprehension check results

Figure 2 shows the ratio of correct answers for the comprehension check. Correct answer rates were higher when the writing process was shown for the prime factorization problem 2, but for the other cases, the rates were the same as or lower than when the writing process was not shown. Although we

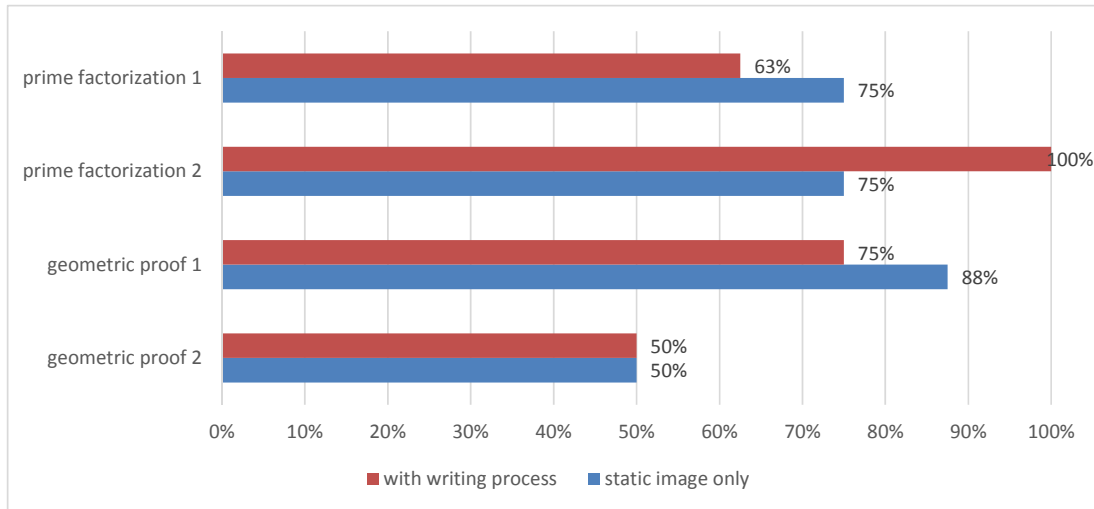


Figure 2. Ratio of correct answers for the comprehension check

Table 1: Questionnaire survey for subjective learner assessment

| Writing process is helpful | prime factorization | geometric proof |
|----------------------------|---------------------|-----------------|
| Strongly agree             | 2                   | 8               |
| Agree                      | 6                   | 3               |
| Neutral                    | 4                   | 1               |
| Disagree                   | 3                   | 3               |
| Strongly disagree          | 1                   | 1               |

predicted that showing the writing process would support student learning, and that this result would be supported by a difference in comprehension check scores, we were unable to obtain data indicating this.

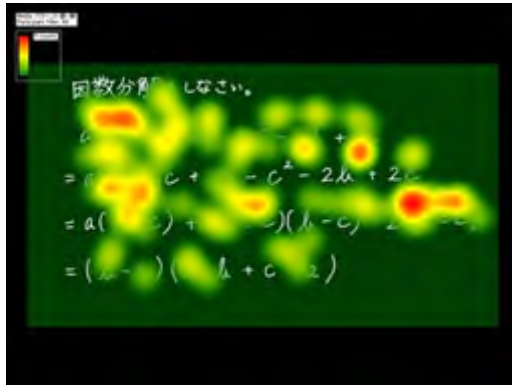
### 3.2 Subjective assessment

Table 1 lists items in the questionnaire survey used for subjective learner assessment. While no difference was seen in the correct answer rate for the examined problems, a difference was seen in responses to the questionnaire. For both the prime factorization problem and the geometric proof, participants reported that they preferred being shown the writing process. For the geometric proof problem in particular, half of the participants reported a strong preference for being shown the writing process, and when responses indicating a mild preference are included, approximately 70% of students preferred being shown the writing process. In contrast, only about half of the students indicated a preference for being shown the writing process for the prime factorization problem.

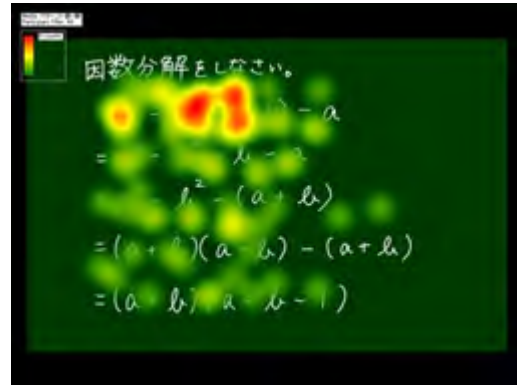
### 3.3 Gaze analysis

#### 3.3.1. Participants for gaze analysis based on subjective assessment

As described in sections 3.1 and 3.2, we saw no difference in correct answer response rates between the cases where the writing process was or was not shown, but participants tended to prefer being shown the writing process. Upon investigating individual responses regarding this preference for being shown the writing process, we found 4 participants who reported a preference for being shown the writing process for one of the two problem types (prime factorization or geometric proof), but for not being shown the writing process for the other. We selected these 4 participants for a follow-up gaze analysis. We designated the 2 participants who reported a preference for being shown the writing process for prime

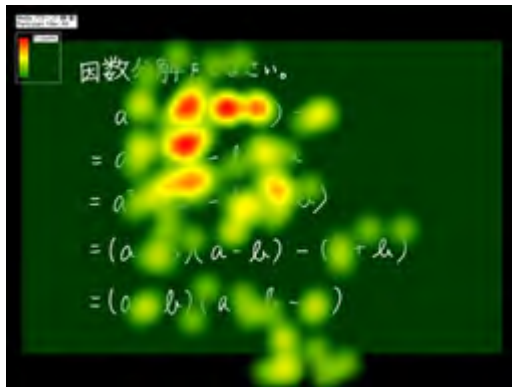


(a) The writing process is presented

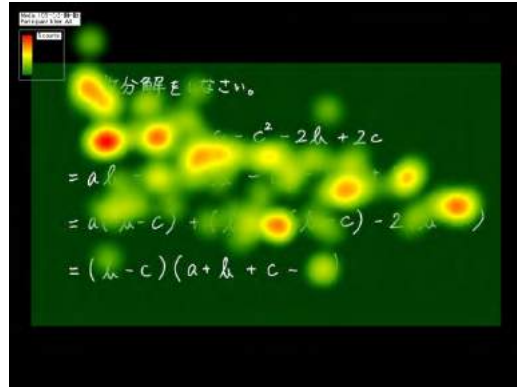


(b) The static image is presented

Figure 3. Heat map examples of participant A



(a) The writing process is presented



(b) The static image is presented

Figure 4. Heat map examples of participant C

factorization but not for the geometric proof as A and B, and designated the 2 participants who indicated the opposite preference as C and D.

### 3.3.2. Gaze analysis for the prime factorization problem

A gaze plot for participants A and B revealed that they followed the writing process when it was shown, but that eye movement was faster and less time was spent examining the presentation when the writing process was not shown. In contrast, the eye movements of participants C and D were slower in both cases, following the presentation when the writing process was shown and reading the presentation more carefully when it was not.

This difference can be seen in the heat maps shown in Figure 3. The heat maps of participants A and B differed between the cases where the writing process was or was not shown. When the writing process was shown the participants were able to focus on the process, and many focal points were seen (Fig. 3(a)). When the writing process was not shown, there was a tendency to quickly scan the entire presentation, indicating that less attention was paid (Fig. 3(b)). In contrast, participants C and D paid close attention to the presentation regardless of whether the writing process was shown, so there was little difference in their heat maps between the two cases (Fig. 4(a)(b)).

### 3.3.3. Gaze analysis for the geometric proof

No difference in the gaze was seen between participants C and D, who reported a preference for being shown the writing process for the geometric proofs, and participants A and B, who reported a preference for not being shown the writing process for those problems. Analysis of the gaze plots for each of the 4 participants did not show differences in their gazes, but some similar features were observed.

## 4. Discussion

As discussed above, a difference was seen between participants A and B with respect to their understanding of the process of manipulating the equations for the prime factorization problem. This difference depended on whether they had been shown the writing process, which promoted attention toward the process of manipulating the equation, resulting in differences in eye movement. This might have led to differences in subjective evaluation.

In contrast, participants C and D placed less of a priority on seeing the writing process when manipulating equations for the prime factorization problems, and they showed similar focus even when the writing process was not shown. These indicate that presenting the writing process promoted an attention effect, and that there was an effect of attention neglect when only a static image was presented.

In the case of the geometric proofs as well, when the writing process was presented to show the characters and symbols representing the geometric elements (angles and sides), participants looked at the associated parts in the figure, which might have provided a trigger promoting verification of the relation between the elements in the figure.

In the solution process to the right of the geometric proofs, there were cases where a participant's gaze did not follow the equation manipulation, despite the writing process being shown. This was possibly because the process of equation manipulation was somewhat difficult and proceeded while learners were thinking and making verifications. In other words, it is possible that the presentation of the writing process was too fast, resulting in a loss of effectiveness.

In contrast, when a static image was shown we saw participants looking at the associated parts of the figure after viewing the equations or after looking at several equation manipulations, indicating that they were confirming the summary of what had occurred.

From gaze analysis, we suggest that presenting the writing process provided a focal point for attention and that the speed and timing of that focal point was important. For those participants who indicated a preference for not being shown the writing process, it is possible that the speed and timing of the presentation was not well suited to them.

Showing the writing process allowed for showing the procedures, relations, and ways of grasping the diagram. It also provided focal points, likely providing a mechanism for focusing attention on the process. When the final results were summarized through presentation of a static image, learners shown this information were able to interpret information obtained on their own.

We call the first case, where information including processes is actively provided, "information push", and the second case, in which the recipients (i.e. learners) derive information themselves, "information pull." Showing the writing process is a form of information push, promoting attention and providing explicit information about individual elements and their relations. In this case, the speed and timing of presentation are important, and care must be taken to tailor the presentation to learners. Showing final results as a static image is a form of information pull, and requires that learners derive for themselves the individual elements and their relations. Information pull does not provide attention focuses or processes, but allows for a higher degree of freedom in interpretation. The appropriateness of providing such a degree of freedom likely varies with individual learners.

Information pull is appropriate for learners who can read problems and independently discover their meaning and identify important problem elements and relations. Information push, with appropriate speed and timing, is best suited for learners who require support in making such discoveries.

In courses where instructors write on a chalkboard, the instructors can monitor student responses and thereby adjust the speed and timing of the presentation. We believe that this makes information push effective, thereby leading to an easier-to-understand class.

## 5. Conclusions and future topics

We have used subjective assessments from learners as well as eye trackers for gaze analysis to investigate and analyze differences between two cases: when learners are presented with a writing process and when they are not. Some participants reported that presentation of the writing process was effective, although others reported that it was not. Differences in gaze were seen between these groups, and we found the possibility that presentation of the writing process can lead to better ease-of-understanding under certain conditions.

Presentation of the writing process provided learners with focal points for attention and let them see how to grasp the subject matter and relations within it. Those who preferred being presented with the writing process were likely those who needed support in understanding the presented information. Conversely, those who preferred not to be presented with such an active display of information were likely those who found it to be a restriction on their free interpretation.

In cases of high readiness for the displayed information, information pull (presenting the final results) is more appropriate due to the freedom of interpretation it provides. In other cases, information push (presenting the writing process) with appropriate speed and timing may be preferable.

In future research, we will investigate in more detail the cases in which information push and information pull methods of information presentation are more effective. We will also perform actual experiments to investigate these differences, thereby revealing how these two methods of information presentation should be implemented.

## Acknowledgements

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# Interactive Environment for Learning by Problem-Posing of Arithmetic Word Problems Solved by One-step Multiplication and Division

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**Abstract:** Problem-posing is effective learning for comprehending problem structure. We have designed and developed the learning environment for problem-posing and performed its practical use for first and second grade students on elementary school continually. The scopes of these systems are one-step addition, subtraction or multiplication arithmetic word problem. The results of these practical uses suggested that the learning environment was effective to comprehend these problem structures. Therefore, as the next step, we have designed and developed a learning environment for posing one-step multiplication or division word problem in order to let learners acquire a difference between multiplication and division. Developed learning environment and its practical use in an elementary school are reported.

**Keywords:** Problem-posing, sentence-integration, interactive environment, multiplication, division, arithmetic word problem, problem structure

## 1. Introduction

Several researchers postulate problem-posing is effective exercise for promoting learners to master the use of solution methods (Polya, 1945; Silver, CAI, 1996). Moreover, it has been proposed that poor problem solvers often fail to elicit problem structures from problem (Mayer, 1982; Kintsch, Greeno, 1985). We design and develop the learning environment which learners acquiring the structure of arithmetic word problem by exercising the problem-posing. Now, our research domain is an arithmetic word problem can be solved by one-step calculation operation. We analyze a structure of arithmetic word problem and develop the learning environment based on its structure (Nakano, et al, 1999; Hirashima, et al, 2007; Hirashima, et al, 2011). Until now, one-step addition, subtraction or multiplication word problem are analyzed and the structure of these problems are implemented on tablet PC (Yamamoto, et al, 2012; Yamamoto, et al, 2013). In addition to the development, we have performed two experimental uses with elementary school teacher, which are first grade students by learning the one-step addition or subtraction and second grade students by learning the one-step addition or subtraction word problem. As this reason, the first grade students have learned the problem-posing by one-step addition or subtraction word problem because they have already known the concept of addition and subtraction in their life. The second grade students only learned to pose one-step multiplication problem because the concept of multiplication is a difficult concept for learners. The results of these experimental uses have proposed that not only the learner improve the problem solving performance, but also this learning environment was effective for the learner who can't judge the problem structure to acquire the problem structure.

The students are only required to consider the multiplication problem structure by learning the assignment of learning environment for second grade student, As the next step, the learner learn not only one-step multiplication but also one-step division word problem. Therefore, they are required to judge whether the story means one-step multiplication or division. For this learning, we have designed a assignment and developed the learning environment by problem-posing. In this paper, a problem structure is explained in the following chapter. A design of developed learning environment based on



this structure is described in section 3. A sequence of assignment is also explained. Subsequently, a procedure of its practical use and an analysis of the results are reported.

## 2. Problem Structure of One-step Multiplication or Division Word Problem

In this section, the model of one-step multiplication or division arithmetic word problem is explained. One-step arithmetic word problems can be expressed by three sentences in our research. Example is shown in Figure 1. Because there are three values in one-step arithmetic word problem, this problem can be expressed by three sentences. Each sentence consists of value, object and predicate. These sentences consist of two sentences mean existence and one sentence means relation between other two values. We call each sentence as existence sentence and relation sentence. In this example, "There are three boxes" and "There are several apples" are existence sentence. "There are five apples in each box" is relation sentence because this sentence shows the relation between the apple and box.

In addition to the kind of sentence, each sentence has a property of quantity in multiplication and division word problem (Yamamoto, et al, 2013). Generally, multiplication is expressed by "multiplicand multiplied by multiplier is product" (Greer, 1992; Vergnaud, 1983). So, it is said that each quantity has different property. This word problem contains the story that the value of apples is expressed as the amount of apple when there are three boxes and the value of apples in each box is basis. Since, in Japanese Education, multiplicand is also called "base quantity", multiplier is "proportion" and product is "compared quantity". Then, the arithmetic word problem that can be solved by one-step multiplication or division has three types of story. (1) Compared quantity divided by base quantity is proportion, (2) Base quantity multiplied by proportion is compared quantity, (3) Compared quantity divided by proportion is base quantity. The story of the problem in Figure 1 is (2).

All of these stories contain the relation that is "Base quantity multiplied by proportion is compared quantity". One-step multiplication or division word problems are expressed by changing the one quantity to required value in each story. Therefore, it is important to extract the base quantity, proportion and compared quantity from problem and to make the relation between these quantities.

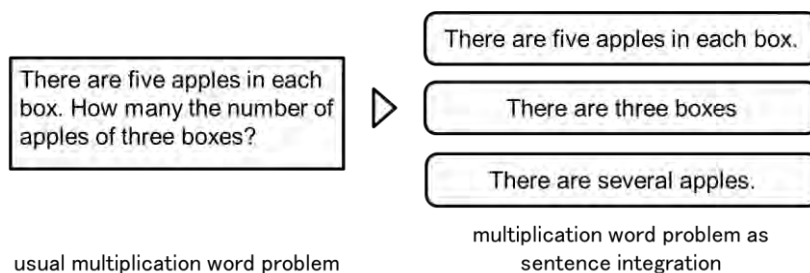


Figure 1. Example of Problem Expression as Sentence Integration.

## 3. Outline of Learning Environment for Problem-posing "MONSAKUN Touch3"

### 3.1 Framework

This learning environment consists of MONSAKUN Touch 3 for learners and MONSAKUN Analyzer 3 for teachers. A result of the learner's learning by problem-posing on MONSAKUN Touch 3 is sent to database server via network. MONSAKUN Touch 3 developed by using Android, MONSAKUN Analyzer 3 by using PHP and JavaScript. Of course, the each software can be run on Android Tablet. RDBMS is used MySQL. The teacher can confirm the graph of learner's learning by using MONSAKUN Analyzer 3 that receives a learning data from database server. The learning data are saved as three data: the number of correct problem, the number of incorrect problem, the number of the each incorrectness and the learner's log. Category of incorrectness is based on a diagnosis of MONSAKUN Touch 3. MONSAKUN Analyzer 3 generates some graph by using these data and displays teacher it. Teacher can limit to an assignment that learner can exercise on MONSAKUN Touch 3 by using MONSAKUN Analyzer 3.

## 3.2 MONSAKUN Touch 3

### 3.2.1 Outline of MONSAKUN Touch 3

In MONSAKUN Touch, after the learner logged in the environment and selected level, he/she sees an interface for problem-posing. This interface presents the assignment for posing problem, the set of given sentence card and three blank for arranging given sentence cards. The learner can pose the problem by selecting three sentence cards from given cards and arranging them in proper order. Given sentence cards are consists of correct card set and dummy card set for leading to errors. If three blank is filled with three sentence cards, diagnosis button will be active. Then, the learner can tap this button and the system diagnoses and generate a feedback his/her posed problem. When the learner finishes answering all assignment in selected level correctly, the interface for posing problem backs to the interface for selecting level. These flow and method of exercise are same as previous MONSAKUN. However, in MONSAKUN Touch 3, the text means the property of quantity is shown in the left side of each blank because let the learner consider the property of each sentence. The assignment that is described next section is renewed.

### 3.2.2 Designing the Level of Assignment

Table 1 shows the all level of assignment by dividing into the number of level, assignment, required activity, contents of assignment and number of assignment. Each level is designed so that the learner acquires to judge the structure of one-step multiplication or division word problem. The learner is required to pose the story from level 2 to 7, to pose the problem from level 8 to 9.

In level 1, the learner is given the story of one-step multiplication and four calculation expression which are expressed by "Base quantity multiplied by proportion is compared quantity", "Proportion multiplied by base quantity is compared quantity" and the cumulation of same number like "4+4+4=12" and "3+3+3+3=12". This assignment is the confirmation of the relation between multiplication and addition. Then, the learner is required to select the correct calculation expression. The purpose of this level is which let the learner comprehend the relation of multiplication story and addition calculation. The learning environment gives the story and several sentence cards to the learner in level 2. The given story as sentence integration consists of two fixed sentence cards and one blank. The learner is required to fill this blank by considering the property of quantity. In this assignment, they learn the property of quantity that is contained each given sentence card. Given sentence cards in level 3 are included two sentence cards that have different text representation and same property. For example, "There are two boxes." and "The number of box is two.". In this level, let the learner learn that the sentence cards include the same property of quantity have various text representation. MONSAKUN Touch 3 present the three blank for putting the sentence cards and several sentence cards in level 4. Then, the learner is required to pose the story by selecting three sentence cards and by arranging them in proper order based on the relation of "Base quantity multiplied by proportion is compared quantity". The assignment of level 5 requires the learner to pose the two stories by using one common sentence card. Through this exercise, the learner comprehend that existence sentence card is able to have two property of quantity. In other words, both proportion and compared quantity are expressed by existence sentence. After that, in level 6, the learner learns that the story has three kinds of calculations expression that are mentioned in section 2. This purpose is that the learner notices the multiplication story contain the calculation (a) and (c). Thus, the learner is given the multiplication and division calculation expression as assignment for posing story. In order to let the learner confirm three properties of quantity and its relation again, assignments of level 7 includes improper assignment which cannot solve because of lack of one proper sentence card. Then, the learner is given a specific sentence card for posing the story in this level, which is labeled "proper sentence card is not given" instead of lacking sentence card. Because the assignments in level 7 are composed of usual assignment and assignment which mentioned above, the learner is required to consider each property of quantity and its relation again. As the next step, the learner is required to pose problem in level 8 because the learner learn to pose the story through level 2 to 7. Finally, in level 9, the learner is required to pose the two problems by using one common sentence card. This assignment is same as assignment of level 5. Through the exercise from level 1 to 9, the learner can acquire the problem structure gradually.

Table 1: The Assignment Level on MONSAKUN Touch 3.

| Level | Required activity             | Contents of assignment   | Number |
|-------|-------------------------------|--|--------|
| 1     | Select calculation expression | Select calculation express given story   | 12     |
| 2     | Pose story                    | Pose story that is expressed by given calculation (one-step multiplication)<br>Required story has already given two sentence cards | 12     |
| 3     | Pose story                    | Same as assignment of level 2<br>Include same property and different text representation   | 12     |
| 4     | Pose story                    | Pose story that is expressed by given calculation (one-step multiplication)<br>Select three sentence cards and arrange them        | 10     |
| 5     | Pose story                    | Pose two stories by using same sentence card   | 10     |
| 6     | Pose story                    | Pose story that is expressed by given calculation<br>But given calculation expression is one-step multiplication or division       | 12     |
| 7     | Pose story                    | Same as assignment of level 6<br>But one proper sentence card is not given   | 12     |
| 8     | Pose problem                  | Pose problem that is expressed by given calculation<br>Select three sentence cards and arrange them                                | 12     |
| 9     | Pose problem                  | Pose two problems by using same sentence card  | 12     |

### 3.3 Outline of MONSAKUN Analyzer 3

After the teacher log in the learning environment by inputting id and password, MONSAKUN Analyzer displays the visualized learning data like Figure 2. These data are consists of the average score of the problem-posing and rate of each incorrectness in his/her each lesson. These data generates and shows as a three bar charts and a doughnut chart. Moreover, this environment indicates the average achievement of the level and assignment number. The count of posed problem and the rate of incorrectness are showed by not only each lesson but also each student. This function is same as previous system. In addition to this function, MONSAKUN Analyzer 3 can extract the data based on the each level and assignment from these data. For example, teacher can see the learning data of level 4. The progress of number of correct and incorrect posed problem is visualized by line chart.

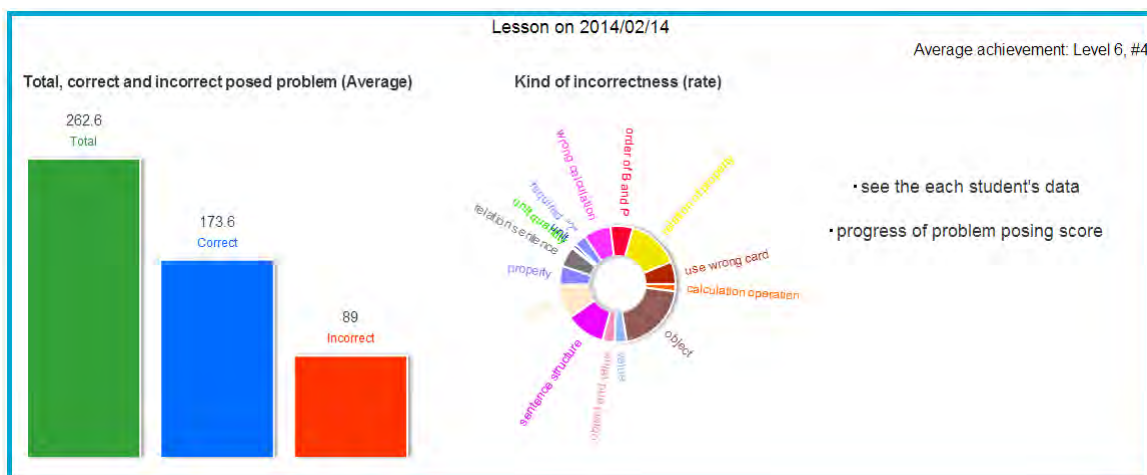


Figure 2. The Part of Main Interface of MONSAKUN Analyzer.

## 4. Experimental Use of MONSAKUN Touch 3

#### 4.1 Procedure of Experimental Use

The subjects were thirty-nine students in the third grade of an elementary school. They were divided into the subjects who experienced MONSAKUN Touch 1 and 2 in our previous research (Yamamoto, et al, 2012; Yamamoto, et al, 2013) and who did not experience it. Also, they had just learned to solve arithmetic word problems that can be solved by one-step multiplication or division. This experimental use has been performed during thirteen lessons that consist of pretest in one lesson, learning by MONSAKUN Touch 3 in eleven lessons and posttest in one lesson (45 minutes per lesson, in 5 weeks). A lesson by using MONSAKUN composes of teaching about problem-posing by a teacher and problem-posing exercise by using MONSAKUN Touch 3. The time of using MONSAKUN Touch 3 is decided by the teacher based on the progress of each lesson. If the subjects have finished twice the current level when they exercise the problem-posing after teaching, they were allowed to work on the previous level. The purpose of this experimental use is to examine the effects of the learning by MONSAKUN Touch 3 and the effects of experience MONSAKUN continually.

We used these three tests: usual problem solving test, extraneous problem solving test and problem-posing test. Usual problem solving test can be solved by one-step multiplication or division that is expressed by three sentences. Usual problem solving test has sixteen questions because each quantity can be the required value in these five stories. Extraneous problem solving test includes extraneous information that is not necessary to solve the problem (Muth, 1992). The extraneous problem solving test is useful to assess learner's comprehension of the problem structure. These problems consists of twelve problems that including the two kinds of extraneous information that change sentence cards except sentence contains required value in each six stories. Problem-posing test examine the problem-posing performance to let the subject pose the problem as he/she can within the time limit. The subject pose problem from scratch. The time limit is ten minutes in each test. The difference between pretest and posttest is order of each problem.

#### 4.2 Analysis of Pretest and Posttest

Analysis of pretest and posttest are reported in this section. And the level by using lecture is described. The teacher performed the lecture based on the level on MONSAKUN Touch 3 and treated one level in one lecture. However, in level 3, it is difficult for the subjects to relate between multiplication calculation expression and text representation contain "cut" because "cut" is associated with division calculation expression. Thus, the teacher has to spend three lessons for resolving this difficulty.

The results of average score and SD in three tests are shown in Table 2. These scores are divided into experienced and inexperienced group of MONSAKUN in our previous research. In addition to this result, we analyze the result in each test by ANOVA. There was an interaction in the score of usual problem-posing test between experience of MONSAKUN and pre-posttest ( $p=.03$ ). So, we analyzed simple effect. There was a significant difference in the score of posttest between experienced group and inexperienced group ( $F(1, 36)=3.193, p=.008$ ). This result suggested that it is effective for the subjects to experience the learning by using MONSAKUN for improving their usual problem solving performance. Next, there was a significant difference in the score of extraneous problem solving test between experienced group and inexperienced group ( $p=.04$ ), and effect size is medium ( $|\eta^2|=0.10$ ). Also, there was a significant difference in the score between pretest and posttest ( $p=.02$ ), and effect size is small ( $|\eta^2|=0.02$ ). In addition to this analysis, we analyzed the correlation between the pretest score and the difference between posttest and posttest score. In this result, there are a negative correlation between them (Spearman's rank-correlation coefficient,  $|rs|=.59, p=2.5E-06$ ). These results suggested that the lesson by using our learning environment promote the subjects to improve their problem structure, in particular, more effective to the subjects who have experienced MONSAKUN to comprehend the problem structure. MONSAKUN Touch 3 is more effective for the subjects who the score of extraneous problem solving test is lower particularly. Last, there was no significant difference in the number of posed problem between experienced and inexperienced group. But, there was a significant difference between pretest and posttest ( $p=.005$ ), and effect size is medium ( $|\eta^2|=0.07$ ). These results suggested that MONSAKUN is useful for the subjects to improve their problem-posing performance regardless of whether the subjects have experienced MONSAKUN.

Table 2: Result of Each Pretest and Posttest in experienced group (N=18) and inexperienced (N=20).

| Test                       | Experience of MONSAKUN | Pretest |      | Posttest |      |
|----------------------------|------------------------|---------|------|----------|------|
|                            |                        | M       | SD   | M        | SD   |
| Problem-posing             | experienced            | 2.50    | 1.57 | 3.56     | 1.42 |
|                            | inexperienced          | 2.10    | 1.45 | 2.7      | 1.52 |
| Usual Problem solving      | experienced            | 13.61   | 1.34 | 14.28    | 0.80 |
|                            | inexperienced          | 13.30   | 1.52 | 12.75    | 2.05 |
| Extraneous Problem Solving | experienced            | 10.83   | 2.14 | 11.38    | 0.76 |
|                            | inexperienced          | 8.80    | 3.54 | 9.75     | 3.40 |

## 5. Conclusion

In this paper, we have described the learning environment for problem-posing in one-step multiplication or division arithmetic word problem and its practical use. In order to realize the learning environment, firstly, we have mentioned that three quantities and its relation define one-step multiplication or division word problem. These three quantities are called base quantity, proportion and compared quantity. Its relation expresses the story that is "Base quantity multiplied by proportion is compared quantity" and so on. At the second step, the problem-posing based on this problem structure and the diagnosis and feedback of posed problem are defined. The levels of assignment were designed so that the learner can judge the story means whether multiplication or division. After that, we have developed learning environment called MONSAKUN Touch 3 and MONSAKUN Analyzer. Lastly, an eleven lesson experimental use is reported. The results of brief analysis suggested that the third grade students who have learned by using MONSAKUN in the past time are improved their problem solving performance and sophisticated their acquired problem structure.

As our future works, we need to verify the quantity of the effect to high group by using MONSAKUN Touch 3. Furthermore, we should perform the practical use for problem-posing in one-step addition, subtraction, multiplication or division to fourth grade students of an elementary school continuously.

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# Question Generation Using WordNet

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**Abstract:** Discourse and argumentation are effective techniques for education not only in social domains but also in science domains. However, it is difficult for some teachers to stimulate an active discussion between students because several students might not be able to develop their arguments. In this paper, we propose to use WordNet as a semantic source in order to generate questions that are intended to stimulate students brainstorming and to help them develop arguments in an argumentation process. In a study, we demonstrate that the system-generated questions sound naturally as human-generated questions as measured by computer scientists.

**Keywords:** Question generation, WordNet, argumentation

## 1. Introduction

Studies have reported that deploying questions are effective for learning. Asking targeted, specific questions is useful for revealing knowledge gaps with novices, who are often unable to articulate their questions (Tenenbergh & Murphy, 2005). Other researchers used prompts as a kind of questions in order to encourage students to self-explain and demonstrated that prompts are a promising instructional feature to foster conceptual understanding (Berthold et al., 2011).

Argumentation is an important skill that is required in any situation, either in research or in daily life, and thus needs to be trained. In order to train students, usually, they are asked to discuss together about a given topic. That is, they need to develop arguments during the argumentation process. However, students may sometimes not proceed with their argumentation. In this paper, we propose to use questions in order to stimulate their brainstorming and the goal is that they use the posed questions to develop new arguments for a given discussion topic. How can questions that are semantically related to a given discussion topic be generated in order to help students develop further arguments?

In this paper, we introduce an approach to exploiting WordNet to generate questions which are related to a discussion topic and investigate the research question: *Do automatic system-generated questions appear as natural as human-generated questions?* This paper reports on results of an evaluation study that is intended to test the specified research question.

## 2. State of the Art of Question Generation for Educational Purposes

Traditionally, questions are generated from a text or from structured data and natural processing techniques are used to analyze a text and to construct a question. In the state of the art, Le and colleagues (Le et al., 2014) classified educational applications of automatic question generation into three classes according to their educational purposes: 1) knowledge/skills acquisition, 2) knowledge assessment, and 3) educational systems that use questions to provide tutorial dialogues.

Examples of the first class of educational applications of automatic question generation include the work of Kunichika et al. (2001) who extracted syntactic and semantic information from an original text and generated questions based on extracted information, the reading tutor of Mostow and Chen (2009), and the system G-Asks (Liu et al., 2012) for improving students' writing skills (e.g., citing sources to support arguments, presenting evidence in a persuasive manner). The second class of educational applications of question generation aims at assessing knowledge of students and includes the approach of Heilman and Smith (2010) for generating questions for assessing students' acquisition of factual knowledge from reading materials, the computer-aided environment for generating multiple-choice test items of Mitkov et al. (2006), and the REAP system of Brown et al (2005), intended to assess the student's understanding after reading a text. The third class of educational applications generates

questions to be employed in tutorial dialogues in a Socratic manner. Olney and colleagues (Olney et al., 2012) presented a method for generating questions for tutorial dialogues. This method extracts concept maps from textbooks in the domain of Biology, questions are constructed based on these concepts. Person and Graesser (2002) developed an intelligent tutoring system for the areas of computer literacy and Newtonian physics. Each topic contains a focal question, a set of good answers, and a set of anticipated bad answers. For the domain of Computer Science, Lane & VanLehn (2005) developed a tutor which is intended to help students develop pseudo-code solution to a given problem.

In the contrast to traditional approaches to generating questions using texts as an input, Jouault and Seta (2013) proposed to generate questions by querying semantic information from Wikipedia to facilitate learners' self-directed learning. Using this system, students in self-directed learning are asked to build a timeline of events of a history period with causal relationships between these events given an initial document. The student develops a concept map containing a chronology by selecting concepts and relationships between concepts from the given initial Wikipedia document to deepen their understandings. While the student creates a concept map, the system integrates the concept to its map and generates its own concept map by referring to semantic information of Wikipedia. The system's concept map is updated with every modification of the student and enriched with related concepts that can be extracted from Wikipedia. Thus, the system's concept map always contains more concepts than the student's map. Using these related concepts and their relationships, the system generates questions for the student to lead to a deeper understanding without forcing to follow a fixed path of learning.

We propose to use WordNet as a semantic source for generating questions that aim at stimulating the brainstorming of students during the process of argumentation. The approach to be presented is different from the work of Jouault and Seta in that we use natural language techniques to extract key concepts that serve as inputs to query semantic information from WordNet whereas Jouault and Seta focused on exploiting linked data technologies to extract semantic information.

### 3. Question Generation Approach

In this section, we describe conceptually how questions can be generated. A detailed description of this approach is referred to Le et al. (2014b). In order to illustrate the question generation approach, we will use the following example discussion topic that can be given to students in a discussion session:

*“The catastrophe at the Fukushima power plant in Japan has shocked the world. After this accident, the Japanese and German governments announced that they are going to stop producing nuclear energy. Should we stop producing nuclear energy and develop renewable energy instead?”*

The question generation approach consists of four steps: 1) analyzing a text structure and identifying key concepts, 2) generating questions using key concepts in a discussion topic, 3) generating questions using related concepts in WordNet, and 4) generating questions using example sentences in WordNet.

#### 3.1 Analyzing text structure and identifying key concepts

In order to automatically recognize key concepts of a discussion topic, a natural language parser is used to analyze the grammatical structure of a sentence for its constituents, resulting in a parse tree showing their syntactic relation to each other. The language parser analyzes a text and identifies the category of each constituent, for instance: determiner, noun, or verb. Since nouns and noun phrases can be used as key concepts in a discussion topic, we select from the parsing results of a discussion topic the constituents which are tagged as nouns (NN) or noun phrases (NP). In our example discussion topic from above, the following noun phrases can serve as key concepts to generate questions: *catastrophe, Fukushima power plant, nuclear energy, renewable energy*.

#### 3.2 Question Generation Using Key Concepts in a Discussion Topic

The extracted key concepts are helpful for generating questions. Yet, an issue that needs to be addressed next is to determine the types of questions to be generated. Several question taxonomies have been proposed by researchers in the area question generation. Among the existing question taxonomies, the

question taxonomy for tutoring proposed by Graesser and Person (1994) has been widely used. This taxonomy consists of 16 question categories: verification, disjunctive, concept completion, example, feature specification, quantification, definition, comparison, interpretation, causal antecedent, causal consequence, goal orientation, instrumental/procedural, enablement, expectation, and judgmental. The first 4 categories were classified as simple/shallow, 5-8 as intermediate and 9-16 as complex/deep questions. We apply this question taxonomy to define appropriate question templates for generating questions. For example, Table 1 defines some question templates for the classes “Definition” and “Feature/Property”, where X is a placeholder for a key concept extracted from a discussion topic. For example, the question templates of the class “Definition” can be filled with the noun phrase “nuclear energy” and result in the following questions: *What is **nuclear energy**? What do you have in mind when you think about **nuclear energy**? What does **nuclear energy** remind you of?*

Table 1: Question Templates proposed for question generation.

| Type             | Question   |
|------------------|--|
| Definition       | What is <X>?                                       |
|                  | What do you have in mind when you think about <X>? |
|                  | What does <X> remind you of?                       |
| Feature/Property | What are the properties of <X>?                    |
|                  | What are the (opposite)-problems of <X>?           |

### 3.3 Question Generation Using Related Concepts in WordNet

In order to generate questions that are related to key concepts of a discussion (but which do not literally contain these concepts), sources of semantic information can be exploited (e.g., Wikipedia, Wiktionary, or WordNet). Currently, we deploy WordNet (Miller, 1995) because it is suitable to find related concepts for a discussion topic. WordNet is an online lexical reference system for English. Each noun, verb, or adjective represents a lexical concept and has a relation link to hyponyms which represent related concepts. In addition, for most words WordNet provides example sentences which can be used for generating questions. For example, if we input the word “energy” into WordNet, an example sentence like “energy can take a wide variety of forms” for this word is available. If we look for some hyponyms for this word, WordNet provides a list of direct hyponyms and a list of full hyponyms. The list of direct hyponyms provides concepts which are directly related to the word being searched. For example, the direct hyponyms of “energy” as listed by WordNet include “activation energy”, “alternative energy”, “atomic energy”, “binding energy”, “chemical energy”, and more. The list of full hyponyms contains a hierarchy of hyponyms which represent direct and indirect related concepts of the word being searched. One of the advantages of WordNet is that it provides accurate information (e.g., hyponyms) and grammatically correct example sentences. For this reason, we exploit hyponyms provided by WordNet to generate questions which are relevant and related to a discussion topic. Placeholders in question templates (cf. Table 1) can be filled with appropriate hyponym values for generating questions. For example, the noun “energy” exists in the discussion topic, so that WordNet suggests “activation energy” as a hyponym. The question templates of the class “Definition” can then be used to generate questions such as: *What is **activation energy**? What do you have in mind when you think about **activation energy**? What does **activation energy** remind you of?*

### 3.4 Question Generation Using Example Sentences in WordNet

In addition to using hyponyms, we propose to make use of example sentences to generate questions. There are existing tools which convert texts into questions. For example, ARK [13] is a syntax-based tool for generating questions from English sentences or phrases. The system operates on syntactic tree structures and defines transformation rules to generate questions. For example, a direct hyponym of the key concept “catastrophe” is “tsunami” for which there is an example sentence “a colossal tsunami destroyed the Minoan civilization in minutes”. Using ARK, the example sentence can be converted into questions: “*What destroyed the Minoan civilization in minutes?*”, “*When did a colossal tsunami destroy the Minoan civilization?*”, “*What did a colossal tsunami destroy in minutes?*”



## 4. Evaluation

The goal of our evaluation is to determine whether automatically generated questions are perceived as as natural as human generated questions. Our study design is similar to the Turing test that requires humans to decide whether they are interacting with an actual computer program or with a human via computer mediation. The study being presented in this paper is a variation of the Turing test: we wanted to know whether automatically generated questions can be distinguished from human generated questions easily by human raters. Human raters we employed in this study were Computer Scientists (including Professors, Senior Researchers, and Phd. candidates).

### 4.1 Design

In the first evaluation phase, we asked eight human experts from the research communities of computer based argumentation and question generation research to generate questions for three discussion topics. We received 54 questions for Topic 1, 47 questions for Topic 2, and 40 questions for Topic 3. These questions are referred to as human generated questions in this paper.

**Topic 1:** *The catastrophe at the Fukushima power plant in Japan has shocked the world. After this accident, the Japanese and German governments announced that they are going to stop producing nuclear energy. Should we stop producing nuclear energy and develop renewable energy instead?*

**Topic2:** *Recently, although the International Monetary Fund announced that growth in most advanced and emerging economies was accelerating as expected. Nevertheless, deflation fears occur and increase in Europe and the US. Should we have fear of deflation?*

**Topic 3:** *“In recent years, the European Central Bank (ECB) responded to Europe's debt crisis by flooding banks with cheap money...ECB President has reduced the main interest rate to its lowest level in history, taking it from 0.5 to 0.25 percent” . How should we invest our money?*

For each discussion topic, the system generated several hundred questions (e.g., 844 questions for Topic 1), because for each discussion topic several key concepts are extracted, and each key concept has a set of hyponyms that are queried from WordNet. For each key concept and each hyponym, fourteen questions have been generated based on defined question templates (see examples in Table 1). Since this set of generated questions was too big for a human expert evaluation, we selected a small subset of these questions manually so that the proportion between the automatic generated questions and the human generated questions was about 1:3. There were two reasons for this proportion. First, if there had been too many automatically generated questions, this could have influenced the “overall picture” of human generated questions. Second, we needed to make a trade-off between having enough (both human-generated and system-generated) questions for evaluation and considering a moderate workload for human raters. The numbers of automatically generated questions and of human generated questions are shown in Table 2.

Then, we mixed human generated questions with automatic generated questions and asked human raters to decide for each question from the mixed set whether they believed it was generated by a computer system or by a human expert. Note that these human raters were not the same human experts who generated the questions and did not know about the proportion between human-generated and system-generated questions. Specifically, the following question was answered by human raters: *Is that an automatic system-generated question? (Yes/No)*

Table 2: Number of questions generated by human experts and by the system for evaluation.

|                  | <b>Topic 1: No. of questions</b> | <b>Topic2: No. of questions</b> | <b>Topic 3: No. of questions</b> |
|------------------|----------------------------------|---------------------------------|----------------------------------|
| Human-generated  | 54                               | 47                              | 40                               |
| System-generated | 16                               | 15                              | 13                               |
| Total            | 70                               | 62                              | 53                               |

## 4.2 Results

We use the balanced F-score to evaluate the ratings of humans. This score is calculated based on precision and recall using the following formula:

$$F = \frac{2 * precision * recall}{precision + recall}$$

The precision for a class is the number of true positives (i.e., the number of system-generated questions correctly labeled as system-generated) divided by the total number of elements labeled as positive (i.e., labeled as system-generated), while the recall for a class is the number of true positives divided by the total number of elements that actually are positive (i.e., that are system-generated). If the F-score is high (close to 1), it shows that the system-generated questions are easy to distinguish from human-generated questions, and vice versa.

Table 3: Classification result of two raters on authorship of questions.

|                | SGQ predicted<br>by Rater 1<br>(% of total) | HGQ predicted<br>by Rater 1<br>(% of total) | SGQ predicted<br>by Rater 2<br>(% of total) | HGQ predicted<br>by Rater 2<br>(% of total) | Total |
|----------------|---|---|---|---|-------|
| <b>Topic 1</b> |   |   |   |   |       |
| System-GQ      | 12 (75%)                                    | 4 (25%)                                     | 13 (81%)                                    | 3 (19%)                                     | 16    |
| Human-GQ       | 45 (83%)                                    | 9 (17%)                                     | 22 (41%)                                    | 32 (59%)                                    | 54    |
| <b>Topic 2</b> |   |   |   |   |       |
| System-GQ      | 13 (87%)                                    | 2 (13%)                                     | 15 (100%)                                   | 0   | 15    |
| Human-GQ       | 24 (51%)                                    | 23 (49%)                                    | 28 (60%)                                    | 19 (40%)                                    | 47    |
| <b>Topic 3</b> |   |   |   |   |       |
| System-GQ      | 10 (77%)                                    | 3 (23%)                                     | 12 (92%)                                    | 1 (8%)                                      | 13    |
| Human-GQ       | 27 (67%)                                    | 13 (33%)                                    | 30 (75%)                                    | 10 (25%)                                    | 40    |

Table 3 shows how two human raters rated the mixed set of questions in the context of Topic 1. A high number (75%) of system-generated questions (SGQ) and 17% of human-generated questions (HGQ) have been correctly identified by this rater, resulting in a low F-score of 0.329 (Recall=0.211, Precision=0.75) that indicates that it was difficult for the rater to identify system-generated questions. This is because the first rater decided wrongly on 83% of the human-generated questions. The second rater, however, achieved a medium F-score of value 0.51 (Recall=0.371, Precision=0.813) that is higher than of the first rater, indicating that also this rater had some difficulties in distinguishing between human-generated and system-generated questions. Interestingly, although both raters had difficulties in distinguishing between human-generated and system-generated questions, the agreement between the two was poor in addition (Kappa=0.086).

In the context of Topic 2, the first rater achieved an F-score of 0.5 (Recall=0.351, Precision=0.867) The second rater showed a similar tendency with an F-score of 0.517 (Recall=0.349, Precision=1). The Kappa value for their agreement was 0.233, which can be considered as fair.

In the context of Topic 3, one question (“What is cheap money?”) was generated by a human expert and by the system in identical form. This was left out from analysis (however, this question was classified as a system-generated question by both human raters). Specifically, the first rater achieved a low F-score of 0.4 (Recall=0.27, Precision=0.769). This can be explained by the fact that the first rater classified 67% of human-generated questions as generated by the system. The second rater achieved a similarly low F-score of 0.436 (Recall=0.286, Precision=0.923). Similar to the case of Topic 2, the agreement between the first and the second raters in the context of Topic 3 was fair (Kappa=0.263).

In summary, we have learned that for all raters and all three topics it was difficult to identify system-generated questions within the set of mixed questions (F-scores between 0.329 and 0.517). This is an indication that the system-generated questions appeared as natural as the human-generated questions to these raters. The agreement between raters was poor or fair, further strengthening this argument (there was little agreement on questions that seemed clearly human-generated or clearly system-generated).

## 5. Conclusions, Discussion and Future Work

In this paper, we have presented an approach to generating questions using WordNet as a source of semantic information. The goal is using generated questions to stimulate students brainstorming and thus, participate more actively in argumentation. We have conducted a pilot study comparing system-generated questions with questions that have been generated manually by researchers of the argumentation and question generation research communities. The study results show that the difference between human-generated and system-generated questions is not large: human raters could not tell the difference easily. However, it needs to be noted that we had to select manually a small number of questions from a huge amount (several hundreds) of system-generated questions. At present, we do not use an automatic algorithm for this task. We also think about limiting the number of system-generated questions, because if a student requests questions for developing arguments and s/he receives such a huge amount of questions, this can impact on the argumentation process negatively. As future work, we will develop criteria to limit the number of system-generated questions and evaluate the system-generated questions with respect to the quality and usefulness.

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# Understanding differences of eye movements patterns while reading musical scores between instructors and learners to design learner-centered teaching strategies

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**Abstract:** While learning instruments playing, one engages in the following mental and motor activities; reading notes in a musical score, retrieving relevant information from long-term memory concerning how to play the notes, moving relevant body parts, and verifying his/her performance against the expected sound. The learner is required to coordinate these activities in the learning process. This paper assumes that how the process of coordination is carried out should depend on the degree of matching between the learner's skill and the musical score which should appear in the process of reading; visually encoding the to-be-played notes and verifying the sound from the instrument he/she has just played. This paper proposes a method for objectively measuring the degree of matching by using eye movements data while reading a musical score with hearing notes.

**Keywords:** Education, Eye-Tracking

## 1. Introduction

Learning instrument playing is one of popular activities that many people do in their lives. One learns instrument playing to become a skillful performer, to enjoy themselves as hobby, to be licensed as a musical teacher, etc. Musical scores are the materials these people would use while learning, and their contents would have a large impact on the course of learning. The learner would be willing to use a musical score that he/she estimates it matches his/her purpose of instrument learning, on the other hand, he/she would not use such a music score that is too difficult for him/her to play. This paper proposes a method for objectively measuring the degree of matching by using eye movements data while one is reading a musical score with hearing notes with some empirical data.

There are many works that deal with eye movements while reading music. Wristen (2005) argued that sight-reading is an integral part of the experience for all musicians, and argued the direction of its ability. In the review, sight-reading task divided into two large phases: preparation and performance, and performance. Especially, performance needs a number of cognitive demands. At least, to recognize the score, the basic elements for sight-reading is rhythm, melody, harmony, and context. After getting the knowledge of the elements, Lehmann and Ericsson (n.d.) showed to decipher a score at sight reading, the musicians have to recognize musical patterns, generate a large-scale performance, plan to govern performance of the piece as a whole, and learn to anticipate how the music continues. With the idea, several researches tried to describe the difference of sight-reading skills for music learners. For example, Kopiez and Galley (2002) tried to compare features of eye movements in musicians to a non-musician. Thus, the relation of eye movement, sight-reading, and the music learners' skills is going to explain. If the idea will be able to be realized practically, we can estimate easily the learners' ability for sight-reading, and expansively. For the perspective, we can easily imagine the application of the method to e-Learning. Before applying, we need to consider how to include the technique for e-Learning. In general, almost instructors thought that training instruments playing skill is incongruous with e-Learning. But during the several years, the causes of incongruence partly have been improved with some researches with the analysis of the relation between training elements and human knowledge or feeling.

Nakahira and Kitajima (2013) proposed an educational design for piano playing and singing that is capable of transferring skill related to not only explicit knowledge but also implicit knowledge. In order to explore specifications of such an educational design, we adopted a methodology called Cognitive Chrono-Ethnography (CCE), which was successfully applied to understand people's daily behavior, for studying how trainees interact with and utilize a proposed educational design in real educational settings, which would eventually lead to an appropriate specification of student-centered educational design for piano playing and singing skill transfer. They set the design consisted of the following three elements: (i) having the trainee watch a video of the model performance for the purpose of building mental image of the performance goal, (ii) having the trainee mimic the model performance while referring to guidance comments added on the musical score, and video-record the performance, and (iii) having the trainee submit the video and critically review his/her own performance. Using this, they designed student-centered design for education in skill transfer. Through the research, they suggested to identify critical parameters and understand the trainees' behaviors while they used the student-centered educational design for piano playing and singing skill transfer.

## 2. Methodology

While a learner is practicing instrumental playing, he/she has to engage in the following four processes;

1. reads the musical score and associate it with his/her body movements,
2. sends signal from his/her brain to his/her body parts,
3. moves his/her body for playing,
4. checks accuracy of his/her playing.

In this paper, we focused on the first process of reading musical score and the fourth process of checking accuracy of their playing

### 2.1 Reading Musical Scores

In the following, we describe in detail the processes involved in reading musical scores.

First, the learner gets notes from the musical score. In this process, he/she visually acquires each note as a code of sound through his/her eyes, and the visual information is sent to his/her brain. The signal of note information is used to retrieve a set of information associated with the note from long-term memory, including the sound pitch, the position of instrument to strike a note, and so on. After retrieving the relevant information, the learner moves his/her body to hit the note. Upon hitting it, the instrument makes some sound. The learner recognizes the sound he/she has just made as a signal, and compares it with the information having been retrieved from long-term memory. If there is no mismatch, he/she recognizes the hitting was correctly carried out, and the learner proceeds to get a next note. If not, he/she recognizes the hitting is incorrectly performed, and the learner retries to play the correct note. We can identify two critical processes that should affect the performance of learners; The first is a visual process which is the process of getting information necessary for hitting the note, including such information as posture of fingers, how to move fingers, sound to be heard, etc. The second is the accuracy check, which is done by comparing the pitch of sound he/she has just played and the corresponding information retrieved from long-term memory. This is essentially the process of matching the auditory image that has been put in working memory by playing the note with the one having been loaded in working memory prior to playing it.

The first process of visual information processing and the second process of mental process of auditory information matching have to be carried out in parallel and in synchronous with the action of instrument playing. We assume that the degree of difficulty in carrying out these processes coherently should appear in the eye movements of the learner. If the learner feels the difficulty level of the musical score just matches his/her skill level, he/she would smoothly get the note information from the musical score. As a result, his/her eye movements would show coherent patterns, which would be observed while one is reading sentences in his/her favorite books. On the other hand, however, if he/she feels the musical score too easy or too difficult, he/she may feel uncomfortable about getting the note

information in his/her favorite page. His/her eye movements would show incoherent patterns, i.e., abrupt leaps, abnormally long fixations at specific places, etc.

## 2.2 A Model of Eye Movements While Reading a Musical Score

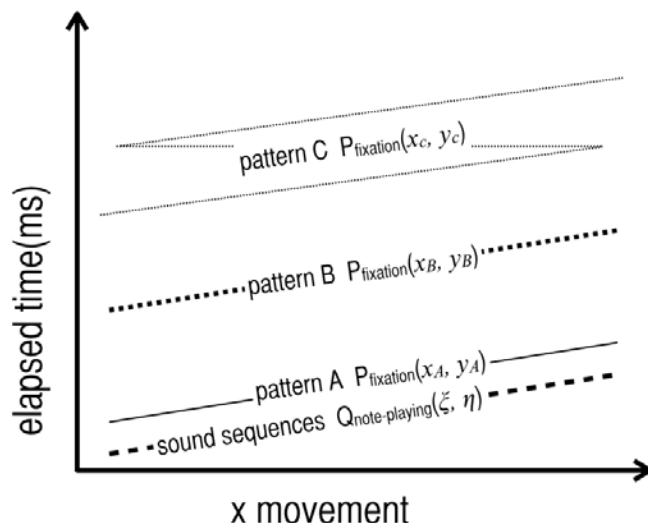
Figure 1 shows a model of musical score reading. Suppose a situation in which a musical score is placed in front of the learner. We are interested in the two datasets; one is the series of eye-fixations on the musical score, and the other is the series of note-playing events. Both datasets can be regarded as a function of time, and therefore we can investigate the mutual relationships by arranging them in the time dimension and trying to discover patterns that would be associated with the degree of matching of the musical score and the learner's skill level. In the figure, the horizontal line shows the eye position in the horizontal dimension, and the vertical line shows the elapsed time since the onset of the first note, which has a linear relationship with the time course of note-playing events. We denote the time course of note-playing events as a set  $Q_{\text{note-playing}}$  (sound sequences in Figure 1) and eye fixation events as a set  $P_{\text{fixation}}$  (pattern A – C in Figure 1):

$$\begin{aligned} Q_{\text{note-playing}} &= \{ (x(t_j), y(t_j)) \mid j = 1, 2, \dots \}, \\ P_{\text{fixation}} &= \{ (\xi(t_k), \eta(t_k)) \mid k = 1, 2, \dots \} \end{aligned}$$

where  $(x(t_j), y(t_j))$  represents the  $(x, y)$  coordinate of the  $j$ -th musical score image, and  $(\xi(t_k), \eta(t_k))$  represents the  $(\xi, \eta)$  coordinate of the  $k$ -th fixation recorded at  $t = t_k$ . Using these descriptions, we assume three possible patterns in the relationships between  $P_{\text{fixation}}$  and  $Q_{\text{note-playing}}$ ;

- **Pattern A:** a large set of  $(\xi, \eta)$  coordinates in  $Q_{\text{note-playing}}$  corresponds with the one in  $P_{\text{fixation}}$ , meaning that the learner reads the musical score as a large chunk while he/she hears the stream of sounds of notes being played with the instrument,
- **Pattern B:** a smaller set of  $(\xi, \eta)$  coordinates in  $Q_{\text{note-playing}}$  corresponds with the one in  $P_{\text{fixation}}$ , meaning that the learner reads less frequently than Pattern A learner does,
- **Pattern C:** there is little correspondence between  $(\xi, \eta)$  coordinates in the set  $P_{\text{fixation}}$  and  $(x, y)$  coordinates in the set  $Q_{\text{note-playing}}$ .

Using the three patterns, we can estimate the learner's status of instrument playing skill. When a learner has sufficient ability to read musical scores and hear the stream of sounds of notes in parallel, the learner would show the behavior, so called "shadow hearing" of the musical score. In this case, he is treated as a subset of  $Q_{\text{note-playing}}$ , that corresponds to Pattern A. A skilled instrumental player would show a stream of eye fixations similar to  $P_{\text{fixation}}$  even if there is no sounds of notes to hear.  $Q_{\text{note-playing}}$ , when exists, might be used as cues for keeping timing, but it would not be necessary for those who can do "shadow hearing." Less skilled players would show less coherent relationship between  $Q_{\text{note-playing}}$



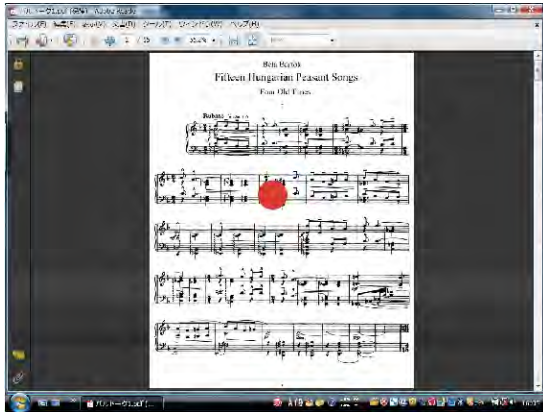
**Figure 1.** A model of musical score reading.

and  $P_{\text{fixation}}$  than the one shown by the skilled players as described above. We assume that there should be two cases that would be distinguishable in terms of the relationship between  $Q_{\text{note-playing}}$  and  $P_{\text{fixation}}$ . The first case is characterized by unstable  $P_{\text{fixation}}$  without musical sounds, but stable  $P_{\text{fixation}}$  with  $Q_{\text{note-playing}}$ ; in other words, musical sounds are inevitable for them to exhibit consistent eye movement patterns. Musical sounds help the learner search the appropriate notes from learner's long-term memory. We assume that this case corresponds to Pattern B. The second case is characterized by a reverse relationship between  $Q_{\text{note-playing}}$  and  $P_{\text{fixation}}$ , namely,

stable  $P_{\text{fixation}}$  without musical sounds, but unstable  $P_{\text{fixation}}$  with  $Q_{\text{note-playing}}$ . In this case, the introduction of musical sounds would cause extra cognitive burden on the learners that make difficult for them to search notes from learners' long-term memory. We assume that this case corresponds to Pattern C

### 3. Experiment

Applying the methodology, we make a hypothesis for eye tracking of reading music and the trajectory. If the learners groups' ability is almost similar, the learners' reading music split some patterns;



**Figure 2.** A screenshot for the experiment. A large red circle displayed on the monitor indicates the recorded participant's gaze point. The musical score was displayed in the entire area of the monitor.

- (1) independently with or without musical sound, the learners' eye tracking pattern has no difference,
- (2) dependently with or without musical sound, the learners' eye tracking pattern has some difference, dividing into learners' ability of reading musics.

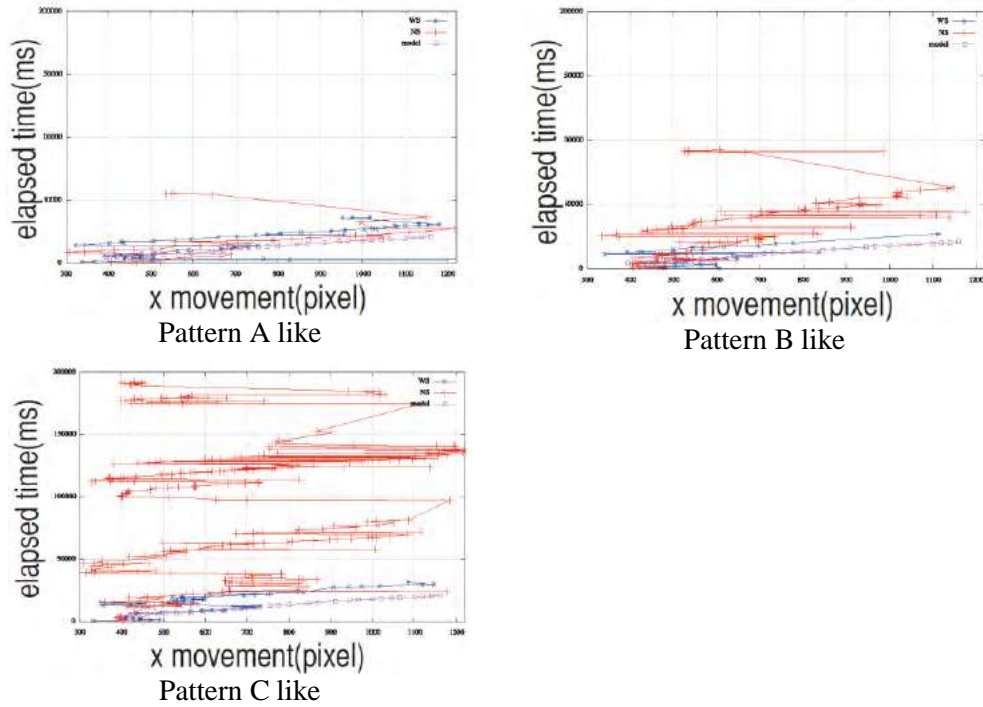
To test the hypothesis, we conducted an experiment. At the experiment, we focus the ability of collaboration between visually and auditory. Due to this, we adopt the model performance for musical sound which means the musical sound does not stop due to the players' mistake. If the learner achieve a mastery of the musical score, he/she can match  $Q_{\text{note-playing}}$  pattern with their  $P_{\text{fixation}}$ , if not, he/she cannot match. And the  $P_{\text{fixation}}$  pattern will change whether the experiment include with or without musical sound. We chose participants, expected to have uniform learners'

level, from a pre-school teacher education institution which has a class for basic piano/singing course. Fourteen students and two instructors participated in the experiment. All students had basic piano playing skills. We prepared a one page musical score whose level was at the middle class for piano instrument, including some chordal notes. Although the score had five lines, we used first two lines for acquiring eye tracking data in order to avoid recording errors. It included nine bars with about 30 note heads. Each musical score was displayed on a 22 inch LCD monitor, with a resolution of 1024 x 768 pixels. The distance between the monitor and an participant was about 30cm. We used a Tobii Eye Tracker to record participants' eye movement with sampling rate of 50Hz. Figure 2 shows a screenshot from the experiment. The experiment was conducted according to the following flow:

First, the experimenter explained the outline of the experiment, then instructed the important points that the participant was expected to follow consisting of the following four items (the participant is indicated as "you" in the following instruction);

- (1) When you read the musical score, please keep your head in the region about 30cm from the monitor's surface;
- (2) There are two conditions. One is "read musical score without sound" condition and the other is "read musical score with sound" condition.
- (3) When you are in the "read musical score without sound" condition, please imagine the melody from the musical score, and try to synchronize the position of notes you read and the sound pitches you image;
- (4) When you are in the "read musical score with sound" condition, please synchronize the sound pitches you hear and the position of the note heads you read from the musical score;

After calibrating the Tobii eye tracker, the experimenter presented the musical score on the monitor with full screen, followed by sending a starting sign to the participant. Between the two conditions, a short break was given to the participant.



**Figure 3.** Typical trajectories of participants' eye tracking patterns.  $\square$  represents  $Q_{\text{note-playing}}$ ,  $+$  represents  $P_{\text{fixation}}$  for reading soundless musical score,  $*$  represents  $P_{\text{fixation}}$  with sound reading music.

#### 4. Analysis

After the experiment, we analyzed the recorded eye movement data. We use first two lines for analysis. At first, we tried to get rid of noises from the data from the  $i$ -th participant's  $P_{\text{fixation}}$ . In this research, we make smoothing the dataset  $P_{\text{fixation}}$ , namely calculated average for  $\xi_i(t_k)$  and  $\eta_i(t_k)$  coordinate per each 10 points. We regard the smoothed  $P_{\text{fixation}}$  as point of gazes. Next step of the analysis is to calculate stationary points for smoothed  $P_{\text{fixation}}$ . In this analysis, we set the human central area of vision  $\theta_c$  as 2 degree ( $\approx 23$  pixels). If the  $i$ th participant's two adjacent gaze points distance is longer than  $\theta_c$ , we judged that the stationary point had moved. If the distance is shorter than  $\theta_c$ , we regarded that the stationary point had not moved. Through this process, we can derive the  $i$ -th participant's stationary points series.

Figure 3 shows the typical trajectories of participants' eye tracking patterns. Square symbol represents  $Q_{\text{note-playing}}$ , plus symbol represents  $P_{\text{fixation}}$  for reading soundless musical score, asterisk symbol represents  $P_{\text{fixation}}$  with sound reading music. From the figures, we find the learners have several difference of  $Q_{\text{note-playing}}$  and  $P_{\text{fixation}}$  with/without sound reading music. From the figures, we find almost learners' trajectories of participants' eye tracking will be distinguished pattern A, B, or C.

#### 5. Discussion

Through the analysis, we considered the learners' types. There are some possibilities for selecting musical score to play appropriate for their playing skill levels. When people want to play a musical instrument, they need to engage in elemental-level training to treat instrument. In the process, learners cannot select the etude or melody music target, because they have least skills for playing instrument. But when they move their skill level status from the elemental level to middle levels, they have possibilities of selecting musical scores due to their variety of playing skills. Though their selections could become diverse, sometimes they tend to choose such musical scores just only too easy or too



difficult. In the case of hobby training, there would be no problem in specific selections. But if the learners need or want to improve their playing instrument skills, they have to select musical scores at a challenging level.

## 6. Conclusion and Future Works

In this paper, we proposed the method for estimating learners' skills to fill in the gaps of their skills and the requirement skill from musical score. Focusing on the processes of reading musical score and of checking accuracy of their playing, we set the hypothesis about the relation between eye movement, auditory checking accuracy for pitch, and reading music. For checking the relation, we set an experiment of eye tracking for reading music, with or without musical sound. We found that the learners state could be divided in four categories by using the features measured by  $dh$  and  $dv$ , showing differences between sound time sequences and eye positions in the horizontal dimension with or without musical sound. With these categories, we proposed a method of easy estimation for learners' skill and musical scores which fits learners' skill for future

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# A Framework of Generating Explanation for Conceptual Understanding based on 'Semantics of Constraints'

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**Abstract:** A framework for indexing problems is proposed, based on which explanation generation and problem sequencing for conceptual understanding in science can be automatized. It helps student learn how to make appropriate models to solve problems and prevents them from superficially read the solution of a worked example and apply it wrongly to others. The results of a preliminary experiment is also described in which the explanations generated based on the framework promoted subjects' conceptual understanding in mechanics.

**Keywords:** science education, problem practice, worked example, explanation generation, semantics of constraints

## 1. Introduction

In problem practice in science (e.g., physics), most students fail to acquire the ability to make an appropriate model for a given task. An expert can model not only the behavior of a system in question, but also she/he can do so in various tasks. Such expertise includes identifying the structure of the system in question and the applicable principles/laws for making the necessary and sufficient model. It also includes understanding how/why a model changes when the task is changed. We call such ability 'conceptual understanding' of the domain.

In order to reach such understanding, students need to learn (1) to infer the structural features of problems from the superficial features, and (2) to apply appropriate principles/laws to structural features to make models. For assisting students, it is insufficient to explain how each problem is solved. It must be explicitly explained why the principles/laws are applicable to the given situation (surface structure) and what physical meaning (physical structure) they imply. It is also important to explain how the model changes when the situation (problem) is changed. Furthermore, it would promote such learning to provide students with an appropriately designed and sequenced set of problems (Scheiter and Gerjets, 2003; VanLehn and van de Sande, 2009).

In this paper, we propose a framework for indexing problems, based on which explanation generation and problem sequencing mentioned above can be automatized. In our framework (called 'Semantics of Constraints: SOC'), making a model in physics is regarded as a process in which various constraints (applied principles/laws and modeling assumptions) are imposed on the target system and its behavior. A model is regarded as the set of constraints.

After introducing the SOC framework, we show the method for generating SOC-based explanations. The results of preliminary experiment are also described which proved the usefulness of our framework.

## 2. Semantics of Constraints and Explanation Generation

Given a physics problem, one makes a model of the target system which is necessary and sufficient for answering the query by embodying an appropriate part of the domain theory. Domain theory consists of a set of propositions each of which describes a principle/law, its applicable condition and resulting constraint(s) on the attribute(s) of the system. Constraints by embodied principles/laws are called the 'constraints of physical phenomenon (PPCs).' In making a model, various modeling assumptions are set. Modeling assumptions define the structure/behavioral range of a system and physical phenomena to be considered. Since an embodied PPC is valid under some modeling

assumptions (applicable conditions), a PPC always has its corresponding modeling assumptions. Constraints by modeling assumptions are called the 'constraints of modeling assumptions (MACs).' Boundary condition of a system is given by the 'constraints of boundary condition (BCCs).' They define the influence from the outside of the system. Making the influence which can't/needn't be calculated with a model means defining the boundary of the model (i.e., what physical processes are considered/ignored). That is, a BCC always has its corresponding modeling assumptions. In our framework, a model is the union of PPCs, MACs and BCCs. Especially, though MACs are usually implicit, they are essential for explaining models because MACs gives the validity of PPCs and BCCs. When MACs are changed, PPCs and BCCs also qualitatively change. In order to make a model correctly, therefore, it is necessary to understand the physical meaning of the constraints based on modeling assumptions (i.e., why an assumption is set and what role it plays). More detail about SOC is discussed in Horiguchi and Hirashima (2009), and Horiguchi, Hirashima and Forbus (2012).

A model-making process (i.e., solution) is described as the procedure in which principles/laws are applied in turn to the given situations (represented with MACs and BCCs) to yield new consequences (represented with PPCs). The explanations about a problem and the difference between problems are generated based on such a representation and the comparison between representations. Such explanations are called 'SOC-based explanations.'

### 3. Preliminary Experiment

We conducted an experiment to evaluate the usefulness of our framework. The purpose was to examine whether the SOC-based explanation promotes students' conceptual understanding, that is, whether their representation of problems was improved and they became able to solve various types of problems by using correct models.

**Subjects:** 15 graduates and under graduates whose majors are engineering participated.

**Procedure:** First, subjects were given problem set 1 (15 problems in mechanics called PS-1) and asked to group the problems into some categories based on some kind of 'similarity' they suppose, then asked to label each category they made (called 'categorization task 1'). Then, they were asked to solve 8 problems in PS-1 (called 'pre-test'). After a week, the subjects were divided into two groups: the 'control group' (7 subjects) and the 'experimental group' (8 subjects). The average scores of both groups in pre-test were made equivalent. The subjects in control group were given the *usual explanation* about the solutions of 11 problems in PS-1 (which explains the calculation of the required physical amount from the given ones) to learn. The subjects in experimental group were given the SOC-based explanation about the same problems as the usual explanation to learn. Then, by using problem set 2 (other 15 problems in mechanics called PS-2), 'categorization task 2' was conducted in the same way as above. Finally, subjects were asked to solve 8 problems in PS-2 (called 'post-test').

**Measure:** The quality of the representation of problems was measured with the categories, their 'frequencies' (number of problems accounted for) and the time required in each categorization task. The ability to solve various types of problems was measured with the scores in each test. The effect of learning with usual/SOC-based explanation was measured with the comparison of the results of two categorization tasks and pre-/post-tests. The superiority of SOC-based explanation to usual explanation was measured with the differences of improvement of categorization and problem-solving between experimental and control groups.

**Results:** The categories made by subjects and their frequencies in categorization task 1 are shown in table 1. Most of the subjects categorized the problems based on the similarity of their superficial features, such as the components of the system (e.g., inclined plane), the figures of motion (e.g., circular motion). Additionally, all subjects finished the task within 10 minutes. The results of categorization task 2 are shown in table 2 (control group) and table 3 (experimental group). Many subjects of control group still categorized the problems based on the similarity of their superficial features, while many subjects of experimental group became to categorize the problems based on the similarity of their structural features, that is, the dominant principles/laws of problems (e.g., Newton's second law, balance of forces, conservation of energy). Additionally, all subjects of control group finished the task within 10 minutes again, while the subjects of experimental group required from 25 to 35 minutes. These results suggest the learning with SOC-based explanation promoted representing problems based on their structural features rather than their superficial features (the increase of the time required suggests the subjects of experimental group inferred the physical structure from surface structure). The average scores in pre- and post-tests are shown in figure 1 (in both tests, full marks were 52). In pre-test, there was no significant difference of average scores between groups (control group: 36.0 and experimental group: 33.6, t-test  $p > .10$ ). In post-test, though there was also no significant difference of average scores between groups (control group: 42.7 and experimental group: 47.6, t-test:  $p > .10$ ), the increase of average score of experimental group was larger than that of

control group. This result suggests the learning with SOC-based explanation promoted the ability to solve various types of problems, that is, to make appropriate models regardless of their superficial features. These results suggest that SOC-based explanation about the solution of problems and their differences can assist students in reaching conceptual understanding.

Table 1: Categories in task-1

|                     | Number of subjects using category labels (N <sub>1</sub> =15) | Average size of category (N <sub>2</sub> =15) | Number of problems accounted for (N=N <sub>1</sub> ×N <sub>2</sub> =225) | Number of problems wrongly accounted for (N'=225) | Number of problems correctly accounted for (N'=N-N') |
|---------------------|---|---|--|---|--|
| Springs             | 12  | 3.1   | 37   | 2   | 35   |
| Free fall etc.      | 9   | 4.1   | 37   | 2   | 35   |
| Collision           | 12  | 2.0   | 24   | 0   | 24   |
| Circular motion     | 12  | 1.9   | 23   | 1   | 22   |
| Acceleration        | 3   | 5.7   | 17   | 1   | 16   |
| Strings             | 7   | 2.0   | 14   | 0   | 14   |
| Inclined planes     | 5   | 2.2   | 11   | 0   | 11   |
| Balance             | 5   | 2.4   | 12   | 4   | 8  |
| Object only         | 1   | 5.0   | 5  | 0   | 5  |
| Friction            | 3   | 1.7   | 5  | 0   | 5  |
| Second law          | 2   | 2.5   | 5  | 2   | 3  |
| Pulleys             | 1   | 2.0   | 2  | 0   | 2  |
| Balance of energies | 1   | 4.0   | 4  | 2   | 2  |
| Motion of weight    | 1   | 2.0   | 2  | 0   | 2  |

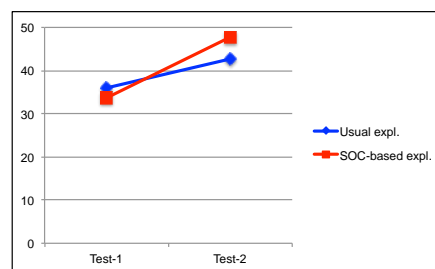


Figure 1. Average scores of tests.

Table 2: Categories in task-2 (usual)

|                        | Number of subjects using category labels (N <sub>1</sub> =7) | Average size of category (N <sub>2</sub> =15) | Number of problems accounted for (N=N <sub>1</sub> ×N <sub>2</sub> =105) | Number of problems wrongly accounted for (N'=105) | Number of problems correctly accounted for (N'=N-N') |
|------------------------|--|---|--|---|--|
| Springs                | 4  | 4.5   | 18   | 0   | 18   |
| Inclined planes        | 4  | 3.3   | 13   | 0   | 13   |
| Balance of forces      | 3  | 3.7   | 11   | 0   | 11   |
| Conservation of energy | 3  | 6.0   | 18   | 9   | 9  |
| Second law             | 3  | 3.7   | 11   | 2   | 9  |
| Pulley and string      | 2  | 3.5   | 7  | 0   | 7  |
| Circular motion        | 4  | 1.5   | 6  | 0   | 6  |
| Pendulum               | 3  | 1.7   | 5  | 0   | 5  |
| Simple harmonic motion | 2  | 2.0   | 4  | 1   | 3  |
| Collision              | 2  | 1.0   | 2  | 0   | 2  |

Table 3: Categories in task-2 (SOC)

|                                   | Number of subjects using category labels (N <sub>1</sub> =8) | Average size of category (N <sub>2</sub> =15) | Number of problems accounted for (N=N <sub>1</sub> ×N <sub>2</sub> =120) | Number of problems wrongly accounted for (N'=120) | Number of problems correctly accounted for (N'=N-N') |
|-----------------------------------|--|---|--|---|--|
| Balance of forces                 | 7  | 4.4   | 31   | 5   | 26   |
| Second law                        | 7  | 3.6   | 25   | 1   | 24   |
| Conservation of energy            | 8  | 4.1   | 33   | 12  | 21   |
| Linear accelerated motion         | 3  | 3.3   | 10   | 2   | 8  |
| Conservation of momentum          | 3  | 1.3   | 4  | 1   | 3  |
| Acceleration                      | 1  | 3   | 3  | 0   | 3  |
| Springs                           | 1  | 3   | 3  | 0   | 3  |
| Pulleys                           | 1  | 3   | 3  | 0   | 3  |
| Simple harmonic motion and period | 2  | 1   | 2  | 0   | 2  |
| String and tension                | 1  | 2   | 2  | 0   | 2  |
| Time                              | 1  | 2   | 2  | 0   | 2  |

## 4. Conclusion

We showed the explanations generated with the SOC framework could promote conceptual understanding through a preliminary experiment. SOC-based explanation generator can provide a basic function for designing various instructional methods (e.g., a detailed explanation is gradually simplified (scaffolding-fading), a sequence of problems is given which promotes spontaneous induction).

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# A Program Transformation Tool for Visualizing Control Structure in Graphical Representations

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**Abstract:** In this paper, we describe a work-in-progress research to develop a program control structure visualization tool for transforming student programs into graphical representations of control structure, including sequences, selections, and iterations. The tool can be used for assisting novice students in debugging their programs by checking whether the transformed control structure of their programs is consistent with their program plans. In addition, the graphical representation of student programs can be compared to that of a model program to detect errors in program plans.

**Keywords:** Computer assisted programming learning, Program transformation, Program visualization, Control structure, Debugging.

## 1. Introduction

Programming involves many complex processes and knowledge, such as designing a program plan, generating program code to realize the program plan, and debugging and fixing the program if errors exist, thus students, particularly novice programmers, may encounter great difficulties (Robin, Rountree, and Rountree, 2003). Teachers and teaching assistants are helpful to diagnose the errors in student programs and to help students fix errors, but it causes heavy workload for teachers and teaching assistants. Some computer automated assessment systems have been developed to assist in assessing student programs (Ala-Mutka, 2005). These systems provide helpful feedbacks by employing two assessment approaches: dynamic assessment and static assessment. Dynamic assessment compiles and executes programs with several test input data to assess functional correctness and efficiency. Static assessment analyzes program code to assess coding style, design, and errors. Program code analysis is complex and difficult because program codes might have many semantic-preserving variations, such as different variable names, different function names, and different statement orders. To improve program code analysis, researchers proposed transforming program codes into semantic graphical representations based on control dependence and data dependence (Li, Pan, Zhang, and Chen, 2010; Wang, Su, Wang, and Ma, 2007; Xu and Chee, 2003). However, these studies hide semantic graphical representations inside the systems and do not visualize graphical representations to assist students in debugging their programs.

Students may have errors in planning and coding, but students might lack of awareness of errors in their programs. Syntax errors in coding can be detected by a program compiler, but it is difficult for students to detect errors in planning and semantic errors in coding. Studies of visualizing control structure of programs revealed that the program visualization, which maps programs to graphical representations, improved students' program comprehensibility and learning (Ben-Ari et al. 2011; Hendrix, Cross, and Maghsoodloo, 2002). In addition, Brusilovsky (1993) suggested that program visualization could be used as a debugging tool for novices. This study presents a work-in-progress prototype system to visualize the control structure of student programs in graphical representations for assisting novice students in debugging their programs.

## 2. The Prototype System and Possible Applications

A prototype system, named ProgramVisualAid, was developed to transform student programs into graphical representations of control structure. A structured program consists of three control structures: sequence, selection, and iteration. Figure 1 displays the graphical representations of a student program, which computes whether a year is a leap year or not. Each node denotes a code and each link indicates a control flow. The representations reveal that the program has three selection structures to check whether the year can be divisible by 4, 100, and 400. The third selection structure is inside the second selection structure and the second selection structure is inside the first selection structure.

The visualization tool can be used as a debugging tool for students. First, students can check whether the transformed control structures of their programs match their program plans or not. If student programs have semantic errors in coding program plans, the transformed control structure will be inconsistent with the plan. For instance, the third selection structure in Figure 1 has two control flow links to separately link two “cout” codes. If the “else” code in the 16<sup>th</sup> line is missed, the graphical representation of the third selection structure will have a control flow link to sequentially link two “cout” codes. Students’ awareness of the inconsistency leads students to fix the error.

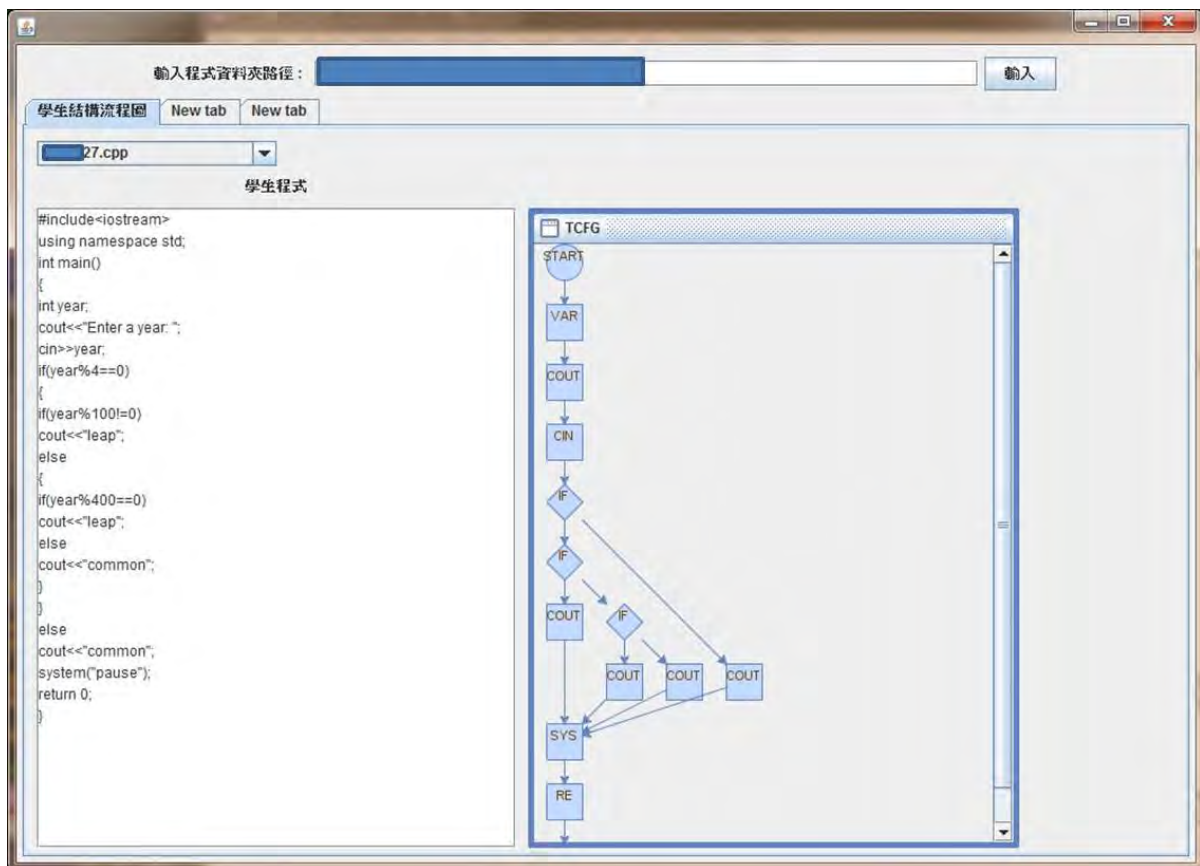


Figure 1. Control Structure Visualization of a Correct Leap Year Program.

Second, graphical representations of student programs can be compared to that of a model program to detect errors in planning. For instance, if the program in Figure 1 is a model program and the program in Figure 2 is a student program, the comparison of graphical representations of these two programs reveals that the student program lacks of a selection structure to check whether the year is divisible by 400 or not. We are implementing a comparison mechanism of comparing graphical representations of two programs to find out the difference of control structures. The difference between a student program and a model program might indicate errors of the student program plan. However, a problem might be solved by many variations of programs. We are also implementing dynamic assessment mechanism, which compiles and executes programs with several test input data to assess functional correctness, to find out more possible model programs. The system will compare a student program to all model programs and adopt the comparison result with the most similar model program.

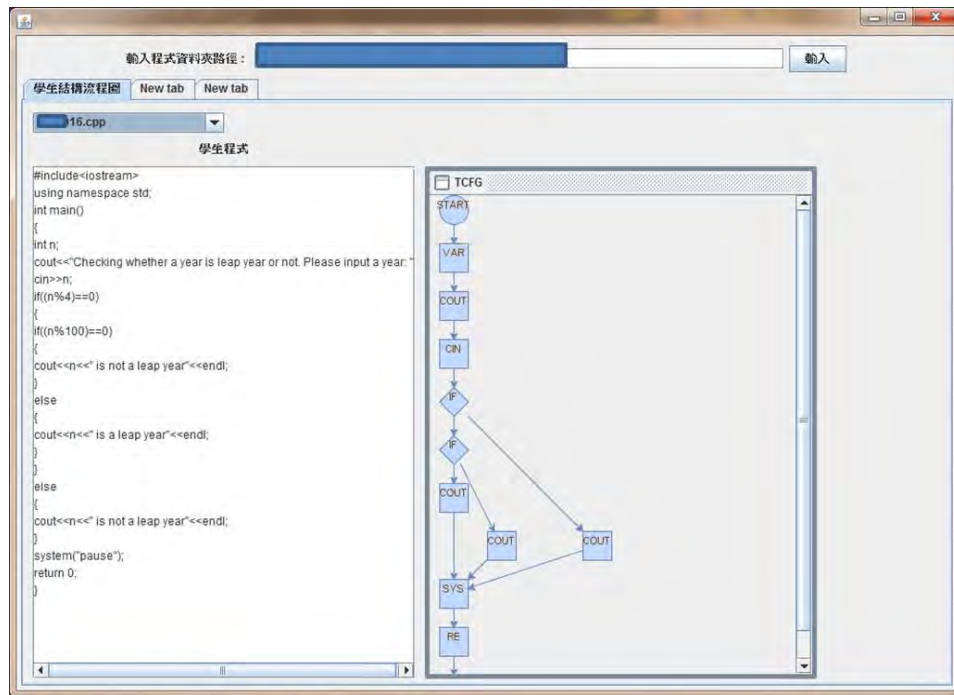


Figure 2. Control Structure Visualization of a Wrong Leap Year Program.

### 3. Summary

This paper presents a work-in-progress research to develop a program visualization tool for transforming student programs into graphical representations of control structure. The tool can be used for assisting students in debugging their programs by checking whether the transformed control structure of their programs is consistent with their program plans. The graphical representations of student programs can be compared to that of a model program to detect errors in program plans. We are developing comparison and more analysis mechanisms to improve the visualization tool.

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# A Students' Mutual Evaluation Method for their Reports using PageRank Algorithm

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**Abstract:** Nowadays, mutual evaluation in education is an available method that students in the learning community use to evaluate each other. The method calculates scores of students' reports by considering who evaluates those reports. In this paper, we propose a student's mutual evaluation method using the PageRank algorithm, an appropriate evaluation method that helps teachers to easily understand whose report is the best from the students' viewpoints. In particular, we perform students' mutual evaluation based on a groupware by utilizing a "Like" function in a course practice. As a result, it was able to not only provide an overall rating from the students' sum of votes but also, by considering who voted, to promote the reliability of the students as evaluators for their mutual evaluation.

**Keywords:** Mutual Evaluation, PageRank Algorithm, Groupware

## 1. Introduction and Motivation

Currently, teachers need to evaluate several student reports after their lectures. Teachers are challenged by not only evaluating reports on multiple topics, but also by a multitude of student viewpoints. Therefore, student reports need to be evaluated from several viewpoints. A great deal of time and effort is required for a fair and multi-faceted evaluation of the reports.

In this paper, we introduce a mutual evaluation method to enable students to evaluate their reports using information technology. In this method, students perform report evaluation instead of the teachers, which produces a positive effect in the students towards education. Therefore, we develop a students' mutual evaluation method using the PageRank algorithm, which provides a graph illustrating which reports received "Like" votes and from whom. During a course, the following steps are followed: 1) Writing reports after lectures, 2) evaluating reports written by other students and voting with a "like" button using the online groupware system; and 3) Receiving votes for their own reports." Therefore, the students obtain the perspective of an evaluator; which promotes their ability of both writing and evaluating reports.

The next section describes a PageRank algorithm and the proposed students' mutual evaluation method. In Section 3, we summarize the results of the students' mutual evaluation method in a course practice. Finally, in Section 4, we conclude this paper with suggestions for future works.

## 2. Students' Mutual Evaluation Method using PageRank Algorithm

### 2.1 PageRank Algorithm

The PageRank algorithm is used by Google Search to rank websites in their search engine results. It is a method of measuring the popularity of webpages. According to website ranking, the PageRank algorithm counts the number and quality of links to a page to determine an estimate of the popularity of the website. A link structure of the Web is shown in Figure 1(1).

- Back link: A page that links to other pages is called the back link of the other pages (e.g., A is a back link of D), which indicates that the back link recommends (is related to) the other pages, and they are important for the back link.



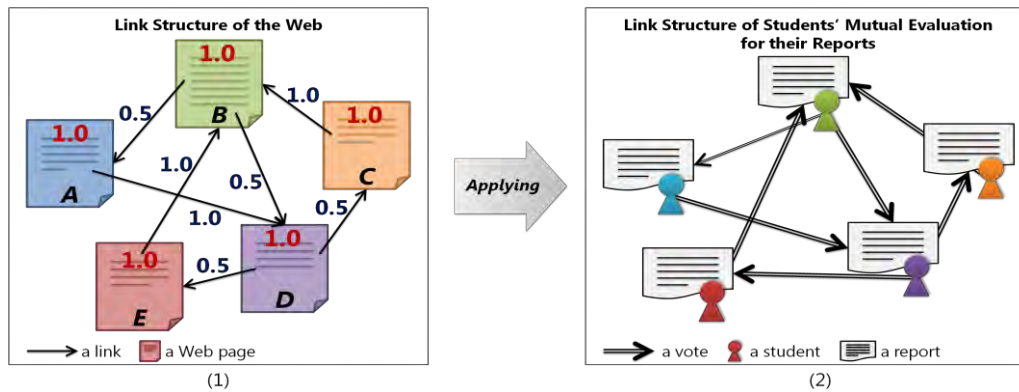


Figure 1. A link structure of the Web applied to Students' Mutual Evaluation

- Forward link: A page that is linked from other pages (back links), is a forward link of the back links (e.g., A is a forward link of B). Then, a page (forward link) has high importance if the sum of the importance of its back links is high.

We calculated the popularity of each page using PageRank as follows (see Figure 1 (1)):

$$PR(u) = (1-d) + d (PR(v_1)/N(v_1) + \dots + PR(v_x)/N(v_x)) \quad (1)$$

- $u$ : a Web page, i.e., A, B, C, D, or E
- $v_1, \dots, v_x$ : the set of  $u$ 's back links, i.e., D's back links,  $v_1$ : A,  $v_2$ : B
- $N(v_x)$ : the number of forward links of page  $v_x$ , i.e.,  $N(B)=2$
- $d$ : a damping factor adjusts the derived value downward. Various studies have tested different damping factors, but it is generally assumed that the damping factor is approximately set as 0.85

Initially, the importance of each page is 1.0, if there are multiple forward links of a page, the importance distributes through each link evenly, e.g., if B has two forward links, A and D, the importance of each link to A and D becomes 0.5. Therefore, B is the most important page in the link structure, since  $PR(B)$  has the highest value.

## 2.2 Students' Mutual Evaluation for their Reports

As depicted in Figure 1, (1) and (2) have the same link structure, and therefore, a back link can be considered as a vote from one student for another student's report. Therefore, in this paper, we are challenged to attempt a students' mutual evaluation of their reports using the PageRank algorithm. In our previous work, we built a system that provides a ranking of Web pages based on the PageRank algorithm by evaluating users who browse the Web pages. In this study, in order to evaluate the students' reports based on their mutual evaluation; we focused on the students who vote on reports.

We conduct students' reports by using a online groupware application; the student can post their reports at anytime and from anywhere in a given period, i.e., after a lecture and before the next lecture. Students can vote on the others' reports by pressing a "Like" button, when they think the report is good. It can reduce the students' burden of evaluating others' reports without specific points.

Using the mutual evaluation method based on PageRank, 1) a report of a student who votes for other students' reports produces a better report himself and 2) a report with many votes raises the reliability of its author's opinion when he casts his own votes. Thus, teachers can easily understand whose report is the best from the students' viewpoints, and we believe that this method can lead to an appropriate evaluation method in education in the future.

## 3. Results of Students' Mutual Evaluation

In this section, we present our findings from the results of the students' mutual evaluation in a course practice. This is a course of Applied Informatics, which consists of 10 lectures on different topics, and 23 students. Using the "Like" function as a vote through a online groupware, 1) we calculated the score of each report based on the sum of the number of "Like" from students; 2) we calculated the score of each report using the number of "Like" by employing a PageRank algorithm, and normalized the score between 0–10.0.

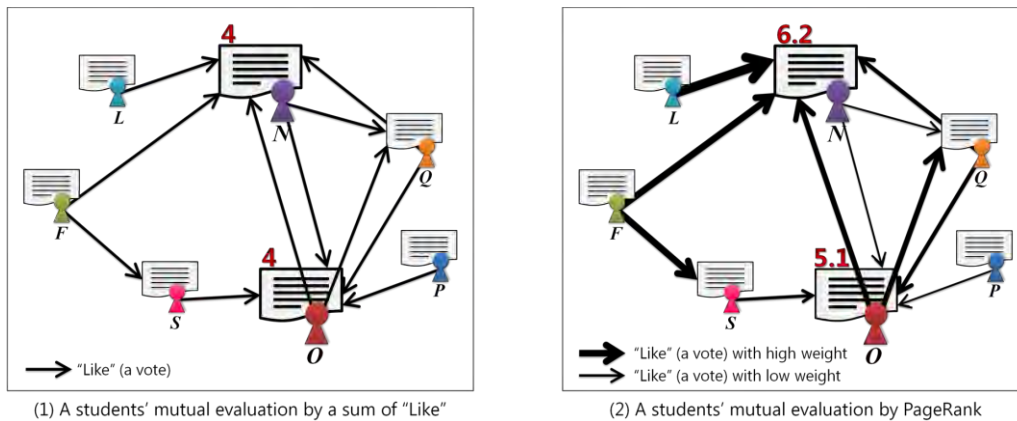


Figure 2. A link structure of the Web applied to Students' Mutual Evaluation

As a result, we determined that the difference of the score of the same report between 1) and 2). As depicted in Figure 2, a report of a student *N* gained four "Likes" from students *F*, *L*, *O*, *Q*, and a report of a student *O* gained four "Like" from students *N*, *P*, *Q*, *S*. The sum of the number of "Like" for the report of *N* and the report of *O* are identical, i.e., 4 (see Figure 2 (1)). However, the score of the report of *N* was 6.2 and the score of the report of *O* was 5.1; they were different due to different weight based on the PageRank, which considers the quality of the evaluators (a thick arrow denotes a high weight) (see Figure 2 (2)). In general, we know that teachers have a higher level of understanding, and their evaluation of student reports is reliable. Therefore, we considered that mutual evaluation becomes more meaningful when using PageRank, since the most reliable votes came from the highest quality students.

#### 4. Conclusions

In this paper, we proposed a group of students' mutual evaluation method for their reports using the PageRank algorithm. In a course practice, students performed a mutual evaluation for their reports by voting for good reports using a "Like" function through an online groupware application. Therefore, it is not only a sum of votes for evaluating the students' reports, but also considering who votes on the reports. It enabled the teachers and the students to understand the criteria for a good report in the education area, and it can lead to a new method of review by mutual evaluation.

In the future, we need to measure inter-rater reliability of our proposed students' mutual evaluation based on the PageRank algorithm by analyzing the correlations between teachers' evaluation and the students' mutual evaluation.

#### Acknowledgements

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# An Ontology to Model E-learning Tools, Events and Experts for their Use in Specific Contexts

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**Abstract:** With the popularization of online repositories and content management systems, digital resources available to organize educational activities proliferate. Digital resources include many different possibilities besides content, like events, people, or hardware devices and software applications. We propose a conceptualization of the educational domain by means of an ontology aimed to comprehensively classify educational resources. This ontology may serve as the foundation of complex knowledge-based systems to assist teachers in the categorization, selection and retrieval of the most suitable resources for any educational activity in any educational scenario they wish to design and implement.

**Keywords:** Educational resources, semantic modeling, ontologies, knowledge engineering

## 1. Introduction

In the context of information science, an ontology is a formal, explicit specification of a shared conceptualization (Gruber, 1995). Ontology construction is one of the tasks associated to semantic modeling, which in turn is aimed to collect the implicit knowledge about the domain (i.e., educational resources). The semantic model will serve as a terminological foundation to explicitly describe, in a way that software applications can process, all the information elements involved. In our case, an ontology for educational resources would provide a shared vocabulary to model the type of educational resources and associated concepts, their properties and relations. With it, we will describe, categorize and classify educational resources, and will provide support for smart tools and personalized services to assist teachers to select the best resources according to the activities they wish to implement.

Once the conceptualization is completed, it has to be encoded in a language for defining ontologies and semantic rules. This encoding is necessary to use the developed semantic model with existing inference engines. We have to encode the ontologic model using a Description Logic-based language (e.g. OWL (McGuinness & van Harmelen, 2004) and the knowledge captured through logic rules using a language supporting Horn-like rules (e.g. SWRL or RIF). In our case, Protégé (Knublauch et al., 2005) has been identified as the most convenient ontology construction tool due to its flexibility versatility, simplicity and availability. A complete version of the ontology in OWL is available at <http://itec.det.uvigo.es/itec/ontology/itec.rdf>, and an ontology navigator including descriptions of all entities can be accessed at <http://itec.det.uvigo.es/itec/ontology/>.

## 2. An Ontology for Educational Resources

We identified three fundamental information groups, namely people, events, and tools. Persons are considered as resources that can be utilized in a classroom to provide added value to the learning process. Besides the teacher, students may have available a rich pool of experts in several areas to provide advice and support. According to this new vision, where persons are also considered resources available to configure learning processes, people characterization goes beyond state-of-the-art people descriptions, and must include all skills, expertise and context about an individual (e.g. fluency in a given language, degree of knowledge of a particular subject, communication tools at his/her disposal, affiliation, etc.).

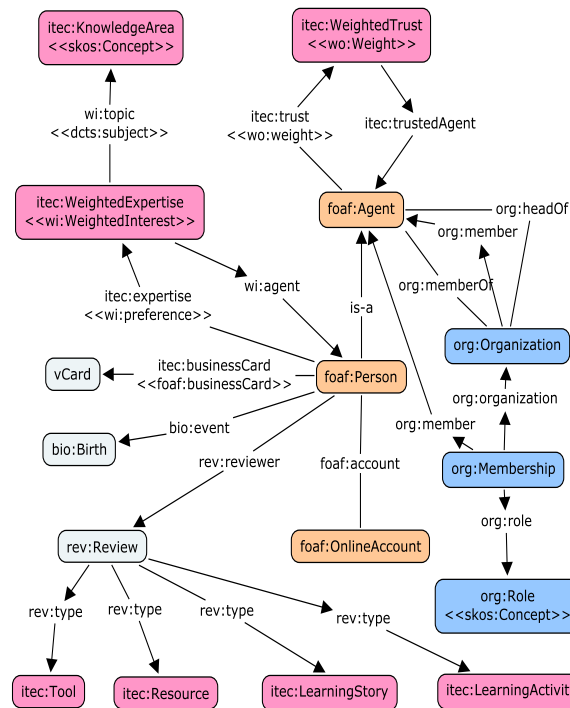


Figure 1. Excerpt of People Conceptualization.

Events should also be considered as relevant resources for the planning of learning activities in any comprehensive conceptualization of educational resources,. An event is a planned activity where participants from several organizations discuss ideas. Workshops, seminars, conferences and virtual meetings are examples of events that may support novel learning activities to improve the educational practice in schools. Event conceptualization should be targeted to model the most relevant features of events, like the type of participants, venue, relevant dates, audience, or specific tools needed to participate.

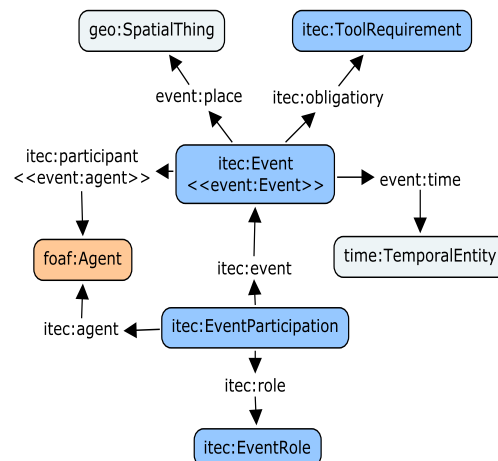


Figure 2. Excerpt of Event Conceptualization.

A key aspect of the actual implementation of learning activities is their technical feasibility, that is, to find out whether a learning activity can be performed in a given school taking into account its functional requirements and the hardware and software tools available there. Thus, the ontology should characterize the set of technological tools available in a school, that is, its technical setting, together with the distinct features of these tools (e.g. technical specifications, functionalities, supported languages, etc.).

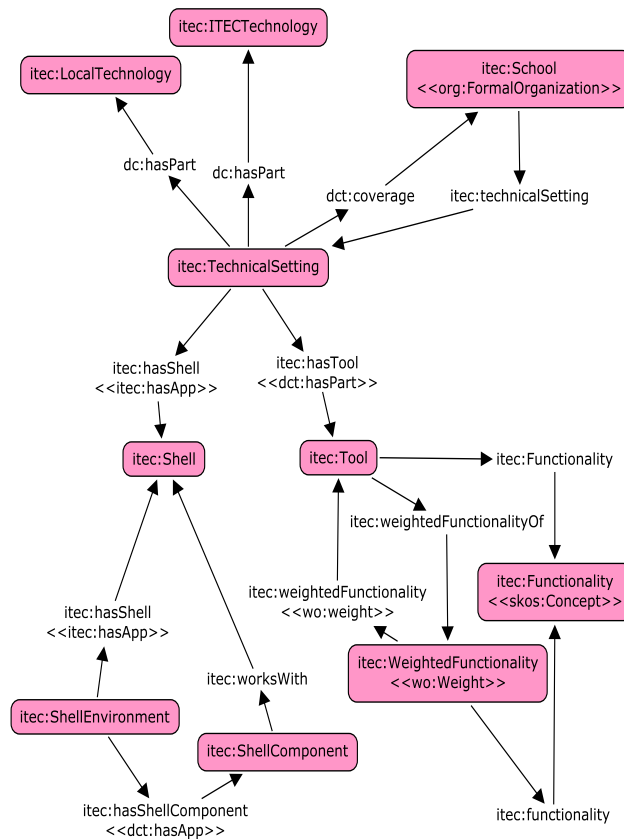


Figure 3. Excerpt of Tool Conceptualization.

### 3. Conclusion

Experts confirmed that most of the ontology does collect concepts and relations from the real world, providing a positive evaluation. However, some elements were identified that were deemed unnecessary for most real world educational scenarios. Several elements (*Trust*, *Expertise*, and the related measurement factors *WeightedTrust* and *WeightedExpertise*) were identified as candidates for removal because they were not considered as relevant. Besides, the data needed for these elements is hard to obtain. Finally, some experts posed some questions on the actual source of some of these pieces of information. Anyway, they were very specific issues that will be assessed once first tests with final users and real working scenarios take place.

### Acknowledgements

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# Capturing Learning Attitudes through Presentation Design Activities

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**Abstract:** This paper describes a unique learning system that cultivates a positive attitude toward learning through presentation design activities. Learners are assigned two tasks: a declarative knowledge task, and a presentation task that involves selecting slides to create a presentation from among a set of slides that is provided. The slides have been prepared so that some of the slides are relevant and support the theme of the presentation while others are redundant or may even contain wrong information. A learner model is presented that captures the attitudes of subjects toward learning as they perform these tasks.

**Keywords:** Meta-Cognition, Presentation Design, Learner Attitudes, Learner Modeling

## 1. Introduction

Our previous study described an approach in which learners are given the task of preparing presentation materials about a particular topic that they have already understood (Seta and Ikeda 2011). We found that by providing a stimulation from the system that prompts learners to reflect back on own learning processes and to acquire domain-specific learning strategies, they achieved (i) tightening of criteria for evaluating own learning processes, (ii) a collaborative meta-learning communications as a way of focusing not on the discussion on attractive appearance of presentation but on ideal learning processes, and (iii) livelier reading between the lines activity touching on things not explicitly mentioned in textbooks.

The learning objective set in this study through presentation design activity is to be aware of the importance of deep understanding, and not mere shallow understanding of a topic in order to produce superior presentations. To achieve this objective, we have developed a learner model to capture their learning attitudes based on which learning-support system prompts learners' awareness on their own learning attitudes by enhancing reflection upon learning activities in pursuing presentation design activity.

## 2. Meta-learning Scheme through Presentation: Slide Selection Approach

Here we basically adopt the meta-learning scheme proposed by Seta et al.. A major difference between the previous study and the approach we adopt here is that, when learners deal with the task of compiling presentation materials, the instructor has pre-edited the slides and loaded them in the system in advance. In other words, the presentation design task does not require the subjects to actually produce the slides, but merely to select from among slides that have been previously prepared, and put them in proper sequence. Learners are faced with three subtasks as they work through the slide design task:

- (2-1) Learners monitor and reveal their own knowledge of the topic described in each slide offered by the system and declare their own knowledge state by selecting from the following three categories: "understand," "do not understand," and "slide is wrong."
- (2-2) Learners formulate a learning plan, and organize their presentations as they proceed with the task by selecting (or not selecting) the offered slides and putting them into order.

(2-3) Learners receive guidance messages provided by the system and reflect upon their learning.

Note that slides loaded into the system include not only slides with correct information, but also slides that are plain wrong and slides lacking any important content for learning about the target domain. Moreover, theoretical back ground of the approach is The Knowledge Monitoring Assessment (KMA), developed by Tobias and Everson, is a well-known instrument for assessing metacognitive monitoring capabilities (Tobias and Everson, 2000). The KMA has students perform two types of problems.

(1) A question is presented, and the learners have to declare whether they can answer correctly or incorrectly.

(2) Candidate answers are presented, and learners choose the appropriate answer.

Type (1) is a comprehension monitoring task, while type (2) is a problem-solving task. Monitoring capability is then measured based on the degree of agreement between the results of types (1) and (2) tasks.

In analyzing the characteristics of learners based on these results, it is apparent that students showing high agreement between the two types of tasks also tend to make a sustained effort to learn, while those exhibiting low agreement between the tasks tend to be lazier with respect to learning and figure higher in the drop-out rate.

### 3. Meta-Model to Construct Learner Models

Here, let us consider the meta-model that forms the foundation for this individual learner model. Table 1 shows a portion of a model capable of inferring metacognitive activity based on declarative knowledge monitoring and slide selection results.

Because the declarative knowledge monitoring and slide selection results reveal the state of a learner's knowledge at two different sequential points in time—that is, before and after the presentation design—this reveals whether a learner with insufficient or mistaken knowledge at the beginning before starting the presentation design project has reconstructed own knowledge through the presentation design task.

Based on this model, we can distinguish four basic types of learners in terms of metacognitive control during the presentation design process using the results of the declarative knowledge monitoring and slide selection:

**MC Learners:** Learners who recognizes through declarative knowledge monitoring tasks or presentation planning activities that "their knowledge is lacking, and correct their understanding by relearning." Learner types (2), (3), (10), and (11) fall into this category, that represents diligent learners who are really serious about learning.

**NonMC Learners:** Learners who recognizes through declarative knowledge monitoring tasks that their knowledge is mistaken or lacking, yet do not address the lack of knowledge in the presentation design activities, and do not make any effort to relearn. Learner types (5) and (8) fit into this category that represents lazy or indolent learners.

**NonExpLStG Learners:** Learners who, even after explaining the topic to another person, this does not trigger awareness that their own knowledge is wrong and they do not pursue relearning. Learner types (6) and (7) fall into this category.

**NonReflective Learners:** Learners who correctly understand learning items, yet have never considered the significance or placed the learning items in the target domain. Type (4) learners fall into this category. These are learners with only modest understanding of how to acquire transferable learning strategies.

Reflecting on these different types of learners, we should be able to generate appropriate advice tailored to each type. We will discuss this matter in another paper.

### 4. Conclusions

**Table 1: Meta-model to Infer Learners' Meta-cognitive Activities through Presentation Design Activities**

| Slide attribute | Declarative Knowledge | Selection Results | Semantic interpretation of declarative results | Semantic interpretation of selection results | Semantic interpretation of metacognitive control  |
|-----------------|-----------------------|-------------------|--|--|---|
| Desirable       | Correct content       | Understand        | M_ ( A )                                       | M: Probably aware of importance              | (1) —   |
|                 |                       |                   | B_ ( A )                                       |  | (2) Based on recognition understanding is lacking, probably correct understanding by relearning.                          |
|                 |                       |                   | Do not understand                              |  |   |
|                 |                       | B_ ( B )          |  |  |   |
|                 |                       | Wrong             | M_ ( C )                                       |  | (3) Recognized own misunderstanding through presentation design activities, probably correct understanding by relearning. |
|                 |                       | B_ ( C )          |  |  |   |
|                 | Do not select         | Understand        | M_ ( A )                                       | M: Lack awareness of importance              | (4) Probably no performing of thinking activity on the importance of a learning topic.                                    |
|                 |                       |                   | B_ ( A )                                       |  | (5) Recognized understanding is lacking, but probably understanding not corrected by relearning.                          |
|                 |                       |                   | Do not understand                              |  |   |
|                 |                       | B_ ( B )          |  |  |   |
|                 |                       | Wrong             | M_ ( C )                                       |  | (6) Not aware of own misunderstanding through presentation design activities, and probably no relearning.                 |
|                 |                       | B_ ( C )          |  |  |   |
| Undesirable     | Wrong content         | Understand        | M_ ( C )                                       | B: Domain knowledge is wrong                 | (7) Not aware of own misunderstanding through presentation design activities, and probably no relearning.                 |
|                 |                       |                   | B_ ( C )                                       |  | (8) Recognized understanding is lacking, but probably performed no relearning.  |
|                 |                       |                   | Do not understand                              |  |   |
|                 |                       | B_ ( B )          |  |  |   |
|                 |                       | Wrong             | M_ ( A )                                       |  | (9) Probably no appropriate efforts during declarative knowledge monitoring.  |
|                 |                       | B_ ( D )          |  |  |   |
|                 | Do not select         | Understand        | M_ ( C )                                       | B: Probably understand correctly             | (10) Recognized own misunderstanding through presentation design activities, probably correct by relearning.              |
|                 |                       |                   | B_ ( C )                                       |  | (11) Relearning based on awareness of misunderstanding, and it probably corrected.  |
|                 |                       |                   | Do not understand                              |  |   |
|                 |                       | B_ ( D )          |  |  |   |
|                 |                       | Wrong             | M_ ( A )                                       |  | (12) —  |
|                 |                       | B_ ( C )          |  |  |   |

B\_ ( A ) : Likely that he understands correctly.

B\_ ( B ) : Likely that he does not understand correctly.

B\_ ( C ) : Domain knowledge is wrong.

M\_ ( A ) : Learner thinks he understands.

M\_ ( B ) : Learner thinks he does not understand.

M\_ ( C ) : Learner does not recognize he is wrong.

Here we have described a learner model that captures learner attitudes based on presentation design activities. Through a declarative knowledge monitoring task we are thus able to partially detect the disparity between the state of the learner's knowledge and the state of the learner's belief, while also capturing the transformation that can be observed through presentation planning activities. In this study we have come up with a novel approach for inferring metacognitive activity of learners by focusing on the transformation of this disparity, then leveraging that information to capture the attitude of subjects toward learning. Building on this approach, we have already developed a scheme for generating advice and guidance based on the learner model described in the paper.

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# Feature Extraction of the Nursing Techniques from Hand Motion Data

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**Abstract:** It is not easy to acquire nursing techniques from lectures only, but research on transforming a tacit knowledge of nursing techniques into a formal knowledge has started recently. In this paper, we analyze the coordinate information of hand motion data in an intravenous injection, and discuss on the possibility of formulating information.

**Keywords:** Nursing techniques, Hand Motion Data, Tacit knowledge, Formal knowledge and Correlation matrix

## 1. Introduction

The knowledge which is hard to express by words is called as a tacit knowledge. On the other hand, the knowledge that can be expressed by text, mathematical expression and figure is called a formal knowledge. In the SECI model of knowledge creation theories (Ikujiro Nonaka & Hirotaka Takeuchi 1995), it is claimed that a tacit knowledge is transformed into a formal knowledge by discussion in an organization. In nursing techniques, tacit knowledge appears in various contexts such as intravenous injection and excretion care (Bowtell, L., Moloney, C., Kist, A.A., Parker, V., Maxwell, A., Reedy, N. 2012). As the study on the inheritance of nursing techniques, for example, the method of using a meta-synthesis of practical examples from prior reports had been proposed (Aya Ueta, et.al 2009).

Recently, the knowledge share system using video data based on SECI model had been innovated in the education of nursing techniques, and it is utilized to transform nursing techniques from a tacit knowledge to a formal knowledge. Moreover, the study to visualize the movement of hand motion during the running of nursing techniques has been starting, and it provides useful information to learner (Majima. Y., Maekawa, Y., Soga, M. 2012). By these recent studies, it can be said that the data including a tacit knowledge concerning nursing techniques are becoming computable by computer.

In this study, we investigated whether the hand motion data includes some tacit knowledge of experts by comparing with the data of learner. In the prosecution of this consideration, we analyzed the hand motion data of two experts and four learners (i.e. 6 testers) by computing correlation matrix of hand motion data. The hand motion data are obtained from 16 location sensors attached at their hand, and one sensor obtains three-dimensional coordinate. To extract the information of experts, we focused attention on the correlation of 16 sensors for each coordinate (i.e. x, y and z coordinate). From the result of data analysis, we could see that there exists important sensor to extract the feature of expert nursing techniques although the number of data is not enough. Furthermore, we proposed the evaluation function to measure the difference between two testers, and showed that the evaluation function could detect the difference between an expert and a learner in the data of this study.

## 2. Data Acquisition System and Hand Motion Data

### 2.1 Method of Data Acquisition

The system to get hand motion data had been developed and is using for the education of nursing techniques (Majima, Y., Maekawa, Y., Soga, M. 2012). In this study, we will analyze the data whose are obtained from this system. The system is LIBERTY 240/16 (POLHEMUS), and it has 16 location sensors. By using this system, we can obtain 240 three dimension coordinate data per second. We fixed 15 (3 sensors \* 5 fingers) sensors at the central outside of a phalange and 1 sensor for measuring the reference position.



Figure 1. The scene of sensor wearing.

In this study, we analyze the hand motion data performing intravenous injections.

## 2.2 Pretreatment of Hand Motion Data

Since the time of intravenous injections differs by tester, the size of hand motion data is unequal. Therefore, we quantized data in the following way. Let  $(x_i, y_i, z_i)$  be the coordinate data of some sensor of the tester  $T_k$  for  $i = 1, 2, \dots, I_k$  and  $k = 1, 2, \dots, 6$ , where  $I_k$  is the number of data,  $T_1, T_2$  are experts and  $T_3, T_4, T_5, T_6$  are learners. Since the data size is different in each tester, we transformed  $I_k$  into 70 and redefined three dimensions coordinate as  $(\hat{x}_j, \hat{y}_j, \hat{z}_j)$  in the following way.

$$\hat{x}_j = \frac{1}{I'} \sum_{i=I'(j-1)+1}^{I'j} x_i, \hat{y}_j = \frac{1}{I'} \sum_{i=I'(j-1)+1}^{I'j} y_i, \hat{z}_j = \frac{1}{I'} \sum_{i=I'(j-1)+1}^{I'j} z_i,$$

where  $I' = \lceil I_k / 70 \rceil + 1$  and  $\lceil x \rceil$  denotes the largest integer not greater than  $x$ .

## 3. Data Analysis and Result

We can express data as three  $70 \times 16$  matrices whose are related to  $x$ ,  $y$  and  $z$  coordinate in each tester. From these data, we analyzed the correlation of 16 sensors in each coordinate  $x$ ,  $y$  and  $z$  by computing 18=(3 sensors  $\times$  6 testers) correlation matrices ( $16 \times 16$  matrix). Then, we obtained the result that only  $y$  coordinate of experts has not correlation with each 16 sensors. Figure 2 is comparison of an expert's correlation matrix and a learner's one. It can be said that this is a big feature of expert's data. Therefore, we may measure the level of nursing techniques by using this feature.

We propose the evaluation function of the level of nursing techniques in the following way. From the above discussion, we had three correlation matrices  $R_{xk}, R_{yk}$  and  $R_{zk}$ . Here,  $R_{xk}, R_{yk}$  and  $R_{zk}$  are correlation matrices of  $x$  coordinate of tester  $T_k$ ,  $y$  coordinate of tester  $T_k$  and  $z$  coordinate of tester  $T_k$ , respectively. Let  $r_{ij}^k$  be  $(i, j)$  element of correlation matrix  $R$  of tester  $T_k$ . We define the count function

$$d(k = k_1, k = k_2) = \frac{1}{16} \mathring{a} \mathring{a} \left| r_{ij}^{k_1} - r_{ij}^{k_2} \right|$$

Then, we got  $d(k = 1, k = 2) < 0.08$ . This means that there is not so much difference between expert's matrices. On the other hand, for  $l = 3, 4, 5, 6$ , we had

$$0.20 \leq d(k = 1, k = k_l), d(k = 2, k = k_l) \leq 0.32.$$

Hence, it may be said that the correlation matrix of hand motion data includes the expert's tacit knowledge, and have possibility that this information can be embedded into the learning system of (Majima, Y., Maekawa, Y., Soga, M. 2012).

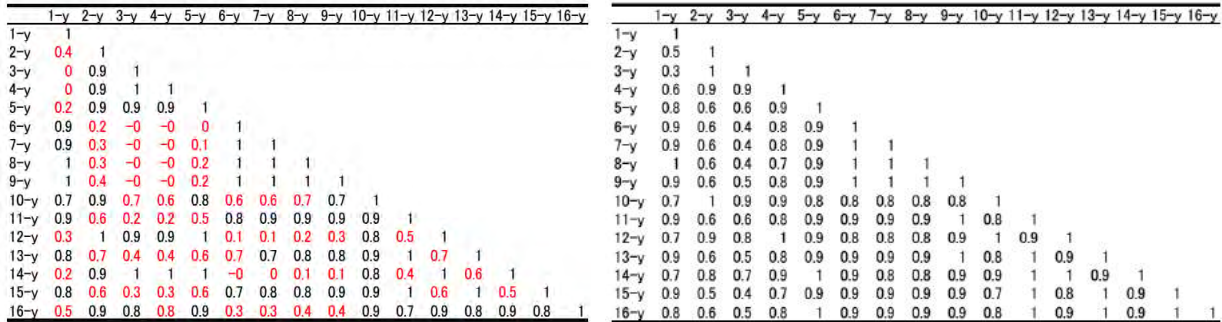


Figure 2. Correlation matrices of an expert's y coordinate (left) and a learner's one (right).

#### 4. Conclusion

In this paper, we analyze the hand motion data during intravenous injections, we clarified that the correlation matrix of some location data may includes a tacit knowledge of nursing techniques. Our future works are the following two things. The one is to collect more data and verify the discussion of this paper, and the other is to develop the learning system based on the result of this paper.

#### Acknowledgements

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# Inquiry-based learning for meta-cognitive training in semantic open learning space

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**Abstract:** This research's objective is to train learners' meta-cognitive skills in self-directed learning of history. Learners use a learning environment that provides support and regulates their learning processes using inquiry-based learning. Learners use the system to learn in an open learning space reinforced with semantic information. All the provided support is generated automatically using this semantic open learning space. The support is provided in the form of inquiry questions generated by the system. These questions are designed to direct learners to new information and trigger history thinking.

**Keywords:** Inquiry Based Learning, Self-directed Learning, Meta-Cognitive Training, History Learning, Question Generation, Semantic Open Learning Space, Adaptive Learning Support

## 1. Introduction

In self-directed learning, learners without the necessary skills have difficulties planning their learning. In an open learning space, such as the Internet, learners can easily become overwhelmed by the quantity of information available. To be able to achieve learning outcomes on the same level as classroom learning, learners need to acquire self-regulation skills.

Learners can be given inquiry in a learning environment, which can be used in a self-directed learning situation. Inquiry-based learning can support learners during self-directed learning by giving them smaller objectives. Giving inquiries to learners also make learners think about what they learned. In history, inquiry is also used in classroom to encourage learners to form an opinion (Husbands, 1996).

We previously proposed a novel learning environment to enhance self-directed learning in the domain of history learning using semantic web techniques (Jouault and Seta, 2013). Our system provides a learning environment to build a concept map while learning, in an open space, about a specified historical period. The originality of our system is that it uses a natural language open learning space (Wikipedia) reinforced by semantic information from two sources, DBpedia and Freebase. This process creates a "semantic open learning space" used by the system. The system can provide content-dependent questions depending on the learner's knowledge level. The generated questions are design to direct learners to new information but also to make them think about what they learned.

In this paper, we discuss the possibility of using our system to enhance meta-cognitive skills in self-directed learning of history. We designed a new version of our system that is not only aimed at improving domain understanding but also improving learners' history learning skills. By implementing inquiry-based learning support into our system, we hope to lastingly improve the learning processes of learners in self-directed learning of history.

## 2. Related Work

To support learners in self-directed learning, systems, such as the Navigation Planning Assistant (Kashihara and Taira, 2009), which provides an environment for describing learners' learning plans and states of understanding to prompt their self-regulation in an open learning space, have been developed. The limitation of this system, however, is that its support is content-independent due to the difficulty in working with natural language information on the Web. Of course, this problem can be overcome by preparing the learning materials in advance. This is the case of the Betty's Brain system (Biswas, Roscoe, Jeong and Sulcer, 2009) which involves using a concept map in learning by teaching environment. However, preparation requires a considerable amount of time even for constructing a

closed learning space. It is not possible to use the same method in an open learning space because there is too much material. In our system, the quality of semantic information is not as good as manually prepared information, but the process can be applied automatically for every concept. Therefore, it can be applied to an open learning space.

In meta-cognitive training using inquiry-based learning, the Web-based Inquiry Science Environment (WISE) (Slotta, 2004), which also provides support in self-directed learning but in the science domain. Learners using WISE gather information to answer a science inquiry. Learners are trained in designing solutions, debating science subjects, and critiquing the resources they learn. However, it requires specialists to prepare all the inquiries. In our system, the use of the semantic open learning space allows us to automatically generate all support.

### 3. Design rationale: Reinforcing inquiry-based learning

We have two objectives with our system:

- A) Reinforce the domain understanding of the subject learned. The system supports learners to help them learn the most important concepts and explore the relation between them.
- B) Reinforce learner skills for self-directed learning of history. The provided support is aimed to help the learner become aware of the important points during the study of an historical period.

Regarding objective A, the system provides support to help learners not only learn history but also understand it. In history learning, an understanding of chronology is necessary. Chronology is defined by Smart (1996) as “the sequencing of events/people in relation to other and existing knowledge of other, already known, events/people”. Learners need, of course, to know events but they also need to understand their context.

Regarding objective B, the system supports the acquisition of two level of awareness:

- Macro level: Inquiry driven self-directed learning process. Learners need to be made aware of the importance of setting objectives in self-directed learning. Learners using the system set an objective every time by choosing a question. Then, they learn from the document to be able to answer the question. Learners will be directly influenced by their choice of objective.
- Micro level: Context-dependent question generation. Learners need to become aware of the importance of asking relevant questions depending on their learning state. All the questions are generated depending on the machine understandable concept map built by the learners. Thus, they can make the connection between their knowledge and the generated questions.

The system, as illustrated in Fig. 1, is composed of four windows:

- Question window (a): the question window displays a list of questions generated by the system.

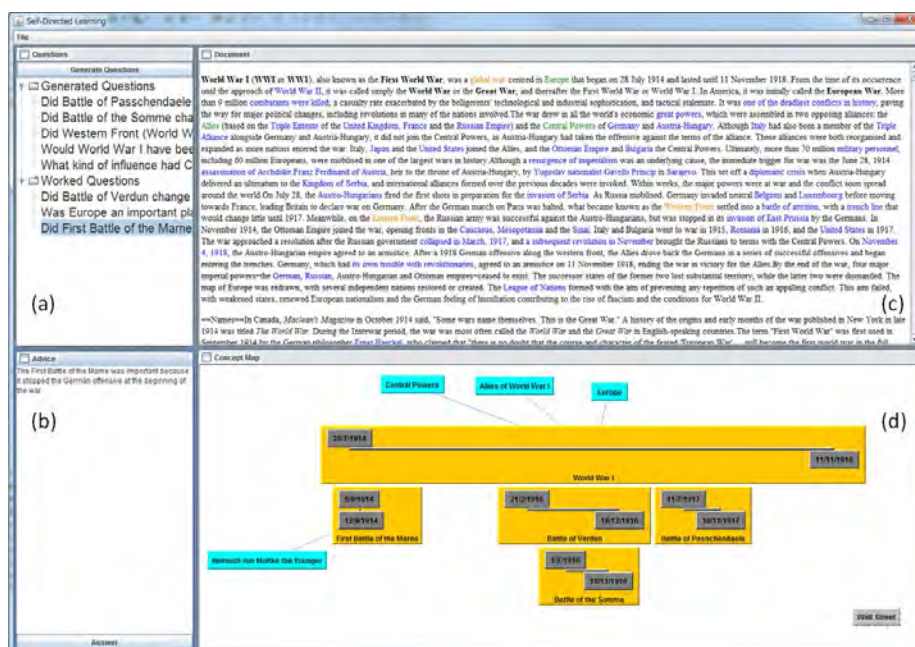


Figure 1. System interface

- Answer window (b): Learners can use this window to answer their active question. They can write their answer in natural language.
- Document window (c): This window displays the document the learner selected. The learner can click on the concepts in the documents to add them to the concept map.
- Concept map window (d): The concept map window is used both to display and manage the concept map. The display of the concept map is built for history learning. The events are organized on a timeline. The learners can also add relations between concepts.

The starting point of learning is the same for all learners: they are provided with the same list of questions. Learners will then build a concept map following what they think the answers to the questions are. Once learners give their answers to the questions, new questions will be generated depending on their concept map. All learners will be directed by the questions to help them correct the weaknesses in their concept map.

To support the acquisition of the macro level of awareness i.e. meta-cognitive training, before learning, learners need to set a learning objective by choosing a question. Then, learners need to gather information to be able to answer the questions. Repeating the process should make learners develop awareness of the importance of inquiry during self-directed learning of history.

The problem in providing good quality training is that the quality of the learning depends on the questions given during this process. According to Riley (2000), a good enquiry question in history should: “capture the interest and imagination of your pupils, place an aspect of historical thinking, concept or process at the forefront of the pupils' minds, result in a tangible, lively, substantial, enjoyable "outcome activity" through which pupils can genuinely answer the enquiry question.” To answer a questions learners should think about what they learned (Husbands, 1996). Generating such questions is possible by using the semantic open learning space.

To support the acquisition of the micro level of awareness, the system generates questions depending on the learner's concept map. Using the semantic information available, the questions will be relevant to the studied subject in most cases. The generated questions use types defined in Graesser's taxonomy (Graesser, Ozuru and Sullins, 2010) which are content-independent. The system uses its own ontology to create links among the questions, concept, and relation types. These natural language patterns are hand written for every concept type.

#### 4. Concluding Remarks

In this paper, we described the additions made to our system to enable meta-cognitive training in self-directed learning of history. Using our semantic open learning space, we are able to automatically generate relevant inquiry questions which are used to train the learners' skills.

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# Learning Method for Understanding Design Policy of Object-oriented Design and its Meta-learning Support System

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**Abstract:** Design pattern is a description of the object-oriented design that gives high-quality and re-usable solutions for frequently occurring problems. A design pattern is formed based on the various experiences of predecessors who made ineffective designs. If students can grasp the design policy of predecessors from the design pattern, they can create good designs and apply them to new problems. The objective of this research is to propose a learning method for understanding design policy of the design pattern and to construct a meta-learning system for proposed learning method.

**Keywords:** design policy, experiential knowledge, meta-learning support system

## 1. Introduction

Design patterns are experiential knowledge for designing better object-oriented programs. They have re-usability and extensibility advantages, so a policy of constructing re-usable and extensible designs in object-oriented designs can be found in the process of forming design patterns. If students can follow the processes of the predecessors who created design patterns, they might learn such good design policy. However, most textbooks of design patterns only describe their definitions and show how to use them (Gamma et al. 1994, & Freeman et al. 2004); since the creation process is not clearly mentioned, students are not able to consider the design policy.

To understand design policy, we believe that following the thinking process of predecessors is effective. The objective of this research is to support students to understand design policy by introducing a new learning method that repeatedly creates ineffective design from the good design and compares effective and ineffective designs under the various conditions. This activity corresponds to the part of the predecessors' processes of creating design patterns to give students a chance to identify good design policy. Some traditional researches give problems that are solved by design patterns and encourage students to create design patterns by themselves (Weiss 2010 & Pillay 2010). This approach is effective if students can derive design patterns by themselves. However, many have difficulty creating them from scratch. Therefore, in our approach, a program based on a design pattern (*design pattern program*) is given and students transform the given program into an inappropriate one (*alternative solution*). Then they compare the design pattern programs and the alternative solutions for a new problem (*extended problem*), which is an extended problem of the original one. By repeating this process and considering the alternative solutions with several different extended problems, the design pattern's design policy can be experientially acquired.

## 2. Approach

When encountering a problem, predecessors created various solutions by trial-and-error and evaluated the quality of their solutions based on how much they need to be modified based on extended problems. During the trial-and-error process, good solutions are selected based on the predecessors' criteria and the final solution becomes a design pattern. Special structures in each design pattern, such as the types of classes and their relations, reflect design policy. Therefore, to replace the special structure in the design pattern program with another structure that can perform the same behavior may lead students to consider the following questions and to learn the design policy of predecessors.

- What special structure is embedded in the design pattern program?
- What kinds of problems can be solved by the design pattern?



Figure 1 illustrates our learning method for understanding design policy. From the given design pattern program, students create alternative solutions. The inappropriateness of the alternative solutions and the effects of the design pattern program are evaluated under the extended problems.

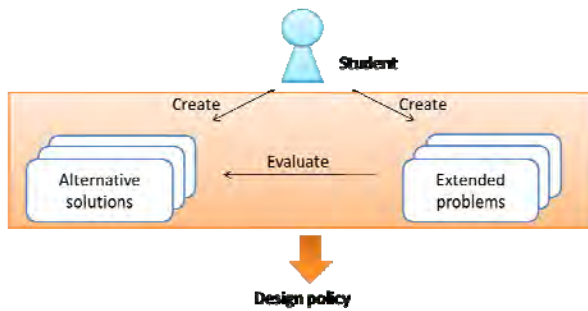


Fig. 1 Method for learning design policy

which supports the creation of alternative solutions from the given design pattern program, holds several alternative solutions as expected answers. It examines the alternative solutions created by students and leads them to derive expected answers. On the other hand, the solution evaluation sub-system gives an example of extended problems so that students can evaluate the qualities of the design pattern program and the alternative solutions. This sub-system is invoked immediately after students have created alternative solutions in the alternative solution creation sub-system. Extended problems are given as multiple-choice questions (Table 1) that ask the part of the programs that should be modified under the extended problems. These questions themselves promote the students' activities of considering the design policy.

Table 1 Example of extended problem for Adapter pattern

|   |
|---|
| <p><b>[Extension of problem]</b> Change the <i>Adaptee</i> class with <i>methodA</i> to <i>Adaptee2</i> class with <i>methodB</i>. Consider which parts you need to modify in both class diagrams.</p> <p><b>[Answer]</b> You only need to [ 1 ] [ 2 ] in class [ 3 ] for a design pattern program, but you have to [ 4 ] [ 5 ] in class [ 6 ] for an alternative solution.</p> <p><b>[Choices for each blank]</b></p> <p>1, 4: Type of modification: change, add, or eliminate</p> <p>2, 5: Target of change, e. g., names of the method, the instance, or the constructor</p> <p>3, 6: Name of existing class</p> |
|---|

### 3. Alternative Solution Creation Sub-system

The alternative solution creation sub-system provides a supporting environment for creating alternative solutions from the given design pattern program. Since its structure in the object-oriented design can be illustrated by a class diagram, our system gives the design pattern program as a class diagram and provides an interface in which the given class diagram can be changed (Fig. 2). The given class diagram is shown on the class diagram display unit. The class diagram can be edited by inputting the class name or the relation name or selecting the class or the relation to remove from the class diagram edit unit. When the re-illustration button is pushed, the class diagram that satisfies the inputted classes and relations is depicted in the class diagram display unit.

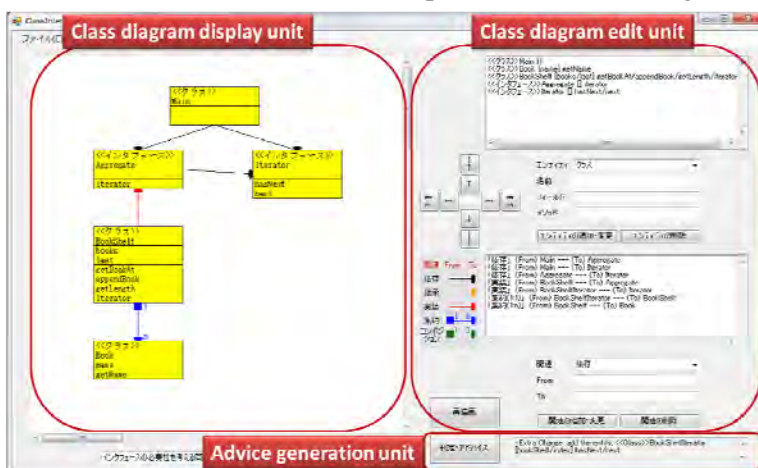


Fig. 2 Interface of alternative solution creation sub-system

relations is depicted in the class diagram display unit.

The system holds the class diagrams of the expected alternative solutions and evaluates those created by students. If a student's class diagram does not match its alternative solutions, advice is generated in the advice generation unit that indicates the differences of the entities or the relations from the expected alternative solution.

#### 4. Solution Evaluation Sub-system

After a student successfully creates one of the expected alternative solutions, the solution evaluation sub-system starts. It displays two windows. One show the extended problem, which consists of problem and answer sentences with blanks and lists of answer choices (Fig. 2). Students need to select one choice for each blank from the list. The other window illustrates the class diagrams of the design pattern program and alternative solutions created by students (Fig. 3). This window is used for comparing the quality of the design pattern program and the alternative solution under the given extended problem. Students can invoke edit windows for freely changing these class diagrams. In addition, by clicking on the classes in the class diagrams, the programs of the classes are displayed.

The system holds the extended problem answers. When students push the answer button, it evaluates the answer and gives advice, if necessary. Currently, three kinds of advice are prepared. Since it is effective to create class diagrams that are modified based on the extended problem, the first piece of advice explains how to modify the class diagrams. The advice is shown in the advice generation unit in Fig. 3. If students are still not able to derive the answer, the system indicates the part of the program that should be changed under the extended problem as the next piece of advice. If students are not able to answer correctly based on the second bit of advice, the system provides text that points out the incorrect choices and explains how to select the right choice

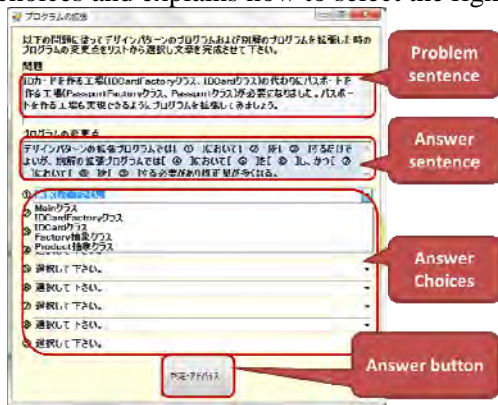


Fig. 2 Window displaying extended problem

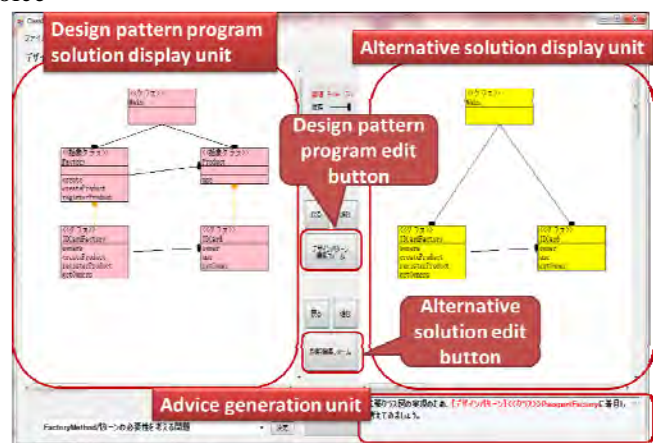


Fig. 3 Window showing class diagrams of design pattern program and alternative solution

#### 5. Conclusion

In this research, we proposed a learning method to acquire design policy by redesigning a design pattern program to reach alternative solutions. In addition, we constructed a meta-learning system in which students can learn the proposed learning method. The alternative solution creation sub-system supports the creation of alternative solutions from the design pattern program. On the other hand, the solution evaluation sub-system supports the evaluation of alternative solutions and the design pattern program by providing extended problems.

In the current system, extended problems are given by the solution evaluation sub-system. However, knowing how to extend the original problem is also important for evaluating designs. The ability to create appropriate extended problems is also worth supporting. Therefore, in future work, we need to extend our system to support trial-and-error activities not only to create alternative solutions but also to derive appropriate extended problems.

#### Acknowledgements

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# Question Type Analysis for Question-Answering Applications in Education

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**Abstract:** In this paper, we present a question-answering (QA) system as a virtual tutor for students in the 5th and 6th grades. Students ask questions and the QA system gives answers to their questions based on a knowledge base. Teaching materials for history and geography are considered as a knowledge source. Because question log is not available in developing QA systems, multiple choice questions (MCQs) in the learning and testing materials are regarded as a training corpus to learn question types, answer types and keywords for retrieval, where an MCQ consists of a stem and a set of options. Options from the same MCQ are grouped into a cluster. Clusters with common elements are merged into a larger cluster. A cluster is labelled with a nominal element selected from the corresponding stems. We also mine question patterns from the stems for question type analysis in the QA system. Because the questions created by instructors in MCQs and the questions asked by students may be different, we develop a procedure to collect possible questions from students in the 6th grade. In the experiments, we first evaluate the question type classification systems using the MCQ corpus and the student corpus with 5-fold cross validation, respectively. Then we train question type classifiers with the complete MCQ corpus, and test them on the student corpus. The student's and the instructor's questions are compared and analyzed.

**Keywords:** Computer-assisted learning, question-answering systems, student intent analysis, text mining

## 1. Introduction

QA system can be introduced to the education domain for collaborative learning, online education and distance learning (Wang et al., 2006; Wen et al., 2012). In this paper, we focus on developing QA applications in education as virtual tutors. Students can post questions anytime anywhere after class, and computer-assisted learning systems response answers to their questions.

A typical question answering system is composed of question type analysis, query formulation, passage retrieval, and answer extraction (Ravichandran and Hovy, 2002). Question type analysis, which aims to understand users' intents, provides important clues for the latter tasks. The clues include the question part referencing to the answer, terms indicating the type of entities being asked for, and a classification of the question into some broad types (Lally et al., 2012). Query log which keeps users' information needs provide some prior knowledge for question type analysis, but it is not always available for all the application domains.

This paper utilizes multiple choice questions (MCQs) in learning and testing materials to mine question patterns to support QA systems in education domain. Section 2 specifies an instructors' MCQ corpus and a students' question corpus used in this study. Their question type distributions are shown and discussed. Section 3 evaluates the question type classifiers with these two corpora. Section 4 concludes the remarks.

## 2. Question Corpora Used in This Study

### 2.1 Instructors' Multiple Choice Questions (MCQ) Corpus

Question type, answer type, and the keywords to retrieve potential passages containing answers are three major elements in a question. An MCQ corpus based on the learning and testing materials is used to mine the important information. An MCQ consist of a stem and 4 options. The stem describes the questions to be asked and the options list the possible answers. The following shows an example.

*What sea area separates Taiwan and South Korea? (a) Bashi Channel (b) East China Sea (c) South China Sea (d) Taiwan Strait*

In this example, the trigger for the question type is “*what*”; the trigger for the answer type is “*sea area*”; and the keyword for retrieval contains the predicate “*separate*” and the related arguments.

We aim to mine entities, entity type, question type, and the relation among entities from MCQs in the teaching materials. A mining algorithm is shown below.

- (1) Collect initial clusters from the options in the same MCQ.
- (2) Merge clusters with common elements into a larger cluster.
- (3) Partition stems in MCQs based on the clusters derived from (2).
- (4) Assign a label to each cluster with nominal keywords in the stems.
- (5) Find the question patterns for each cluster.
- (6) Extract the relations among entities.

### 2.2 Students' Questions Corpus

The users of the proposed question-answering system are students in the 5th and 6th grades. In this study, we would like to know how children formulate their questions, and the effects of fuzzy questions and incomplete questions on students' question type analysis and question-answering.

Sample topics about history or geography are given first, and then three different methods are proposed to guide students to formulate questions. Method 1, which rewrites the given sentences from declarative to interrogative, is the simplest way. Method 2, which keeps the same answer, but presents different views, is more complex. Method 3, whose answer is different from the original topic, is the most complex. The following lists an example.

**Sample Topic:** Zheng Chenggong led his troops across the sea to Taiwan, expelled the Dutch, and made Taiwan to be a base for rebelling Qing dynasty and rebuilding Ming dynasty.

**Method 1:** Please change the above declarative sentence into an interrogative sentence whose answer is “Zheng Chenggong”, e.g., “Who expelled the Dutch who occupied Taiwan?”

**Method 2:** Please list questions whose answer is “Zheng Chenggong”, e.g., “Who was called Koxinga?”

**Method 3:** Please list questions related to “Zheng Chenggong” and their answers, e.g., “Where did Zheng Chenggong land Taiwan?”

### 2.3 Corpus Annotation and Comparison

There are 11 common question types including (T1) people, (T2) event, (T3) time, (T4) location, (T5) object, (T6) quantity, (T7) application, (T8) theory, (T9) reason, (T10) nickname, and (T11) language. We label a question type for each question. Table 1 lists the distribution of the 11 types in the MCQ corpus (M) and the student corpus (S). These two corpora contain 593 and 395 instances, respectively. The top 5 types in the MCQ corpus are location (45.36%), object (12.48%), theory (11.80%), reason (9.28%) and people (7.92%). They occupy 86.84% of instances. Comparatively, the top 5 types in the student corpus are location (23.04%), time (21.77%), object (17.97%), people (16.46%) and event (8.61%). They cover 87.85% of instances. Location is the most interesting type in the two corpora. Object and people types are also interesting to instructors and students. Surprisingly, only 0.84% of the instances are related to event type in the MCQ corpus. In contrast, 8.61% of students' questions related to this type. Similarly, 11.80% of instructors' questions touch on theory, but only 1.01% of students' questions belong to this type. It may be because this type of questions is difficult to be formulated by students. In both corpora, quantity, nickname and language are the three minority types.

Table 1: Distribution of question types in the two experimental corpora.

|   | (T1)  | (T2) | (T3)  | (T4)  | (T5)  | (T6) | (T7) | (T8)  | (T9) | (T10) | (T11) |
|---|-------|------|-------|-------|-------|------|------|-------|------|-------|-------|
| M | 47    | 5    | 30    | 269   | 74    | 9    | 31   | 70    | 55   | 1     | 2     |
| % | 7.92  | 0.84 | 5.06  | 45.36 | 12.48 | 1.52 | 5.23 | 11.80 | 9.28 | 0.17  | 0.34  |
| S | 65    | 34   | 86    | 91    | 71    | 3    | 10   | 4     | 23   | 1     | 7     |
| % | 16.46 | 8.61 | 21.77 | 23.04 | 17.97 | 0.76 | 2.53 | 1.01  | 5.82 | 0.25  | 1.77  |

### 3. Question Type Analysis

In the first set of experiments, we train and test the question type classifiers by 5-fold cross validation with the MCQ corpus and the student corpus, respectively. In the second set of experiments, we train the question type classifiers with the complete MCQ corpus, and test it with the student corpus. L2-regularized L2-loss support vector classification in LIBSVM (Chang and Lin, 2011) is adopted. Two sets of features are explored. The first contains triggers for question types, triggers for answer types and the relation keywords. The second contains bigrams and trigrams features. All the features are binary. Table 2 lists the accuracies of the proposed classifiers. Using triggers and relation keywords is better than using 2-grams and 3-grams in all the evaluation experiments. The classification performance in 5-fold cross validation on the student corpus with the triggers and relation keyword approach is better than that in 5-fold cross validation on the MCQ corpus. There are performance drops from cross validation on the MCQ corpus to testing on the student corpus.

Table 2: Accuracies of the proposed question type classifiers.

|   | Triggers and relation keyword | 2-grams and 3-grams |
|---|-------------------------------|---------------------|
| 5-fold cross validation on the MCQ corpus     | 0.7707                        | 0.7673              |
| 5-fold cross validation on the student corpus | 0.8608                        | 0.7468              |
| Test on the student corpus                    | 0.5848                        | 0.4734              |

### 4. Conclusion

To understand how children formulate their questions, we design a procedure to collect students' questions and analyze the qualities of the questions. We found that 155 of 683 students' questions, i.e., 22.69%, contain some incomplete, vague, ambiguous or erroneous information to QA systems. The experimental results show that the classification system using triggers and relation keywords achieves accuracies 0.7707 and 0.8608 when 5-fold cross validation on the MCQ corpus and the student corpus are adopted, respectively. The system trained with the MCQ corpus and tested on the student corpus has accuracy 0.5848.

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# Revealing Students' Thinking Process in Problem-Posing Exercises: Analysis of First Sentence Selection

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**Abstract:** We have developed a computer-based learning environment called MONSAKUN to realize learning by problem-posing, where students pose arithmetical word problems by selecting and arranging several sentence cards. As the next step of MONSAKUN development, we analyze the sentence selection process which is considered to reflect students' thinking process. In the first step of analysis, we focused on first sentence selection. We found that the selection approach changed based on different type of story and students' exercise experience. This result is an important step towards building elaborate process model of problem-posing and adaptive support of the process.

**Keywords:** Arithmetical word problems, learning analytics, problem posing, reverse thinking problem, sentence integration

## 1. Introduction

Problem posing practice, one of the central themes in mathematics education, involves the generation of new problems in addition to solving pre-formulated problems (English, 1998). In learning by problem posing, one of the most important issues is the way to assess and give feedback to posed problems. In traditional problem posing method, teachers and students were faced with difficulties to conduct the learning activities effectively. It is not easy for students to pose mathematically correct problems in a given time, and teachers were having problems to assess and give feedback to the wide variation of problems that students pose. The inefficiency of time and available method made problem posing activity less attractive for most mathematics educators.

In order to realize learning by problem-posing in a practical way, we have been investigating a computer-based learning environment to assess and give feedback to problems posed by students (Hirashima et al., 2007). The software, named MONSAKUN (means "Problem-posing Boy" in Japanese), provides an interactive support for learning arithmetical word problems solved by one operation of addition/subtraction. The practical use of MONSAKUN at several elementary schools has been reported in previous studies (Hirashima et al., 2007; Yamamoto et al., 2013).

In this study, we examine how learners pose arithmetical word problems as sentence integration on MONSAKUN. Our assumption is learners do not choose sentence cards randomly - they arrange sentence cards based on some sort of thinking. In the analysis, as the first step toward analyzing problem-posing activity, we especially focus on what kind of sentence card was firstly selected by the learners in different types of story.

## 2. Analysis of First Sentence Selection from MONSAKUN Log Data

### 2.1 Modeling of Problem Posing Activity in MONSAKUN

The interface of an assignment in MONSAKUN is shown in Figure 1. A learner is provided with a set of sentence cards and a numerical expression, and then he/she is required to pose an arithmetical word problem using the numerical expression by selecting and arranging appropriate cards.

While it is difficult to trace thinking process in a free problem posing activity, we can trace learners' card selection in MONSAKUN which can be considered to reflect their thinking process. Learner's assignment is to choose appropriate cards from several sentence cards provided by the system in order to fill the requirement of numerical expression and story type.

In MONSAKUN, problem posing can be considered as combinatorial search of sentences. Figure 2 illustrate a search space of problem posing in a MONSAKUN assignment which provides six sentence cards. This search space is a tree structure of combination of cards. Here, the root is the starting point and the numbers represent identifiers of cards. For example, the starting point is empty and the combination of cards 1, 2 and 3 indicates the correct answer at the top left. The links between nodes represent possible paths that learners can follow in selecting cards during their problem posing activity.

Bold links in Figure 2 represent links actually followed by learners in a particular assignment. This indicates that not all paths were followed by learners. From this fact, there is a possibility that learners choose combination of cards based on some sort of thinking processes. The goal of this study is to investigate tendencies of students to choose cards. Especially, this study pays attention to the first card that learners select at the start of each assignment.

## 2.2 Change of Approach through the Problem Posing Activity

In this research, the analysis of MONSAKUN log data from an experiment of MONSAKUN used by eleven undergraduate students from Faculty of Education is reported. We analyzed the subjects' log data in assignments at Level 1 (lowest difficulty) and Level 5 (highest difficulty) which require the subjects to pose forward-thinking problems and reverse-thinking problems, respectively. Both levels consist of 12 assignments and four story types: combination, increase, decrease, and comparison.

The sentence cards in MONSAKUN contain different number according to the given assignment. Here, cards are distinguished by the order of numbers in the required calculation expression. For example, in an assignment "Make a story problem about "How many are the difference" that can be solved by  $7 - 3 = \_$ ", where the required calculation is " $7 - 3 = \_$ "; a card contains the first number (7) is called "first number card". Similarly, a card contains the second number (3) or the third number (blank) is called "second number card" or "third number card", respectively.

From the analysis, we found that the proportion of each sentence card to be selected firstly is entirely not even. In Level 1, the percentage of first, second, and third number card being firstly selected are 91.8%, 3.3% and 4.9%, respectively. However, in Level 5, the percentage changed to 58.7%, 16.5% and 24.8%, respectively. We found that there is a bias against first selected card, which shows our assumption that the subjects did not choose a card randomly, but with some sort of approach. Furthermore, there is a different trend between Level 1 and 5. We presume that this difference between Level 1 and Level 5 appeared because subjects had different approach to pose either forward-thinking or reverse-thinking problems.

Table 1 shows the characteristics of first selected card from each assignment at Level 5 that has marginal or significant difference in number of selection from the average. These results were

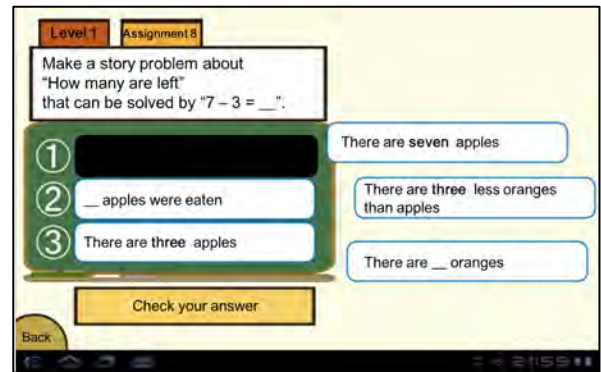


Figure 1. Interface of MONSAKUN

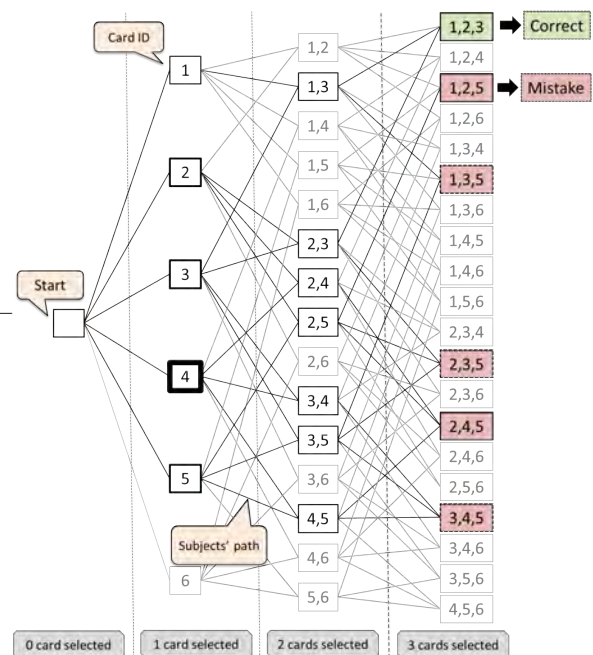


Figure 2. Illustration of a search space in a MONSAKUN assignment

analyzed with binomial test to the amount of each card being firstly selected or not in each assignment. Binomial test is an exact test of the statistical significance of deviations from a theoretically expected distribution of observations into two categories. Based on our assumption that students posed problems by selecting cards through a thinking process, we expect the distribution of first selected cards to have a significant difference in comparison with other cards.

Table 1. Result of binomial test of first selected card in Level 5 assignments

| Assignment Number | Type of story      | Order of assignment | Type of first selected card | Type of sentence | p-value               |    |
|-------------------|--------------------|---------------------|-----------------------------|------------------|-----------------------|----|
| 1                 | <b>Combination</b> | 1 <sup>st</sup>     | First number card           | Existence        | $7.05 \times 10^{-5}$ | ** |
| 2                 |                    | 2 <sup>nd</sup>     | First number card           | Relational       | $1.88 \times 10^{-7}$ | ** |
| 3                 |                    | 3 <sup>rd</sup>     | First number card           | Relational       | $1.97 \times 10^{-3}$ | ** |
| 4                 | <b>Increase</b>    | 1 <sup>st</sup>     | First number card           | Existence        | $1.89 \times 10^{-5}$ | ** |
| 5                 |                    | 2 <sup>nd</sup>     | Second number card          | Existence        | 0.0504                | +  |
| 6                 |                    | 3 <sup>rd</sup>     | First number card           | Existence        | 0.0504                | +  |
| 7                 | <b>Decrease</b>    | 1 <sup>st</sup>     | First number card           | Existence        | $2.35 \times 10^{-4}$ | ** |
| 8                 |                    | 2 <sup>nd</sup>     | Second number card          | Existence        | $2.35 \times 10^{-4}$ | ** |
| 9                 |                    | 3 <sup>rd</sup>     | Second number card          | Existence        | $2.35 \times 10^{-4}$ | ** |
| 10                | <b>Comparison</b>  | 1 <sup>st</sup>     | -                           | -                | -                     |    |
| 11                |                    | 2 <sup>nd</sup>     | Third number card           | Relational       | 0.0266                | *  |
| 12                |                    | 3 <sup>rd</sup>     | Third number card           | Relational       | 0.0266                | *  |

\*\* : significant difference ( $p < .01$ ), \* : significant difference ( $p < .05$ ), + : marginal difference ( $p < .1$ )

Subjects are firstly given simple forward-thinking problems to pose at Level 1 of MONSAKUN. Here, we found that they first simply selected an existence sentence card with the first number in the required calculation expression, and then proceeded to choose other appropriate cards. This approach worked well for Level 1. When subjects arrived at Level 5 Assignment 1, they initially approached the assignment with the same way of thinking. However, this did not work well, and they tend to make more mistakes than in the previous levels. We presumed that the subjects were aware that the previous approach did not work for reverse-thinking problems, because as seen in Table 1, in Level 5 Assignment 2 they selected different type of card, which is a relational sentence card containing first number. In a similar way, subjects changed their approach from the first order of assignment in a type of story to the second and third order of assignment in the same story type.

This leads to two findings about changes in subjects' way of thinking through the exercises. The first one is that subjects change their approach to pose problems after they had experienced posing the same story type. The next finding is that the change of approach depends on the story type.

These changes of thinking approach seem to bring a good effect, because in comparison to the first order of assignment in a story type, the average of steps and mistakes in the second and third order of assignments of the same story type are mostly decreased.

### 3. Concluding Remarks

In this research, we have conducted analysis of MONSAKUN log data of university students to investigate their thinking process in problem-posing activity. We found that depending on type of story and subjects' exercise experience, they selected different first sentence card. These findings proved our assumption that users of MONSAKUN did not chose sentence cards randomly, but with some sort of thinking process.

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# Towards an Evaluation Service for Adaptive Learning Systems

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**Abstract:** This paper presents a service that supports the evaluation of adaptive learning systems. This evaluation service has been developed for and tested with an adaptive digital libraries system created in the CUTLURA project. Based on these experiences an approach is outlined, how it can be used in a similar way to evaluate the features and aspects of adaptive learning systems. Following the layered evaluation approach, qualities are defined that are evaluated individually. The evaluation service supports the whole evaluation process, which includes modelling the qualities to be evaluated, data collection, and automatic reports based on data analysis. Multi-modal data collection facilitates continuous and non-continuous, as well as invasive and non-invasive evaluation.

**Keywords:** Evaluation service, layered evaluation, adaptive learning systems

## 1. Introduction

Evaluation is an important task, because it reveals relevant information about the quality of the technology for all stakeholders and decision makers. It involves collecting and analysing information about the user's activities and the software's characteristics and outcomes. Its purpose is to make judgments about the benefits of a technology, to improve its effectiveness, and to inform programming decisions (Patton, 1990). The evaluation process can be broken down into three key phases: (1) Planning, (2) collecting, and (3) analysing (Cook, 2002). However, conducting evaluations is usually a time consuming task. Besides planning and data collection, it requires a lot of time to analyse the collected evaluation data. Including log data in the evaluation further increases the evaluation task and also makes it more complex. In order to address these aspects needed for a sound and systematic evaluation and to reduce workload for the evaluator, a holistic conceptual and technical approach has been created and based on that the evaluation service Equalia has been developed (Nussbaumer et al., 2012). This approach and the developed service has been tried out and tested in the context of the digital library project CULTURA (<http://cultura-project.eu/>). This paper suggests that this approach and service can also be applied to evaluate adaptive learning systems.

## 2. Evaluation Approach and Conceptual Design

In order to evaluate adaptive learning systems, Brusilovsky et al. (2004) propose a layered evaluation approach. Instead of evaluating a learning system as a whole, they suggest to evaluate the core components, which are user modelling and the adaptation decision making. This approach has been extended in the GRAPPLE project, where also other aspects are evaluated, for example usability, user acceptance, and adaptation quality (Steiner et al. 2012). A similar approach has been applied on the digital library system CULTURA that serves as an adaptive information system for historians. Relevant qualities have been defined and evaluated individually including usability, user acceptance, adaptation quality, visualization quality, and content usefulness (Steiner et al., 2013). Though applied in digital libraries, these aspects are also relevant in adaptive learning systems.

The general goal of the evaluation service is to support the whole evaluation process, consisting of planning the evaluation, carrying out the evaluation, as well as analysing the data and creating reports

(Fig. 1). The evaluation model is the core part of the conceptual approach. It allows for explicitly modelling what and how should be evaluated. Therefore, the evaluation model formally represents the evaluation approach and thus represents the evaluator’s expertise. It consists of two parts. First, the quality model is an abstract model that defines what should be evaluated. It defines evaluation aspects (such usability (Brooke, 1996), user acceptance (Davis et al., 1989), or recommendation quality), which express the qualities of a system including its content. Second, the survey model defines the items for measuring these quality aspects. Items might be concrete questions, but can also be specifications, how tracking data covers the user’s behaviour (for example, how often a user follows a recommendation).

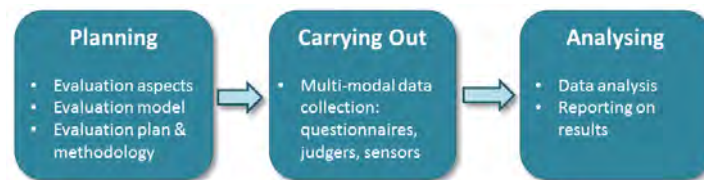


Figure 1: Evaluation Process as supported by the Equalia evaluation service.

The data collection approach consists of two main aspects. First, the data collection instruments are based on the evaluation model and thus related to system qualities that should be evaluated. Second, three different types of instruments are defined (questionnaires, sensors, judgets) that allow data collection on different dimensions, namely invasive and non-invasive, as well as continuous and non-continuous data collection. Questionnaires are the traditional way of capturing data about the user's opinion. A different way of collecting evaluation data is realised with judgets, which are little widgets integrated in the system to be evaluated where users can give immediate feedback (e.g. ratings). Software sensors are instruments that establish a continuous and non-invasive evaluation method. Sensors are not visible to the users, but monitor and log the interaction and usage behaviour, and collect evaluation data in this way.

An important feature of the evaluation system is the generation of automatic reports from the collected evaluation data on the basis of the underlying evaluation model. A report is made upon a survey model by aggregating all participants’ data related to the respective survey model. The data from different sources (questionnaire, judgets, sensors) are compared according their relations to quality aspects. Thus overall scores for each quality are calculated.

### 3. Application in Adaptive Learning Environments

In order to apply this approach and the Equalia service in adaptive learning environments, the most important step is to identify which qualities should be evaluated and how the measurement can be accomplished. Beside the aforementioned qualities, such as usability, usefulness, and content quality, in typical adaptive learning systems, the qualities outlined in Tab. 1 are of specific interest:

| Quality Name           | Explanation  | Measurement  |
|------------------------|--|--|
| recommendation quality | how well are learning resources recommended to the learner   | (1) ask the learner about appropriateness; (2) track how often learners follow a rec. resource     |
| visualisation quality  | how useful are visualisations for the learner                | (1) ask learner about usefulness of vis. (2) track how often learner uses a visualisation          |
| collaboration quality  | how good is the collaborative support to interact with peers | (1) ask learner about benefit of coll. mechanisms; (2) track how often learner uses coll. features |

Table 1: Possible evaluation qualities and measurement methods in adaptive learning systems.

Integration with an adaptive learning system is easy, because the Equalia service is an independent Web service that can be loosely coupled with the system to be evaluated (Fig 2). It exposes a REST interface to collect evaluation data from different sources. Judgets and sensors have to be integrated in the adaptive learning system capturing the user's opinion and monitoring the user's system interactions and sending them to Equalia. Furthermore, Equalia provides a Web interface for creating and managing the evaluation models, for generating questionnaires, and for creating evaluation reports.

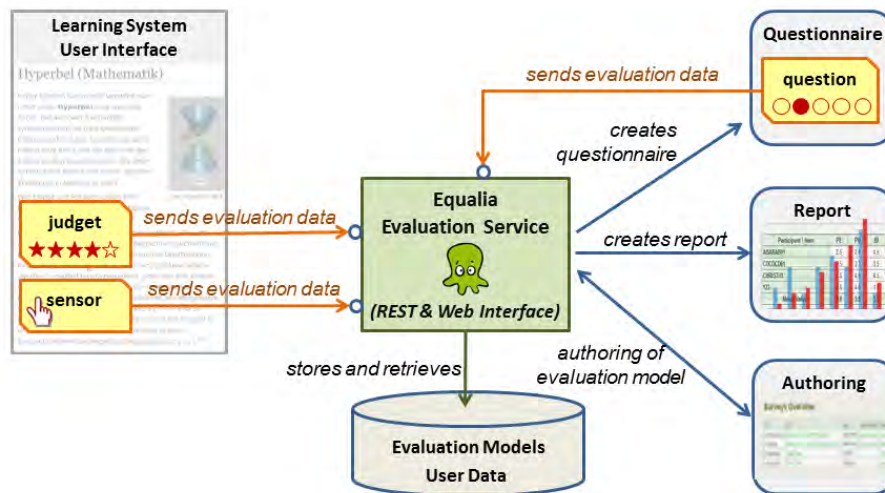


Figure 2: Integration architecture of Equalia with an adaptive learning system.

#### 4. Conclusion and Outlook

This paper presented the evaluation service Equalia that can be used to support the evaluation of adaptive learning systems. Based on the experiences made with this service to evaluate an adaptive digital libraries system, we propose to use it in a similar way for adaptive learning systems. The most important necessary steps include the identification of the qualities to be evaluated, the injection of judget and sensor code (functionality) in the system to be evaluated, and the authoring of the survey model (questionnaires, judget questions, interaction behaviour). Then the evaluation can be conducted more or less automatically.

#### Acknowledgements

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# A Shareable Whiteboard System for Distance Collaborative Learning which Enables Instruction for Multiple Groups of Students

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**Abstract:** In order to help collaborative learning with multiple groups of students participating over a network, we developed a shareable whiteboard system that allows a teacher to observe multiple groups simultaneously and provide instruction to specific groups directly. Through an analysis of log files and video recordings, obtained from an experimental lesson, we investigated the effectiveness of the proposed system. Based on these records and a questionnaire survey, we found the proposed system to facilitate the implementation of collaborative learning over a network.

**Keywords:** Computer-Supported Collaborative Learning, Distance Learning, Collaborative Learning, Shareable Whiteboard

## 1. Introduction

Collaborative learning—based on the premise of communication among students—is a method of knowledge acquisition that is more effective than conventional learning methods by teacher centered didactic teaching. Therefore, collaborative learning is currently being actively implemented in various educational institutions (e.g., Sugimoto *et al.*, 2002; Kaneko *et al.*, 2007). In addition, collaborative learning using a whiteboard, which is one form of collaborative learning, is expected to facilitate discussions and develop students' imaginations, because students can discuss their ideas using graphics (Obata, 1998; Kobayashi, 2002). Therefore, many past studies have attempted to implement distance collaborative learning using a whiteboard through a network (e.g., Gall and Hauck, 1997). However, there remain several problems that must be solved if we are to successfully implement collaborative learning using a whiteboard through a network.

In order to perform effective collaborative learning, it requires that multiple students participate in the collaborative learning activities. Typically, for these activities, students are divided into multiple groups. When learning begins, the teacher, who oversees the collaborative learning process, needs to simultaneously observe the activities of multiple groups of students and must grasp the progress of each group. Conventional collaborative learning is implemented in one location itself, and the teacher can move among the different groups of students; in this situation, it is not difficult for a teacher to watch the students' learning. However, distance collaborative learning is implemented over a network, in different locations; therefore, it is more difficult to observe multiple groups simultaneously. In addition, teachers may need to intervene in students' activities, either instructing them or imparting advice to specific groups or all groups, as required.

In order to overcome these problems, Koga *et al.* (2002) developed a system by which students can exchange their opinions using text chat and a drawing editor; using this, the teacher is also able to observe the students' learning processes. However, in this system, it was difficult for teachers to observe multiple groups of students simultaneously, since the teachers had to run as many client systems as there were groups. On the other hand, Matsuuchi *et al.* (2010) developed the TERAKOYA learning system according to which the teacher can share his/her screen with the students using an electronic blackboard. Through this system, the teacher was able to intervene in the students' activities. However, this system was not developed for collaborative learning with multiple groups.

In order to achieve an effective collaborative learning system with multiple groups of students over a network, in this study, we developed a shareable whiteboard system using which the teacher could observe multiple groups simultaneously and provide instruction to students. In this paper, we describe the results of an experimental lesson conducted using the proposed system.

## 2. Intended collaborative learning styles and requirements

### 2.1 Collaborative learning

The type of collaborative learning targeted in this study is that which can be implemented from remote locations over a network. Students will be divided into multiple groups, and during the learning process, they will draw their ideas on a whiteboard, which will be arranged for each group. Students belonging to the same group will share the ideas they have drawn on the whiteboard. Moreover, they will be able to modify their drawn ideas by exchanging opinions. Then, as a group, they will arrive at a single idea.

The learning activities are aimed not only at knowledge acquisition in a given subject but also at the development of the skills of idea creation and communication.

### 2.2 System requirements

The system proposed in this study aims to help collaborative learning with multiple students from different locations over a network. Therefore, one of the requirements of the system is that it should be able to divide students into small groups. The system should also be equipped such that students can draw their ideas on the whiteboard; the drawn ideas should then be shared among members of the same group, and the students should be able to exchange opinions regarding these shared ideas.

With regard to the teacher, the system should enable him/her to observe multiple groups simultaneously and provide instruction to each or all groups. We determined that a total of 36 students (6 groups  $\times$  6 students) would be using the proposed system at the same time, which is the maximum number of students one teacher can instruct, based on the premise that the proposed system will be used for higher education.

## 3. Related studies

We surveyed related studies that aimed at collaborative learning using a shareable whiteboard. We also surveyed previous studies that had used shareable whiteboard systems not only for collaborative learning but also for electronic meetings.

As stated above, Koga *et al.* (2002) developed a collaborative learning support tool for use in distance learning. According to their system, learners can use a drawing editor and text chats to exchange ideas. On the other hand, the teacher can observe and monitor the activities of the learners according to a learning process model that prepared by the teacher beforehand. However, the drawback to this system was that it was difficult to use with multiple groups. Matsuuchi *et al.* (2010) developed the TERA KOYA learning system, a support system for interactive teaching using a shareable whiteboard. This system can transmit pictures and figures drawn by a teacher onto the screens of students' PCs, and the students can make notes on this screen. In addition, the teacher can even write on the students' screens directly. However, this system does not support a collaborative learning scenario that involves multiple groups of students; further, with the TERA KOYA learning system, students cannot hold discussions with others, view each other's screens, or write on their screens. Ito *et al.* (2003) proposed a support system for cooperative working. It allows students to draw pictures on a whiteboard and view texts as the object of the whiteboard linking to the pictures. This system also has a function to output a log in which texts and pictures are recorded along timeline so that students can reflect on their activities after a lesson. However, this system is also not intended to be used for a collaborative learning environment that involves multiple groups. Moreover, this system is not equipped with the function of allowing teachers to intervene in their students' activities for the purpose of delivering instruction. Suzuki *et al.* (2013) developed "edutab," a support system for remote teaching. This system targets for the teaching of the Japanese language in elementary schools. Using this system, a teacher can display texts and pictures on

students' client systems, and students can write on the screens of their clients. The teacher can view the screens of multiple clients at one time and write on the screen of any client, when needed. However, since this system was not designed for collaborative learning, it is not equipped for communication among students. Roseman *et al.* (1996) developed a groupware tool called "TeamRoom." This tool creates virtual rooms in which users can hold meetings from remote locations. Users can also display pictures and text messages and can write on their screens. However, since this tool was not intended to use for the educational purpose, it does not have functions to observe students' activities can be observed across multiple virtual rooms.

#### 4. A system for collaborative learning among multiple groups

##### 4.1 Framework of the proposed system

In order to implement collaborative learning for multiple groups over a network, we are proposing the following system with a shareable whiteboard. Figure 1 shows the framework of the proposing system.

In order to allow a teacher to instruct multiple students in collaborative learning with a shareable whiteboard over a network, our system consists of three sub-systems: (1) a client system for students, which has a whiteboard with multiple pages that students can use for learning; (2) a client system for the teacher, which the teacher can use to observe and instruct students; (3) a server system, using which the teacher and students' client systems communicate with others. We show each sub-system below.

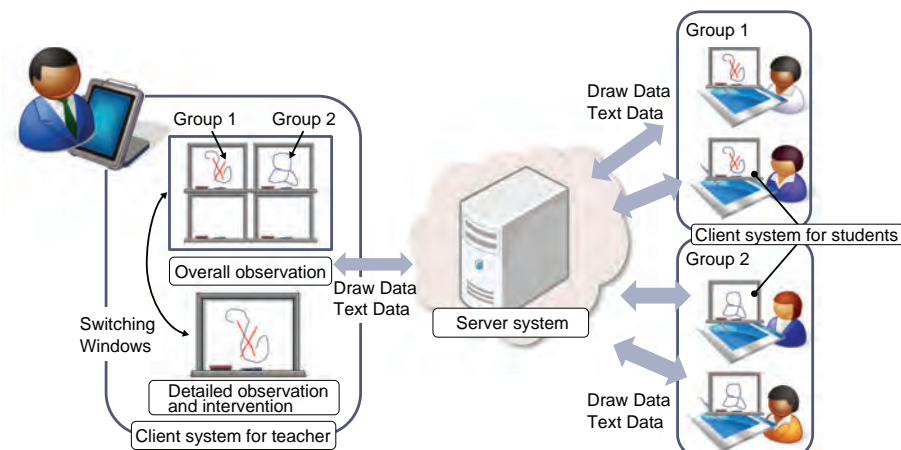


Figure 1. Framework of the proposed system

##### 4.2 A client system for students

The client system for students is equipped with functions for a shareable whiteboard, text chat, and the facility to call the teacher. Figure 2 shows a screenshot of the client system for students, which runs on Microsoft Windows system.



Figure 2. Client system for students

A shareable whiteboard is requisite for students to discuss ideas with members of the same group. Members of the same group share their content on the whiteboard by drawing in the whiteboard area of the client system using specified colors and thicknesses. In addition, the whiteboard has multiple pages that can be turned by clicking on the forward and back buttons. Although the content on each page is shared among members of the same group, as previously described, each page can also be used as a personal space that students can draw on if other members of the group do not use this space. Students of the same group use the text chat function to exchange opinions. Messages—which are inputted by a student into the text box at the lower right-hand side of the client system—are displayed on screens of the other members. Moreover, this chat display can also contain messages from the teacher and other system messages. To distinguish between messages, they are categorized according to color. Therefore, in this system, the teacher can accurately observe and watch the students’ learning progress. However, in the case of too many groups, the teacher will not always be able to gather detailed information on the progress of all the groups. If the students have questions to ask the teacher, they can click on the “teacher icon” at the upper right-hand side of the client.

### 4.3 A client system for teachers

In collaborative learning, it is important for the teacher to provide appropriate instruction to the students; therefore, our client system had the following functions for teachers: the teacher can (1) observe multiple groups of students simultaneously (overall observation); (2) observe individual groups in detail (detailed observation); (3) intervene in the whiteboards of arbitrary groups; (4) manage the members of all groups.

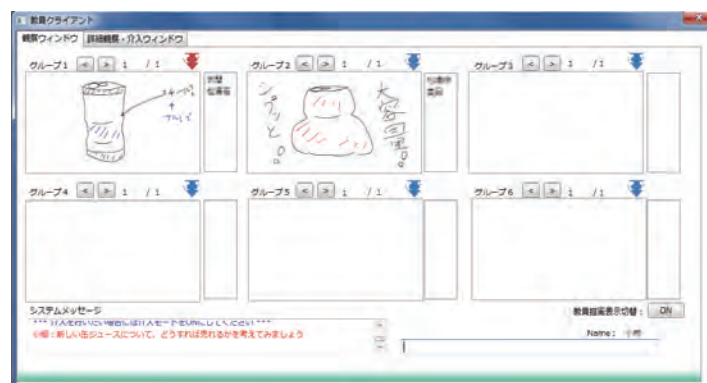


Figure 3. Client system for teachers: an interface for overall observation

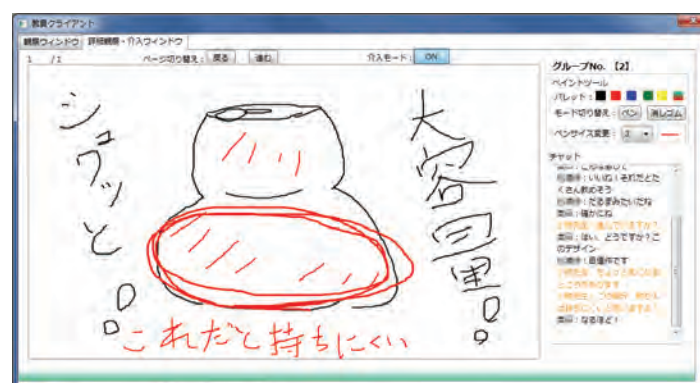


Figure 4. Client system for teachers: an interface for detailed observation and intervention

Figure 3 shows the teacher’s interface for viewing multiple groups at the same time (overall observation). As shown in this image, the teacher can observe multiple groups simultaneously by looking at small-sized versions of all the groups’ whiteboards in one window. Moreover, the teacher can observe by turning the pages of the whiteboard when there are students who draw on different pages.

The functions for detailed observation and intervention, as shown in Figure 4, enable the teacher to observe a full-scale whiteboard and chat display that are not displayed in the “overall observation” window. The teacher can also provide instruction to students by writing directly on the whiteboard or in

the chat boxes, as necessary. Moreover, if the teacher wants to select one particular group to impart instruction, he/she can click on the reduced-size whiteboard for that group. The management function allows the teacher to manually divide students into groups.

## 5. The experiment

In order to investigate whether collaborative learning can be implemented using our proposed system, we conducted an experimental lesson.

### 5.1 The experimental lesson and evaluation methodology

The duration of the experimental lesson was set to 100 minutes, with an interval of 10 minutes between the first and second halves, which were 45 minutes each. The participants comprised five Japanese undergraduate or graduate students in their 20s, with experience in operating PCs. The role of the teacher was played by one of the five participants, who had taken a course in teacher training. The remaining four participants played the role of the students. Taking into consideration the environment suitable for collaborative learning over a network, the participants were assigned to separate rooms to avoid interference, as shown Table 1. A screen separated participants who happened to be placed in the same room. In addition, we made the participants use earphones. To allow students to converse with members of the same group, we set up their PCs with Skype before the experiment. Therefore, students were able to communicate with members of their group through three modes: text chat, the whiteboard of the proposed system, and Skype. To allow the teacher to conduct lessons, we also configured the students' PCs with Ustream, which would deliver video streaming from the teacher. We also equipped the teacher's PC with Skype, in case it was required. Therefore, the teacher could use four modes of communication by which to intervene in the students' activities: text chat; the whiteboard, equipped with the detailed observation function; Skype; and Ustream, which was used for the simultaneous distribution of information. We explained our proposed system to the participants and conducted a trial session in order to make any necessary adjustments to the system before the actual experiment could begin. The entire experiment was recorded by video.

Table 1: Arrangement of rooms and participant grouping

| Participants   | Teacher | Student A | Student B | Student C | Student D |
|----------------|---------|-----------|-----------|-----------|-----------|
| Assigned Group | —       | Group 1   |           | Group 2   |           |
| Room           | Room 1  | Room 2    | Room 3    | Room 2    | Room 3    |

The subject of the experimental lesson was “an examination of new package designs for drinks.” We planned the experiment with the aim of enabling students to understand that cooperation with other members of the same group is essential by giving them the goal of building a one design; students had to realize this goal by sharing information with each other voluntarily, using the predetermined channels. In order to promote its activities, we confirmed whether the teacher was able to observe the students' activities and provide support. The first 30 minutes of the experiment consisted of the teacher's

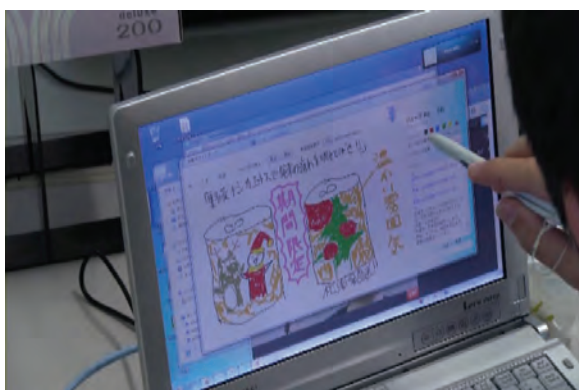


Figure 5. A student using the proposed system

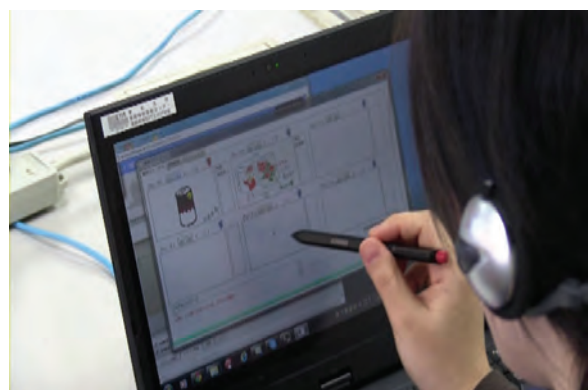


Figure 6. The teacher using the proposed system



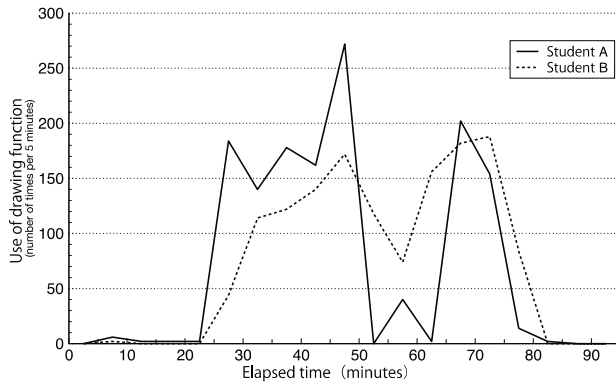


Figure 7. Changes in the use of the drawing function in Group 1

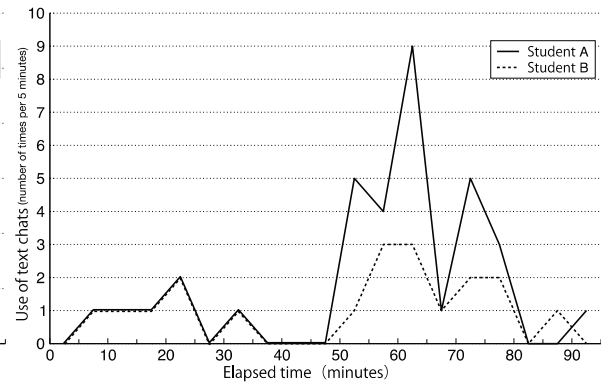


Figure 8. Changes in the use of text chats in Group 1

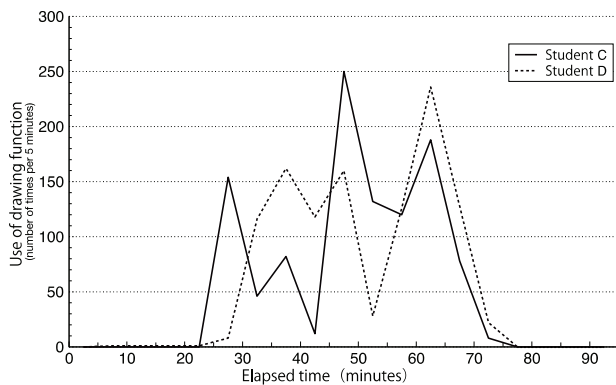


Figure 9. Changes in the use of the drawing function in Group 2

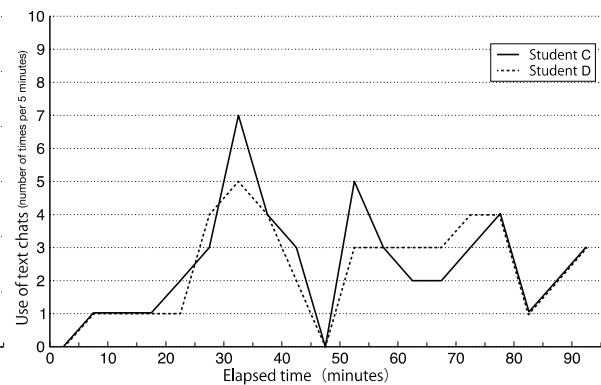


Figure 10. Changes in the use of text chats in Group 2

explanation of premise knowledge for the subject over Ustream. In the next 15 minutes, the students had to draw their ideas on the whiteboard. In the second half of the experimental lesson, 35 minutes were assigned to the students for discussions and for organizing their ideas to arrive at one final idea for the group. In the final 10 minutes, the teacher provided comments and feedback to each group over Ustream. Figure 5 and 6 are pictures of the participants using the system.

In order to evaluate the proposed system, we distributed a questionnaire after the experiment and identified different types of behavior exhibited by the participants at varying times during the experiment by comparing log files with the video recordings. The questions in the questionnaire were based on the following categories (for students): whether the students used the proposed system as a communication tool; whether the students were conscious of the teacher's presence at all times; (for the teacher) whether the teacher could support the students' learning progress by using the functions of overall observation, detailed observation, and intervention; and whether the teacher could impart teaching smoothly. The questions in the questionnaire had a five-point evaluation as well as multiple-choice options; participants were also requested to insert free descriptions.

## 5.2 Results and evaluation

### 5.2.1 Behavior of the participants

We analyzed the participant's use of the proposed system by checking the logs of the drawing function and the text chats for each group and comparing these with the video recording.

#### (1) Behavior of the students

Figure 7 and 8 show the changes in the number of text chats and the use of the drawing function in Group 1 every 5 minutes. In Group 1, there was an inverse relationship between the number of text chats and the use of the drawing function: there was a decrease in text chats and a corresponding increase in the use of the drawing function.

For example, there was a rapid increase in the number of text chats between 50 and 55 minutes, as shown in Figure 8. From the recorded video, we found that at 43 minutes and 42 seconds, the teacher instructed each group over Ustream to begin their discussions; at 50 minutes and 07 seconds, Student A from Group 1 requested to start discussions with Student B, and they started their discussion. We believe this to be the reason behind the decreased use of text chats.

Figure 9 and 10 show the changes in the use of text chats and the drawing function in Group 2. Unlike the case with Group 1, in Group 2, both the drawing function and text chats were used at the same time, as seen from these figures; we believe that in this group, the students were drawing their ideas on the whiteboard while simultaneously engaging in a discussion via text chat. However, between 45 and 50 minutes, the use of text chats, which thus far had been used continuously, suddenly disappeared and was replaced by an increased use in the drawing function. We believe this was because at 43 minutes and 01 seconds, Student C from Group 2 proposed a concrete design to Student D, and in response, both the students started drawing on the whiteboard.

Although the students had the option of communicating within the group using Skype voice calls, none of the students used this medium; they exclusively used text chats and the whiteboard for communication.

## (2) Behavior of the teacher

We analyzed how the teacher observed the learning activities of multiple groups. Figure 11 depicts a graph of the duration at which the teacher observed each group in detail or intervened in the activities of those groups.

In this experiment, the teacher began to use the proposed system after 9 minutes and 44 seconds. Therefore, we recorded the durations at which the teacher observed each group in detail after 10 minutes from the start of the experimental lesson. In the following 10 minutes, the teacher requested the students for the use of text chats in response to the teacher's lesson; the teacher also checked the students' text messages while switching between groups frequently.

Figure 11 shows that the highest duration of time that the teacher observed each group in detail was between 30 and 45 minutes. From the recorded video, we found that the teacher spent more time observing Group 2 from minutes 30–35 and spent more time observing Group 1 from the minutes 40–45. From the recorded video, we noticed that the teacher was checking to ensure the success of each group while simultaneously checking the text chat logs. We also believe that the teacher observed each group in detail for a longer duration, because the number of ideas being drawn on the whiteboard was increasing toward the end of the first half of the lesson.

From the recorded video, we could see that the teacher called for a break for less than 10 minutes, from 40 minutes and 45 seconds to 50 minutes and 08 seconds. Therefore, at the elapsed time of 45–50 minutes, the teacher observed each group in detail for less than 50 seconds. On the other hand, the students continued their learning activities even though the teacher was not virtually present.

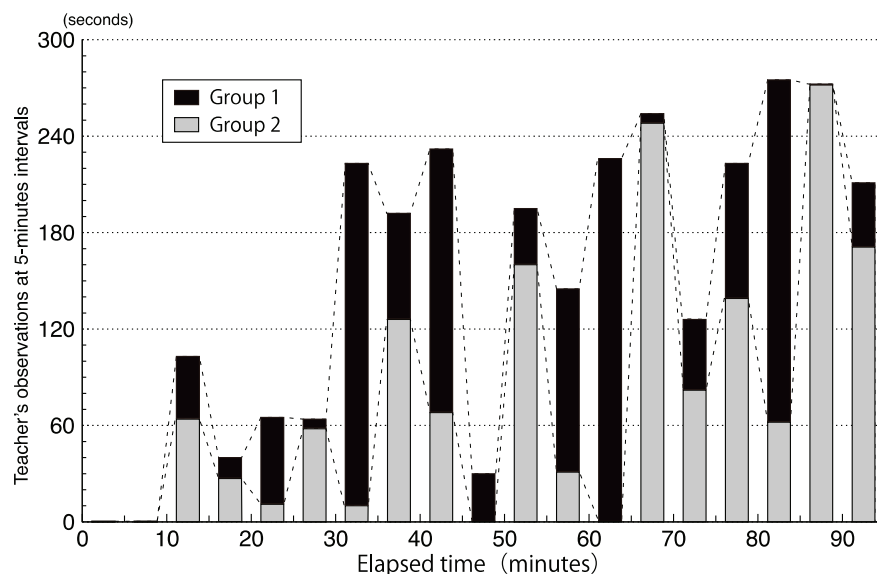


Figure 11. Durations at which the teacher observed each group in detail or intervened

At the elapsed time of 60–65 minutes, the teacher observed Group 1 in detail for longer than 200 seconds, but the duration that the teacher observed Group 2 was much shorter. This is because the teacher intervened in Group 1’s activities by drawing directly on the whiteboard from 62 minutes and 16 seconds to 64 minutes and 48 seconds. On the other hand, at the elapsed time of 65–70 minutes, the teacher observed Group 1 in detail for a very short time. We found that the teacher intervened in Group 2’s activities by drawing on the whiteboard from 68 minutes and 22 seconds to 69 minutes and 40 seconds.

From Figure 11, we can see that at the elapsed time of 70–75 minutes, the teacher observed each group in detail for a short amount of time. Since the teacher observed the students—using the overall observation function—from 70 minutes and 29 seconds until 72 minutes and 23 seconds, the teacher did not have much time to use detailed observation at this time. In contrast, after the elapsed time of 80 minutes, the teacher observed each group in detail for a longer time. It is because the teacher commented on and displayed the outcomes of each group over Ustream.

Although the teacher could use Skype voice calls to communicate with either group, the teacher did not do so. If the teacher needed to communicate with both groups simultaneously, Ustream was used; when the teacher had to communicate with specific members of either group, text chats were used.

### 5.2.2 Evaluation by the participants

#### (1) Evaluation by the students

Table 2 shows the results of the questionnaire survey conducted for the students. The first three questions pertained to whether the proposed system could support students as a communication tool. The results showed that the students gave high ratings for both the shareable whiteboard and the text chat function. Based on opinions such as “it’s useful” and “it’s convenient,” elicited from the free description section of the questionnaire, we can say that the proposed system was considered a useful communication tool for collaborative learning.

The next four questions pertained to whether the students were able to focus on collaborative learning with the constant presence of other students and the teacher. The results revealed a few affirmative answers, such as “agree,” and some neutral answers, such as “undecided.” For example, 50% of the students responded that they were “undecided” about whether the constant presence of the teacher made them feel tense or relieved. Since the teacher mentioned that he/she could observe the students’ learning activities and comment on them several times during the experimental lesson, we thought that the students would be conscious of being constantly observed by the teacher. However, the students did not feel as tense and relieved as we expected.

Table 2: Results of the questionnaire for students (N=4); the 5–1 scale corresponds to “agree,” “moderately agree,” “undecided,” “moderately disagree,” and “disagree.”

| Questions  | Answers (number of persons) |   |   |   |   | Mean |
|--|-----------------------------|---|---|---|---|------|
|  | 5                           | 4 | 3 | 2 | 1 |      |
| You could express your opinion through the whiteboard  | 3                           | 1 |   |   |   | 4.7  |
| You could ascertain others’ opinions through the whiteboard  | 2                           | 2 |   |   |   | 4.5  |
| It was helpful to exchange opinions using text chats   | 3                           | 1 |   |   |   | 4.7  |
| You were able to focus on collaborative learning with the presence of the teacher and other students | 2                           | 2 |   |   |   | 4.5  |
| You were able to learn even though you felt tense and relieved because of the teacher’s observations |                             | 2 | 2 |   |   | 3.5  |
| You could recognize the quality of the activities because of the teacher’s direct instructions       |                             | 4 |   |   |   | 4.0  |
| It is necessary to cease operations while the teacher is instructing you directly                    | 1                           | 1 | 2 |   |   | 3.8  |

When the students were asked whether it was fitting for them to stop drawing on the whiteboard while the teacher intervened, none of the students said they “disagreed”; however, their answers ranged between 3 and 5. We think this is because those students misunderstood the intervention as a system malfunction, and they did not notice that the teacher had actually intervened. From the recorded video, we noticed that while some students paid careful attention to the teacher’s intervention, there were others who did not even notice that the teacher had intervened; they continued to operate the system (for example, turn pages). Based on this finding, we believe that, in the future, it will be necessary to investigate how a teacher can intervene and manage his/her students’ operation of a system, and how a system can be configured such that a student gets a notification whenever a teacher intervenes.

In the free description section of the questionnaire, one of the students commented that the function for voice communication was not built into the proposed system. This student was unable to talk to the teacher via Skype when the teacher does not operate to connect with the Skype even if the student wanted to communicate with the teacher. Therefore, we thought that the students found it inconvenient to use the different means of communication, which could be why they did not use Skype voice calls.

(2) *Evaluation by the teacher*

Table 3 shows the results of the questionnaire from the perspective of the teacher. We found that the proposed system received high scores, overall. However, the teacher gave a low score for the question on whether it was helpful that the students cease operation when the teacher intervened. Further, in the free description section of the questionnaire, the teacher provided the following feedback: “Students could not draw on the whiteboard during my intervention (I was worried about students’ time constraints).” Since the students were not allowed to operate the system while the teacher intervened, we believe that the teacher hesitated to intervene and stop the students’ activities, considering their time constraints.

Table 3: Results of the questionnaire for the teacher (N=1)

| Questions                             |  | Answers                 |
|---------------------------------------|--|-------------------------|
| Overall observation                   | The system helped you grasp the learning progress of multiple groups                                   | 4 (moderately agree)    |
|                                       | The text chat function, by which you could transmit messages to all groups simultaneously is necessary | 4                       |
| Detailed observation and intervention | The system helped you grasp the learning progress of specific groups                                   | 4                       |
|                                       | Joining the text chats of specific groups was helpful to grasp their learning progress                 | 5 (agree)               |
|                                       | You could advise students on procedures related to their learning                                      | 4                       |
|                                       | You could instruct students on issues related to the content   | 4                       |
|                                       | The fact that students had to cease operations while you gave instructions was helpful                 | 2 (moderately disagree) |

## 6. Conclusions

In this study, we developed a shareable whiteboard system for use in collaborative learning, whereby a teacher could observe multiple groups simultaneously and provide instruction from a remote location over a network. The developed client server system consisted of a client system for students, a client system for teachers, and a server system for management. The client system for students was equipped with a shareable whiteboard. Moreover, the client system for teachers allowed the teacher to observe and provide instruction to multiple groups simultaneously.

In this study, we conducted an experiment using the proposed system and acquired usage log files and video recordings. Based on these records, we found that the students were successful in collaborative learning. In addition, we also found that the teacher could instruct students in three ways: through overall observation, detailed observation, and intervention, where required. Further, the

participants responded positively to the questionnaire. Therefore, we believe that the proposed system works favorably for collaborated learning.

In terms of drawbacks, we found that the proposed system did not have adequate functions such as voice chat, exchange of information among other groups, and controlling permission of drawing. If we were to overcome these drawbacks, we believe that the proposed system would be very valuable. Yet another drawback is the sample size. In this study, we conducted the experiment using only five participants. This number is not large enough to be representative of a larger sample. We should note that there are various forms of collaborative learning other than the type used in this study. Therefore, by way of further study, we would like to investigate the proposed system in different lesson with a larger number of participants.

## Acknowledgement

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# Improving 10-12 Year Olds' Epistemic and Conceptual Understanding in a Computer-supported Knowledge-building Environment

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**Abstract:** This study investigated the design of a computer supported knowledge-building environment in fostering 10-12 year olds' epistemic and conceptual understanding. Two classes of 5th graders in Guangzhou China participated in this study while they were learning a unit about electricity. One class engaged in knowledge building, supported with a computer supported platform--Knowledge Forum®, and the other class was taught with traditional approach for comparison. The results showed significantly stronger effects on epistemic view of science and conceptual understanding for knowledge-building group compared with the traditional group. Regression analysis showed that knowledge-building environment and post epistemology of science contributed to students' post scientific understanding, over and above their prior science knowledge. Qualitative analysis of students' Knowledge Forum discourse and interviews showed how the design had helped improve students' epistemic view on the social and progressive nature of scientific inquiry and conceptual understanding.

**Keywords:** Knowledge building, epistemic view of science, conceptual understanding, CSCL

## 1. Introduction

The research on the design of computer-supported collaborative learning (CSCL) environment has received much attention in the recent years. Studies have been conducted to investigate the effectiveness of CSCL on students' conceptual change, inquiry process, and other cognition and skills (Liu & Hmelo-Silver, 2007; Tao & Gunstone, 1999; Vosniadou & Kollias, 2003; Hakkarainen, 2003; Lazakidou & Retalis, 2010; Salovaara, 2005). However, very few have been conducted to examine its effect on students' epistemic view of science (Chan & Lam, 2010). Sophisticated epistemic view of science is important as part of students' scientific literacy. Researchers have proposed different ways to conceptualize epistemic view of science. This study built on the line of research that examined students' epistemic view of science from the role of idea and theory building perspective (Carey, Evans, Honda, Jay, & Unger, 1989; Carey & Smith, 1993; Chuy et al., 2010; Smith, Maclin, Houghton, & Hennessey, 2000), and extended it to examine students' understanding about the social aspect of the theory building process in science. Previous research has shown that many students have naïve epistemic view, and they regard science as concrete activities rather than idea-driven process (Carey et al., 1989; Smith et al., 2000). Therefore, the current study is trying to design a computer-supported knowledge-building environment to improve students' epistemic view of science, and to help them understand the role of idea in science, and the collective and progressive nature of scientific inquiry.

## 2. Theoretical Background

### 2.1 *Epistemic View of Science*

Improving students' understanding about the nature of science has always be the focus of science education. Some science educators have proposed to examine students' nature of science views from

seven aspects: tentative nature of science, empirically based nature of scientific knowledge, subjective nature of science, science involving human inference, imagination, and creativity, the relation and distinction between scientific laws and theories, and observation and inferences (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). It has been argued that even these seven aspects did not capture the whole nature of science, they were accessible to students and were well recognized by scientists and science educators (Lederman et al., 2002). Some other researchers have followed the psychometric tradition initiated by Perry (1970), Schommer (1990), and Hofer and Pintrich (1997), and examined students' epistemological beliefs on science on four dimensions: development of knowledge, certainty of knowledge, justification for knowing, and source of knowledge (Conley, Pintrich, Vekiri, & Harrison, 2004).

Even though these approaches have portrayed the important aspects of the nature of science, the constructive nature of science was still neglected. Premised on constructivism paradigm, Carey et al. (1989) initiated a line of research that examined how students understand science as an idea driven process. Smith et al. (2000) and Chuy et al. (2010) further contributed to the line of research by elaborating on the specific components of the nature of science and making theory building more explicit. This study followed this line of research and examined students' understanding about the nature of science from the role of idea perspective. Meanwhile, we also tried to extend beyond it by focusing on the social aspect, to examine how students understand science as a collective theory building process, which involves negotiation of ideas, co-construction of ideas, and integration and creation of ideas.

## *2.2 Computer Supported Knowledge Building*

Knowledge building is one of the inquiry based educational models focusing on knowledge creation and theory building. The central idea of knowledge building is about students taking epistemic agency and taking collective cognitive responsibility to advance the community knowledge (Scardamalia, 2002). To support students' knowledge building effort, Knowledge Forum®, a computer supported learning platform, has been created. It provides students with a multimedia community knowledge space where their ideas can be displayed, linked, built on, revised, and integrated (Scardamalia, 2004).

The design of knowledge building environment and its relation to students' learning outcomes has been examined by a growing number of studies (Chan, 2009; Lee, Chan, & van Aalst, 2006; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007; Zhang, Scardamalia, Reeve, & Messina, 2009). Scardamalia and Bereiter (2006) have been advocating that the goal of knowledge building is not to evolve into a series of procedures, but a pedagogy guided with workable principles. 12 principles have been proposed to guide knowledge building practice (Scardamalia, 2002), including real ideas, authentic problems, improvable ideas, idea diversity, rise above, epistemic agency, community knowledge, collective responsibility, democratizing knowledge, constructive uses of authoritative sources, etc.

To sum up, the purpose of this study is to examine the design of knowledge building environment on students' epistemic and conceptual growth. Three research questions were addressed: (1) Do students engaging in knowledge building achieve more epistemic and conceptual growth than students in traditional classroom? (2) What are the relationships among knowledge building, epistemic view of science, conception of collaborative discourse, and conceptual understanding? (3) How does knowledge building help students improve their epistemic view of science and conceptual understanding?

## **3. Method**

### *3.1 Participants and Context*

Two classes of 10-12-year-old 5<sup>th</sup> graders (n=61) in Guangzhou China participated in this study. One was engaged in computer-supported knowledge building inquiry, supported with Knowledge Forum; another one was taught with traditional approach for comparison. Students were learning a unit about electricity while we conducted the intervention. Both classes were taught by the same science teacher,

who was experienced in science teaching and just started to learn knowledge building pedagogy. The whole intervention lasted for 3 weeks and was implemented in 6 sessions.

### 3.2 Designing Computer Supported Knowledge-building Environment

The knowledge building class was designed with knowledge building pedagogy and was mainly guided with four knowledge-building principles, “improvable idea”, “epistemic agency”, “constructive use of authoritative information”, and “community knowledge”(Scardamalia, 2002). The key idea of the design was about letting students pursue inquiry like scientists community. They posted their questions and ideas on Knowledge Forum, tested their ideas with experiment, and continued to revise and improve their ideas on Knowledge Forum. The specific design was described below:

(1) Initiate inquiry on Knowledge Forum. The first two classes were conducted in the computer room. After trying out the Knowledge Forum function in a demo view, students were asked to put their questions and ideas on the electricity view. We did not teach them how to respond to each other, but let them try out and figure out themselves. However, they were encouraged to use the scaffolds in their notes writing: “I need to understand”, “my theory (explanation)”, “new information”, “a better theory (explanation)”, “your theory cannot explain”. This session was mainly designed to put students’ ideas in the public place as subject to build on, and to let them get familiar with the Knowledge Forum functions.

(2) Reflect on Knowledge Forum discourse. After letting students experience the discussion on Knowledge Forum themselves, we designed a session on “what is good discussion”, so that they could reflect on the quality of their own discussion. We prepared two threads of notes, one was from their own Knowledge Forum discussion, and another one was from a primary science database in Hong Kong, which was chosen as a good model. We let students compare these two threads of notes and choose a better one. Then we let them discuss in groups and write down on poster why they think the chosen one was a better discussion. To nurture a knowledge-building culture in the classroom, students were asked to put their group poster on blackboard, and then everyone could write a note to comment and put the notes on the posters. This was designed to simulate the threads on Knowledge Forum and to let students aware that their ideas could be made in public and improved by the community. At the end of the session, the teacher related students’ collective ideas on the criteria of good discussion to knowledge building principles, and encouraged them to use these principles to guide their later Knowledge Forum discussion.

(3) Deepen inquiry. To make students have a more focused discussion, a deepening view was created, as Figure 1 shows. Many students were interested in the discussion on whether wet wood conducts electricity. They proposed different ideas and theories to explain the conductivity of wet wood. Then they were asked to work in groups to design experiment to test their own ideas. After students completed their designs, each group presented their design poster in the classroom, and put it on the blackboard for further improvement. Again students were asked to write notes to comment on the designs and stuck it on the poster, as Figure 2 shows. To make the classroom knowledge-building look as similar as the Knowledge Forum one, and also to make them aware of the connection between their classroom ideas and Knowledge Forum ideas, we put their Knowledge Forum question in the middle of the blackboard, and drew lines between students’ experiment designs and this question (Figure 2). It was hoped that this design could help students understand the role of idea in experiment. After the experiment, students were encouraged to continue to write on Knowledge Forum.

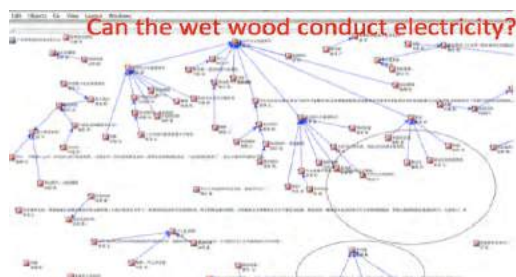


Figure 1 Deepening view on electricity



Figure 2 Visualize KF ideas in classroom



(4) Reflect on science learning and nature of science. At the end of the program, students were asked to reflect on their changed epistemic and conceptual understanding. They were asked to write in a piece of paper on “what I knew about electricity before, what are the new understanding I have now about electricity; what I knew about the nature of science before, what are the new understanding I have now about nature of science”.

The comparison class was also learning electricity but was taught with traditional approach. According to the teacher interview, in each class, he usually lectured first according to the textbook, and then would let students discuss among themselves. No scaffold was provided.

### 3.3 Measures

**Written Test on Epistemic View of Science.** Pre and post written test on epistemic view of science were given to all students to fill out before and after the program. The written test consisted of 7 items adapted from Carey, et al. (1989), Smith et al. (2000), Chuy et al. (2010), Conley et al. (2004), and Lederman & Ko’s (2004) items. Students were given 20-30 minutes to finish the test. Four components were identified to characterize students’ epistemic view of science: (1) Role of idea (“What is science”; “What do scientists do”; “How do scientists do their work”; “Why do you think scientists do experiment”); (2) Theory building (“How do you think new theory is developed”); (3) Theory-fact understanding (“What are the relationships between theory and fact”); (4) Social process of scientific progress (“Scientists may have different even contradictory ideas, do you think it is good for science?”).

Premised on knowledge building theory, students’ responses were coded on a 3-point scale, ranging from viewing science as concrete activities to collective theory building process. Take an item on role of idea for example, at level 1, students do not understand the role of idea in science, they only mention some concrete activities scientist do, such as work in the lab, mix things together, and invent things (“*scientists do experiment in the lab*”; “*they pour tubes in the lab*”); at level 2, students mention some abstract entity, such as theory, question, explanation, hypothesis, and laws, etc, and they also have some understanding about the connection between idea and experiment (“*They propose some ideas, and do experiment to prove*”); at level 3, students can make the connection between the abstract ideas and experiment, and also mention about the social aspects of science and knowledge creation (“*Scientists do experiment, questioning, propose new ideas, test ideas, and get conclusions*”). For the component on social process of scientific progress, at level 1, students do not appreciate the role of different ideas for scientific progress, or have some superficial understanding of the role of different ideas in science (“*It is a good thing, because it will improve scientists’ hard working spirit*”); at level 2, students appreciate of the role of idea interaction for science, (“*It is a good thing, because new evidence may come out from the argument*”); at level 3, students understand the role of different ideas for theory improvement/knowledge creation (“*it is a good thing, if everyone has the same idea, there won’t be better ideas. When we combine different ideas, there will be a even better idea*”).

**Interviews.** Interviews were conducted before and after the program to examine students’ epistemic change process. Eight students from each class were recruited for the interview. The first part of the interview asked similar questions as the written test to have deeper understanding about students’ epistemic views; the second part of the interview asked how students have changed their epistemic view and conceptual understanding about electricity.

**Knowledge Test on Electricity.** A knowledge test was designed to measure students’ conceptual understanding on electricity. The first part contained close-ended questions asking whether certain material (e.g., metal, lemon juice, graphite, distilled water, etc.) conducts electricity, the second part included open-ended questions asking students to explain the conductivity of different material, e.g., why do some material conduct electricity, and some do not? The first part of the test was scored according to the correctness of answers and the second part was coded based on scientificness of ideas (Zhang, et al., 2007). Both parts of the test were transformed into percentage score and were averaged into an overall conceptual understanding score.

**Knowledge Building Engagement.** Students’ performance on Knowledge Forum was measured with a software Analytic Toolkit (ATK) developed by the Knowledge Building Research Team at the University of Toronto (Burtis, 1998). ATK could provide us quantitative measures such as number of notes created, percentage of notes linked and read, number of notes with scaffolds or keywords, etc.

We selected two measures: number of notes write and percentage of notes read to represent students' knowledge building participation and knowledge building awareness.

**Conception of Collaborative Discourse.** Students' conception of collaborative discourse was measured with an open-ended written test containing an item on "what is good discussion". Students were asked to fill out this test at the end of the program. A 3-point scale coding scheme was developed to capture the patterns of understanding. At level 1, students only focus on the behavioral aspects of discussion (e.g., "try our best to discuss"; "people discuss carefully"); at level 2, students mention about the importance of diverse ideas, questioning, or using new information for good discussion (e.g., "There are different ideas, questioning...in a good discussion."); at level 3, students understand that a good discussion is a progressive and deepening process, involving questioning, emerging ideas, building on, and idea improvement (e.g., "I think a good discussion should be like this: propose questions, answer the questions, different suggestions to the ideas/new understanding about the ideas, build on the previous ideas and make a even better idea. It keeps circulating.....")

## 4. Analysis and Results

### 4.1 Effects of Knowledge Building on Epistemic View of Science

To examine the effects of knowledge building on students' epistemic view of science, a 2 x 2 (group x time) repeated measure MANOVA was conducted for all four components; the mean and standard deviation (SD) were presented in table 1. Results revealed statistically significant multivariate effects. The following univariate ANOVA showed significant main effect for time for role of idea  $F(1, 59)=7.459, p=.008, \text{Partial } \eta^2=.112$ , suggesting that both classes improved over time on role of idea. There was also a significant main effect for group for role of idea  $F(1, 59)=6.987, p=.011, \text{Partial } \eta^2=.106$ , and theory building  $F(1, 59)=6.393, p=.013, \text{Partial } \eta^2=.100$ . Importantly, significant time x class was found for theory-fact understanding  $F(1, 59)=4.33, p=.042, \text{Partial } \eta^2=.068$ , and social process  $F(1,59)=4.104, p=.047, \text{Partial } \eta^2=.065$ . This indicated that knowledge building class improved more on their epistemic view on theory-fact understanding and social process of scientific progress than did the comparison class.

Table 1: Pre and posttest mean scores (SD in parentheses) in epistemic view across classes

|                   | Knowledge building class(n=39) |            | Comparison class(n=22) |           |
|-------------------|--------------------------------|------------|------------------------|-----------|
|                   | Pre-test                       | Post-test  | Pre-test               | Post-test |
| Role of Idea      | 1.24(.43)                      | 1.39(.51)  | .98(.31)               | 1.14(.34) |
| Theory-Fact       | 1.26(.72)                      | 1.62(.75)  | 1.45(.60)              | 1.37(.49) |
| Theory Building   | 1.59(.64)                      | 1.92(.87)  | 1.45(.51)              | 1.36(.49) |
| Social aspect     | 1.49(.76)                      | 1.79(.73)  | 1.64(.66)              | 1.55(.51) |
| Epistemic overall | 5.57(1.75)                     | 6.72(2.13) | 5.52(1.27)             | 5.41(.94) |

### 4.2 Effects of Knowledge-building on Conceptual Understanding

Repeated measure ANOVA was conducted to examine the intervention effect on students' conceptual understanding. The mean and Standard Deviation of the pre and post conceptual understanding scores is .59(.08) and .70(.13) for knowledge building class, and .55(.07) and .59(.54) for regular class. The results showed significant main effect for time,  $F(1,57)=21.05, p=.000, \text{Partial } \eta^2=.27$ , suggesting that both groups have improved their conceptual understanding over time. There was no main effect for group. Significant time and group interaction,  $F(1,57)=4.08, p=.04, \text{Partial } \eta^2=.07$ , indicated that knowledge building group improved more on their conceptual understanding on electricity than did the comparison group.

### 4.3 Relationship among Epistemic View of Science, Conceptual Understanding, Understanding of Collaborative Discourse, and Knowledge Building Engagement

Correlation analysis was conducted within knowledge building group (n=39) (see table 2). Results showed that students' post epistemic view was correlated with their conception of collaborative discourse, Knowledge Forum awareness, and post conceptual understanding. It also showed that students' conception of collaborative discourse was significantly correlated with post conceptual understanding and Knowledge Forum awareness.

**Table 2. Correlation among post overall epistemic view, post conceptual understanding, KF participation and awareness, and conception of collaborative discourse (n=39)**

|                         | Post epistemic | Post conceptual | Conception of discourse | KF participation | KF awareness |
|-------------------------|----------------|-----------------|-------------------------|------------------|--------------|
| Post epistemic          | 1              |                 |                         |                  |              |
| Post conceptual         | .611**         | 1               |                         |                  |              |
| Conception of discourse | .677**         | .417*           | 1                       |                  |              |
| KF participation        | 0.113          | 0.021           | 0.325                   | 1                |              |
| KF awareness            | .363*          | 0.212           | .591**                  | .641**           | 1            |

Note: \*p<.05; \*\*p<.01

Hierarchical regression (see table 3) was conducted for the both group (n=61), first entering prior science knowledge (prior conceptual understanding and academic science score), followed by pre epistemic view, and then learning context. Learning context was coded into two variables (Knowledge building group=1; comparison group=0). Results showed that prior science knowledge explained 12.6% of the variance, when pre epistemic view was added, additional 18.0% of the variance was explained. When learning context was added, additional 10.8% of the variance was explained. This indicated that over and above prior science knowledge, epistemic view and knowledge building context further contributed to post science knowledge.

**Table 3. Hierarchical regression on post conceptual understanding with prior science knowledge, pre epistemic view, and learning context (n=61)**

|  | R    | R <sup>2</sup> | R <sup>2</sup> Change | F Change | Sig. |
|--|------|----------------|-----------------------|----------|------|
| Prior science knowledge & academic science score | .355 | .126           | .126                  | 4.043    | .023 |
| Pre epistemic view                               | .554 | .307           | .180                  | 14.317   | .000 |
| Learning context                                 | .644 | .414           | .108                  | 9.910    | .003 |

## 5. The Epistemic and Conceptual Change Process

### 5.1 Changed Epistemic Practice on Knowledge Forum

To understand how students changed their understanding of the social process of scientific progress, we examined how they have experienced this aspect of inquiry in knowledge building. Therefore we examined students' collective discourse on Knowledge Forum, which was the place they might experience the social aspects of the inquiry. Meanwhile, interviews and classroom observation were also used to triangulate and enrich findings from the discourse data.

The knowledge-building students wrote 202 notes in total, and much of the notes were written during the class. Examination of students' earlier notes on Knowledge Forum showed that, students posted many fact-seeking or definition seeking questions in the beginning (e.g., "*can rubber conduct electricity*", "*what is conductor*", etc. they also answered some of these questions with intuitive opinions or undigested information from Internet. For example, a student asked: "*can we see electricity?*", another student responded and said: "*we can not see it*". No more response followed. Another example is, a student asked, "*what is conductor*", another student copied a definition from the textbook and said: "*conductor is a substance that conducts electricity*", that was the end of the discussion. These excerpts indicated that in the beginning students might regard scientific inquiry as a one-question-and-one-answer type of activity.

After the class on what is good discussion, students seemed to be more awareness of the progressive nature of inquiry and their discourse pattern started to shift in more sustained one. For example, student A initiated a question about whether electricity is hot, student B responded and said “[my explanation/theory] when electricity pass through the conductor, it will generate heat, because of the existence of resistance”, the teacher further prompted: “[I don’t understand] why does it generate heat when there is resistance?”, Student C further explained and said: “[my explanation/theory] when the free electron moves in certain direction with the electric force in the conductor, it keeps bumping on metallic ions, and transforms the energy into the ions. Therefore the ions moves more intensively, and cause the heat...”. This example showed how teacher scaffolded students to sustain the inquiry, and how students built on each other, and incorporated new information to address the problem and to deepen their understanding.

The most sustained thread was the one about wet wood conduct electricity. 44 notes had addressed and built on this problem. Students proposed different ideas and theories to explain the conductivity of wet wood. Some said that it couldn’t conduct electricity; while others said “it can, because water can conduct electricity”. A student further explained, “the dry wood originally does not conduct electricity, however, after it was wet by the water, some of the impurity of the wood dissolved into water, the water is no longer pure any more, and can therefore become conductive. It is the water that conduct electricity, but not the wood”. As described in the instructional design session, to test these ideas, students designed experiment in groups. They found that dry wood could not conduct electricity, running water was a little bit more conductive, and salt water was most conductive. They started to wonder why salt water was more conductive and whether different kinds of water had different conductivity. Therefore they posted their emerging questions on Knowledge Forum again for further inquiry. This example showed that students’ discourse pattern had started to shifted into more sustained one that reflected the progressive and emerging nature of inquiry.

## 5.2 Interpretation of the Epistemic Design of Knowledge Building

Qualitative analysis of students’ interview transcripts indicated that how students interpret the design and their inquiry process might have influenced how they understand the nature of science, as the following excerpts illustrates:

*I (interviewer): what are the new understandings you have about the nature of science after the knowledge building?*

*Students Q: Develop new theory out of the existing theories.*

*I: How?*

*Student Q: If you discover a new problem, you can make an inference about the result of the problem according to existing theories.*

*I: Why do you think like that?*

*Student Q: Because science itself is a circulating process. After you solve a problem, you find another new problem, then you solve it and you find another new problem, it keep circulating.*

*I: when did you start to think like this?*

*Student Q: After the computer (Knowledge Forum) class*

*Student M: Because in the first beginning we pose some questions and ideas in the initial view about electricity, later another new deepening view about electricity was created where we found the questions we posed earlier, and we raised more questions building on the responses of the original questions.*

It showed that these students have made the connection between their understanding about the “ever deepening and emerging” design features of knowledge building environment and their understanding about the progressive nature of science. It indicated that the epistemic feature of our designed learning environment might have influenced students’ epistemic understanding.

Regarding how knowledge building helped them understand electricity better, some students mentioned about the importance of *taking over agency* in helping them improve their conceptual understanding, as a student reflected in the interview: “*knowledge building helps us understand things better. Because in the forum, we proposed many questions, and we search on Internet to find answers. Actually we were not just searching for answers, we also learned from the internet about why there is such kind of thing, and how it becomes this.....*” This except also showed how knowledge building

might help students expand and deepen their knowledge by let them aware of their own agency in the knowledge construction and knowledge creation process.

## 6. Discussion and Conclusions

This study designed of a computer-supported knowledge-building environment and examined its role on students' epistemic and conceptual growth. The first research question asked about the effects of the design on students' epistemic and conceptual understanding, quantitative analysis was conducted and it showed that knowledge-building students improved more on epistemic view of science and conceptual understanding compared with the traditional group. To address the second research question, correlation analysis was conducted and results showed that students' epistemic view of science was highly correlated with conception of collaborative discourse, which indicated that the better students understand their own collaborative knowledge building process, the better they may conceive scientists' collective theory building process. Further regression analysis indicated that both knowledge building environment and post epistemology of science predicted students' post conceptual understanding. These quantitative findings were consistent with the previous studies on the effects of knowledge building on epistemic and conceptual understanding (Chan & Lam, 2010), and on the relationship between epistemic cognition and conceptual change (Qian & Alvermann, 1995; Stathopoulou & Vosniadou, 2007), and we further related these constructs to conception of collaborative discourse, and extended the research on epistemic view to the social-cognitive perspective.

The third research question asked the change process of epistemic view and conceptual understanding. Qualitative analysis of students' Knowledge Form discourse showed that the structure of students' discourse shifted from "one question and one response" type of pattern to more sustained and progressive one, which indicated that students' epistemic practice became more sophisticated over time. Meanwhile, qualitative analysis of students' interview showed that students' interpretation of the epistemic design of the knowledge building influenced how they understand the nature of science and learning, which accordingly changed their conceptual understanding about electricity.

This study showed the possibility of changing young students' epistemic view of science with computer-supported knowledge building design. It also showed how students' experience with knowledge building and reflection of this process might have helped them understand the nature of science better. This study contributed to our understanding about way we could embed epistemology components in technology and learning environment design to improve students' epistemic and conceptual understanding. It indicated that if we embed the epistemic feature, such as "deepening", "progressive", and "emerging", in the technology-supported learning environment, students might start to aware of the collective and progressive nature of scientific inquiry through engaging in it and reflecting about it.

This study is only the first iteration of an intervention project. Students' epistemic reflection of their inquiry process was not well scaffolded, future study could be conducted to further improve the design by letting students reflect on the epistemic implication of their experience, and helping them make the connection between their inquiry process and scientists' inquiry process. It was a short intervention, the sample size was small, and the comparison group was not equivalently controlled. The inferences made about the effects of the learning environment should be carefully interpreted; future studies could be designed with longer duration, larger sample size, and better controlled comparison group, to further test the theory. Meanwhile, the mechanism of the knowledge building process could also be further unpacked to provide a richer understanding about the relationship between knowledge building dynamics, epistemic view of science, and conceptual understanding.

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# Math Creation: Integrating Peer Tutoring for Facilitating the Mathematical Expression and Explanation

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**Abstract:** The purpose of this study is to contribute insights into how math creation integrated peer tutoring can facilitate students' mathematical expression and explanation. Twenty-five second-grade primary students play the role of teachers to construct their math creations as the teaching materials to teach their partners. Specifically, the students need to solve given word problems and produce three forms of creation—including drawing expression, arithmetic expression, and solution explanation—to justify their solutions. This study shows that peer tutoring can promote students' drawing expression and solution explanation by providing opportunities for students to reexamine their math creation mutually. However, the progress of arithmetic expression does not achieve significantly. Besides, this study also finds that high and low achievers have different sequences in completing math creations and ways of participation. Finally, how computers facilitate and change students' mathematical expression and explanation compared with paper-based environment is also discussed.

**Keywords:** Math creation, peer tutoring, mathematical explanation, mathematical expression

## 1. Introduction

During the last decade, the educational reform movement in Taiwan has advocated for increasingly emphasizing students' mathematical expression and explanation. One of the government policies in Ministry of Education of Taiwan (2003) is "to understand the comprehension of the mathematical language, such as symbols, terms, tables, graphs and informal deductions". Furthermore, mathematical expression and explanation, a critical approach to present the mathematical language, may show how people understand mathematical concepts and use those ideas. More specifically, peer explanation may facilitate spontaneous using the mathematical language such as diagrams in solving mathematics word problems (Uesaka & Manalo, 2011).

Teaching mathematical concepts and principles by depicting problems graphically and using peer explanation activities during mathematics instruction had found to be consistently effective (Griffin & Jitendra, 2009). During peer explanation, students' gains in drawing diagrams likely contributed to their diagram construction skills (Uesaka & Manalo, 2011). Besides, the explanation of students as explainers may become more complete because they have to monitor their own misunderstanding and knowledge gaps (King, 1994), which may help them understand (Roy & Chi, 2005). In other words, mathematical explanation may facilitate mathematical comprehension (McNamara, 2004). On the other hand, learning in pairs or small groups has positive learning benefits on children's learning development (Dillenbourg, 1999). Therefore, applying peer explanation to peer tutoring could be an adequate learning approach to foster students' mathematical expression and explanation because tutors' explanations may expose tutees to the information they lacks (VanLehn et al., 2007), which may assist their tutees' learning (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001).

Nowadays, as most classrooms have provided Internet access and one-computer-per-student, it is possible for students to create their own math creations as an educational strategy for training mathematical expression and explanation. Chi (2009) posits that learners benefit most from active constructing their own artifacts and explanations. Furthermore, peer tutoring is used as a good strategy



for the facilitation of mathematical explanations (Berghmans, Neckebroeck, Dochy & Struyven, 2013). Developing mathematical representation and solution explanation by constructing an appropriate math creation for integrating peer tutoring activity is likely to improve the comprehension and completion of the math creation. Students are also more likely to apply these skills through peer tutoring, thus advancing the quality of their works. Taking the literature and current trends together, a question arises if constructing math creation could enhance students' mathematical expression and explanation in a peer tutoring activity. Therefore, the current study is conducted to examine the effects of math creation followed by peer tutoring to improve the performance of second graders in their mathematical expression and explanation. The method for exploring this question is described as follows.

## 2. Method

This research investigated how students constructed their math creations by integrating peer tutoring for facilitating mathematical expression and explanation. Students had to write down their solutions (arithmetic expression), draw the mathematical representation (drawing expression), as well as explain how and why they solve word problem in their own ways (solution explanation). This section will describe the participants, the activity procedure, the learning system and the supplementary learning sheet, followed by data collection and analysis.

### 2.1 Participants

Twenty-five second-grade primary students (13 boys and 12 girls) and their teacher from the same class at a public school in the north region of Taiwan participated in this study. The students had their own tablet PCs brought by their parents in schools since first grade and had developed good competence and familiarity in mathematical self-learning. In this study, they were assigned to six groups by their teacher. There were four or five students in each group, where everyone was further paired to each other. The teacher was willing to participate in the activity of math creation, so she encouraged students to engage in peer tutoring and math creation. Besides, she also provided students with many opportunities to show their works and to teach the whole class in front of the classroom.

### 2.2 The Learning System & Supplementary Learning Materials

The system of math creation was called Little Mathematical Teacher (LMT), which was designed to assist students' learning and to visualize their math creations with a sketch-board and a sharing zone. Besides, the researchers also provided the supplementary learning sheets to scaffold students during the math creation and peer tutoring.

For the purpose of assessing students' mathematical expression and explanations in math creation, students were asked to complete a word problem solving assignment in the sketch-board. The sketch-board was divided into three parts, including drawing expression, arithmetic expression, and solution explanation (see Figure 1). The sketch-board provided a component library, which contained various mathematical components, such as coins, building blocks, and carton images etc., suggested by the teacher in order to meet the needs of primary students. Students can utilize those components to prepare their drawing expression, arithmetic expression and solution explanation for concretely explaining their solution procedures in their math creations.

Meanwhile, different word scaffoldings were used according to students' abilities of mathematical explanation. In initial activities, more word descriptions were provided to help students think related mathematics concepts by completing the keywords of the word problems. Students can learn how to explain their mathematical ideas to others through imitating the similar explanatory patterns. After that, the system only provided simple conjunctions to facilitate students to think appropriate solutions, the ways of solving, and what the most important reason was. For example: *[First, I used] one calculating method, [because] (I) wanted to .... [Then, I used] one calculating method, [because]...*.

Besides, the LMT provided a sharing zone to display all students' math creations. When students finished their math creations and saved them, the creations were uploaded to the sharing zone. Students only had to choose the classmate's number and then his/her creation would show up (see

Figure 2). This function helped students share, observe, and understand the math creations of the whole class. They can thus learn mutually and take advantage of this function to teach their partner about what the mathematical concepts applied and how to solve the problem.

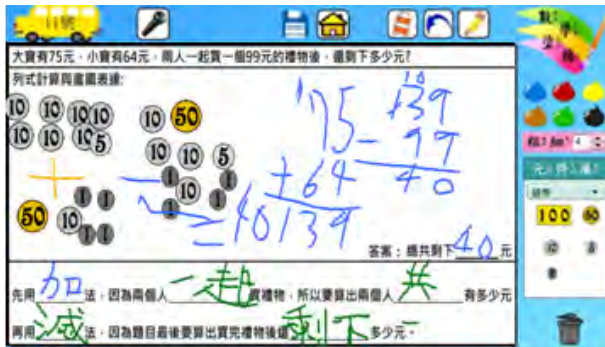


Figure 1. The interface of the sketch-board



Figure 2. Individual's math creation displaying in the sharing zone

To facilitate students' math creations, three supplementary learning sheets were given. Two question sheets embedded in the system were used in different stages. One question sheet listed relevant questions about the assigned word problems. This study adopted two forms of a question sheet revised from Mason (2000) to prompt students' awareness development of mathematical thinking and to allow students to answer questions for themselves or a partner. The two forms were enquiring and testing questions. First, enquiring questions guided learners to understand every meaning through several divided problem solving steps. Hence, this study adopts enquiring questions to guide students explaining the meaning of problems by drawing and arithmetic expression when students created mathematical artifacts. Students can also ask their partner or classmates some questions as those on question sheet. Thus, even if they have not thought of any questions on their own, they can still take advantage of the question sheet to join the peer tutoring activity. The example questions were shown as follows. (1) What does this problem ask for? (2) How do you express six boxes of milk and each box have twelve bottles of milk by drawing expression? (3) How do you express the milk drank by drawing expression? (4) How do you express the milk left by drawing expression? (5) What does each calculation mean?

Second, testing questions were used to ask students to explain their own mathematical thinking in order to evaluate their understanding, and help peer mutually examine the correctness of their drawing expression, arithmetic expression, and word explanation. Additionally, students can ask relevant questions if they have any unclear or doubtful part, for example:

(1) If there is something unclear or incorrect in the instructor's drawing expression, please question him/her.

(2) Is his/her arithmetic expression correct? If there is something wrong, please find out and tell him/her the correct arithmetic expressions.

(3) Is his/her explanation correct? If there is something wrong, please find out and tell him/her how to modify it.

Many students spent most of their creating time in thinking about how to draw the mathematical representation to express their solutions. Therefore, the researchers provided an additional supplementary learning sheet with six examples of mathematical representation in paper form to assist students' drawing expressions.

### 2.3 Learning Procedure

This study was conducted for 13 weeks. All students participated in 13 times of learning activities, and each learning activity took two class periods, approximately 80 minutes. Before the experiment, the researchers explained the usage of the sketch-board to the students and asked them to construct their own math creations for teaching their students (*i.e.* paired members). These creating steps were chosen and proceed in the sequence based on Polya's (1957) four stages of problem solving: understanding the problem, devising a plan, carrying out the plan, and looking back. However, the final step, *i.e.* checking

calculations, was revised to solution explanation to help students re-think how they solved the problem. Furthermore, in order to promote the activity of math creation smoothly, the first step, *i.e.* understanding the problem, was conducted as an independent session by discussing solutions with their partners to understand the condition given and the problem asked. Therefore, four learning sessions were described as follows.

*Session 1: Understanding the word problem.* In the first session, each student received a word problem and a question sheet (the details were in the Supplementary Learning Sheet). Students read the word problem and, as a group, tried to understand it by discussing what the problem meant and how to explain its solution with their partners. They, furthermore, tried to connect with the requirement of solving such problem and think about what was the proper strategy of the problem. Students thus got joint understanding of problem required. This session usually took five minutes.

The students worked in pairs. In the first to seventh activities, students were provided the same word problem in order to help them familiar with the activity and discussed with each other more easily. In addition, they were able to learn how their peers solved the same problem with different strategies and explanations. After that, students were given parallel word problems in the same pair to enhance their learning and thinking more other word problems with similar concept and structure, but had different scenarios and numbers for avoiding students feeling bored with the same word problems, which may lead to reduce the benefits of peer tutoring. The examples of parallel word problems were shown as follows.

(1) Liz invited 26 classmates to her home for eating cakes. Every cake was divided into 13 pieces. Liz prepared 4 cakes, and everyone could have one piece. How many pieces of cakes left at last?

(2) Mei prepared 7 cakes, and each cake was divided into 10 pieces. She invited 26 classmates to her home for eating the cakes. Everyone had 2 pieces. How many pieces of cakes left at last?

*Session 2: Prepare one's math creation.* All students prepared their math creations as the teaching materials individually in the classroom. More specifically, s/he solved a problem on his/her own and preparing his/her math creation on the sketch-board, including: (1) Drawing expression: Students used words, symbols, models and manipulative materials as their mathematical representations to devise a plan and convey their ideas and communicative information; (2) Arithmetic expression: Students wrote down their mathematical equations for solving this problem as carrying out the plan; (3) Solution explanation: Students reflected how and why they solved the problem and wrote their solution explanation for looking back. Students had to try an understandable approach in his/her drawings and explanation for others because one's drawing created the mental representations of the solution. After finishing the math creation, the student could save it and then view other math creations made by their classmates in the online sharing zone.

*Session 3: Peer tutoring.* Students were given ten minutes for tutoring the partner in each group. The researcher asked students to use a recorder as a microphone. For sharing ideas with a peer, students may hold the recorders to play the role of little math teacher and debrief the representation of his/her thinking, such as how s/he solved the problem and what s/he considered. And then the partner had to take over the recorder and play the role of learner to ask the little math teacher some relevant questions. The little math teacher had to answer these questions. At the time, the learner was easy to check with the solution of the little math teacher, because s/he might discover some incorrect parts of the solution during debriefing. In another turn, the paired students had to switch their roles.

*Session 4: Presenting solution.* Students had to teach the whole classmates by presenting their drawing and solutions of math creation in the electronic whiteboard in the final session. However, due to the time limit, the teacher only chose seven or eight students as the presenters in each activity. Then the other students may ask the presenter some questions about their solutions. After the solution presentation, s/he may reflect on his/her math creation and oral explanation for improving next time.

## 2.4 Data collection and analysis

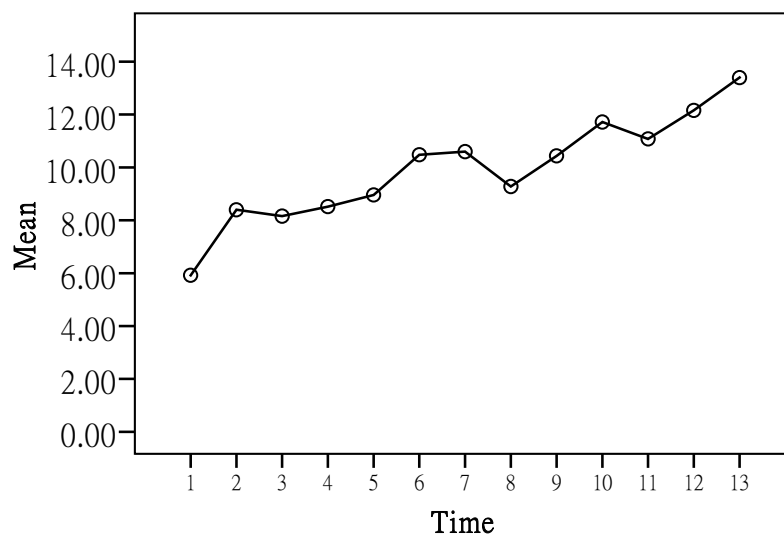
To examine how students advanced the mathematical expression and explanation in LMT, data collection included students' math creations, class observations, and interview. The researchers calculated the scores of three sub-abilities in students' math creation, which included: drawing expression, arithmetic expression, and solution explanation. Each sub-abilities was 5 points at most, so the total score is 15 points. We scored the expression and explanation by considering if the key concept was involved in the description and if the relationship of conditions problem given were showed. The

evaluation criteria of drawing expression were shown as follows. (a) 1=incorrect representation, which using concrete objects referred to the problem, but the representation was incomprehensible; (b) 2=correct but drawing objects without marking meanings; (c) 3=calculation form of calculating representation; (d) 4=correct but incomplete schematic representation; (e) 5=schematic visual representation, which could express the spatial relations between objects in a problem for explaining their solution strategy. To ensure the reliability of scores of math creation, the scores was evaluated by two raters simultaneously. The inter-rater reliability of was  $0.91 \cdot p < .000$ . Besides, that classroom note focused on the nature and type of tutoring undertaken by primary students. In addition, the semi-structured interviews were conducted to interview the class teacher and the high, moderate, and low achieving students according to their performance of math creations. These qualitative data was transcribed, coded, categorized, and compared in multiple ways for emerging meaningful themes. The classroom notes were used throughout the data analysis process for the purposes of triangulation.

### 3. Result

#### 3.1 The progress of the expression and explanation in the math creations

The aim of this study was to investigate the mathematical expression and explanation advancement. We examined and marked the online math creation of whole class to gain better understanding of the students' learning process. Figure 3 provided the information about how the means of students' expression and explanation in their math creations changed in 13 times. Overall, it was clear that their mathematical expression and explanation had upward trends.



**Figure 3.** The means of students' expression and explanations of math creations in each time.

Moreover, Figure 4 showed the information about how the means altered by the three sub-abilities in their math creations among 13 times. The score of arithmetic expression was only 2.68 points at the first time. Because some students thought drawing expression was equal to the arithmetic expression and thus did not write the part. However, the mean was a rapid climb to 4.64 points as students caught the key in the second time. After the third time, the following means were a steady increase scores from 4.56 to 5 points. As for the scores of drawing expression, it started at 2 points at first time and after a slight fluctuation reached to just less than 5 points in thirteenth.

It was notable that the scores of both drawing expression and solution explanation had similar patterns. In contrast with the relatively stable performance in the arithmetic expression, the scores of both drawing expression and solution explanation were matched from first to fourth time with 2 points, after a slight increased at sixth time, then dropped to 2.4 points at the eighth time because students had to deal with an advanced learning topic. More specifically, the topic shifted from addition and subtraction mixed problems to addition, subtraction, and multiplication mixed problems. Students had to use new explanatory approach. Meanwhile, students were given parallel word problems from eighth

time. But their scores later sustained increased and reached to the highest score at thirteenth time. To identify the relationship between drawing expression and solution explanation, Pearson correlation coefficient was applied. There was a positive correlation between the two variables,  $r = 0.894$ ,  $p = 0.000$ , which mean that drawing expression and solution explanation had a high, positive correlation. Increases in overall performance of the drawing expression were correlated with increases in performance of the solution explanation.

Overall, students' scores in drawing expression and solution explanation were lower than arithmetic expression from beginning to the end, which meant that the two sub-abilities needed further enhancement. However, through the activity, students gradually improved their drawing expression and solution explanation, which were closed to the level of arithmetic expression in the end.

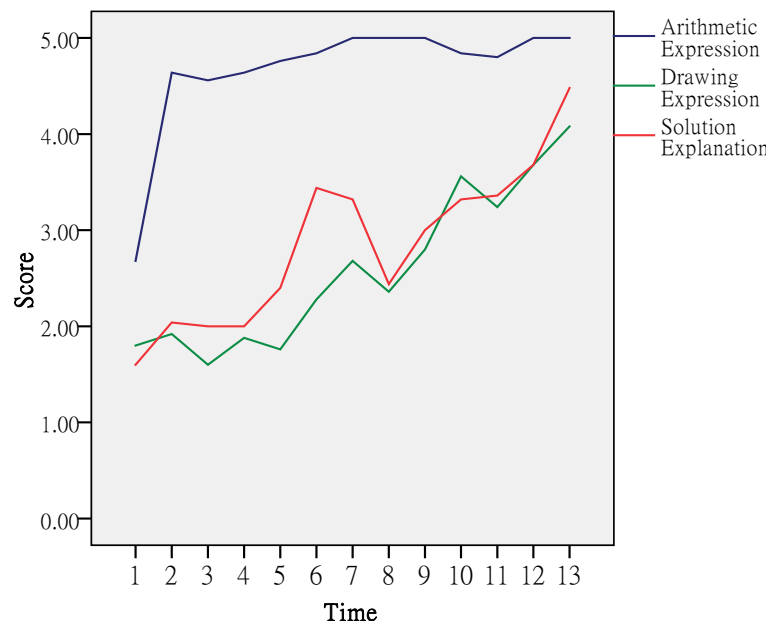


Figure 4. Means of each dimension in students' math creation.

Nevertheless, this study did not have the control group and thus needed more evidence to confirm the improvement of math creation. The researchers compared the initial and final score of math creation to understand the degree of advancement. As mentioned earlier, students were unfamiliar the system operation and rules of math creation at first. However, once students were proficient with system and peer tutoring procedures, they can devote their full attention to the actual content of the lessons (Mathes, Howard, Allen, & Fuchs, 1998). So this study used paired samples t-test to compare the means of second and thirteenth math creation. The students achieved mean scores in second math creation (Mean = 8.40, SD = 2.52) and thirteenth math creation (Mean = 13.40, SD = 3.06) (see Table 1). The result showed a significant difference between the total scores of the two math creations ( $t(24) = -10.74$ ,  $SE = .47$ ,  $p = .00$ ).

Table 1: Students' performances on the second and thirteenth math creation.

| Math creation         | Second artifacts |      | Thirteenth artifacts |      |
|-----------------------|------------------|------|----------------------|------|
|                       | Mean             | SD   | Mean                 | SD   |
| Arithmetic expression | 4.64             | 1.15 | 5.00                 | 0.00 |
| Drawing expression    | 1.92             | 1.91 | 4.08                 | 1.29 |
| Solution explanation  | 2.04             | 0.61 | 4.48                 | 1.08 |
| Total                 | 8.40             | 2.52 | 13.40                | 3.06 |

Furthermore, in order to investigate the effect of these sub-abilities in the math creation individually, further analysis was conducted. The results showed that integrating peer tutoring for facilitating mathematical expression and explanation resulted in significant improvement on the drawing expression ( $t(24) = -2.28$ ,  $SE = .2$ ,  $p = .00$ ), on the solution explanation ( $t(24) = -14.03$ ,  $SE = .17$ ,  $p = .00$ ). However, there was no significant difference in the arithmetic expression ( $t(24) = -1.57$ ,

$SE=.23, p=.13$ ). The findings suggested that these sub-abilities of drawing expression and solution explanation in math creation could be fostered at the same time when they were trained through integrating peer tutoring, while most of their arithmetic expression were very close to the full score therefore it did not show significant improvement.

Apart from the statistic data from the scores of students' math creation, the researchers also interviewed the class teacher to get her perception about students' improvement. The teacher responded "some students, such as S5, when he found out an appropriate drawing expression like number line; he would adopt this method afterwards and solve problems accurately. Besides, as student introduced his/her math creation, I could find their confidence never showed before." As long as students found out their ways to overcome their difficulties of mathematical expression and explanation, they could perform well in the later math creations and have more confident in peer tutoring. They were also more willing to raise their hand for presenting to the whole class. After doing so, they got more feedback from other classmates and teacher, and thus modify their math creations to make a positive loop.

### 3.2 Progressive examples of the math creations

The progress of math creation was observed by different achieving students. A high achieving student S15 said: "I didn't know how to explain or teach others about how to solve the problem at first, but now I learned how to explain why I use the addition, multiplication, and subtraction." The case of S15 reflected that students had got the point on how to explain the solving method for helping others understand in his solution explanation of math creation through peer tutoring. In addition, S5, a moderate achieving student mentioned that "I could learn another method [for problem solving] and solve the mathematical problem better" implying that peer tutoring allowed students to talk over mutual solutions, and students were able to view other classmates' math creations in the sharing zone. Through sharing knowledge and assimilate each other's ideas, students learned new problem-solving strategies and used those for refining their expression and explanation of the math creation. Similarly, another low achieving student S2 stated "My classmates and I checked the answer mutually to make sure that our equations and answers were correct." Students' behavior suggested that integrating peer tutoring into math creation facilitated students not only to provide helps but also to receive aid from their partners.

Additionally, this study provided a typical example among students to show the progress of students' math creations. In the early period, most children's drawing expression only adopted coins to reflect their calculation process. Figure 5 was a typical example. It showed that student did not understand how to map the details of the problem onto his drawing expression. The word problem was "Da-bao had 75 dollars, and Xiao-bao had 64 dollars, they bought the gift with 99 dollars together, how much money did they leave?" S5 used many coins as representations in his drawing to replace the number in calculation. Besides, he used apples as the left money, and each apple represent 10 dollars. More specifically, he only put all coins together. All the numbers in the problem were showed in the drawing, but the relationship between the money was not clear, such as which is addend, which is minuend, or subtrahend. In addition, the student misused two different things, coins and apples as the same representations: money. Although the student could calculate by using the information the problem provided as his arithmetic expression, and also fill correct key words in the blanks as the solution explanation, the representation implied that he did not really understand how to draw the mathematical meaning of addition and subtraction mixed problem or could not convey it. The drawing was not correct for other students to understand his thinking and the concept of problem solving.

In the end of the study, the students began to think different explanatory methods and examine the process and reason one step after another. Figure 6 illustrates the students' mathematical expression and explanation in the final math creation. In this example, the word problem was that "A packet of biscuits costed 15 dollars, Miu bought 5 packets, she paid 100 dollars, how much change should she get?" S5 drew the box represented the money of a packet and marked 15 in each box, so there were five boxes, and he wrote the total boxes meant 75 dollars. This drawing corresponds with the representation of the problem identified in the first step. Next he drew two row blocks. There were ten blocks in the upper row and seven blocks with half size of block in the lower row. It's obvious that S5 combined the information of the same unit onto the relevant diagram and flagged the goal needed to be found in the problem by using a question mark. More specifically, he drew ten blocks of ten as the paid money, one hundred dollars, then seven blocks and half size of block of ten as the total money needed to pay, and

finally used a question mark to represent the unknown money given back. The student's understanding was demonstrated by how he mapped the details of the problem onto his drawing expression.

Furthermore, S5 knew the reason why he used the multiplication and subtraction and the representing meaning of each number. He explained that “[First, I used] multiplication, [because] one packet cost 15 dollars, and Miu bought 5 packets (calculated the price of five packets). [Then, I used] subtraction, [because] Miu should paid 75 dollars, but she paid 100 dollars (and the change was the price).” It was clear that the student properly used the representation and explained his solutions.

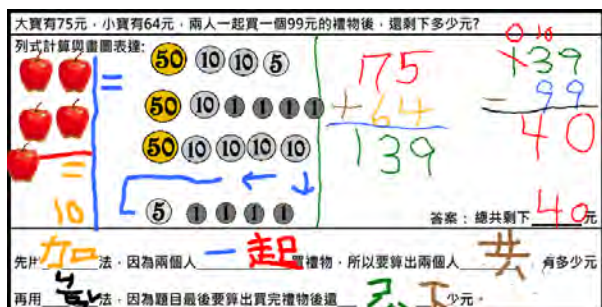


Figure 5. The initial math creation.

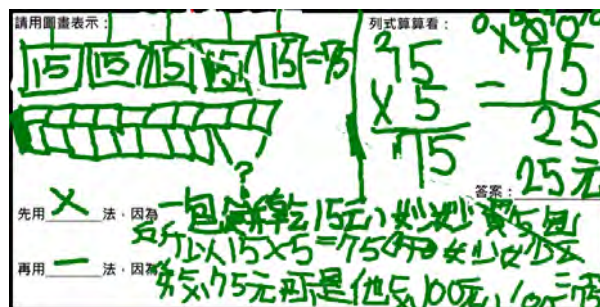


Figure 6. The final math creation.

The difference of two math creations showed the improvement of mathematical explanation from the beginning to the end. It was obvious that constructing students' own math creation and peer tutoring may facilitate students' mathematical explanatory strategies, enhance spontaneously constructing more appropriate diagrams, absorb the mathematical expressing methods of their classmates, and then contribute to his own mathematical expression and explanation.

### 3.3 The sequences in completing math creation and ways of participation

The teacher and most students had positive attitudes toward constructing their own math creations and engaging in using their works to the peer tutoring activity. However, the classroom observation and interview showed that some students encountered obstacles and tried different ways to involve themselves in the learning activity. The researchers interviewed two low achievement students S13 and S14 and two high achievement students S1 and S15 to further inquiry their perceptions and habits for math creations. Both low achieving students preferred to finish the arithmetic expressions first. S13 emphasized that “Drawing is a little bit difficult, so I write the arithmetic first. I can calculate the answer”. It reflected that S13 might not able to draw his solution, but at least he could finish the arithmetic expression in his math creation whether the answer was right or not. Similarly, S14 usually tried many different drawing expressions and then erased them repeatedly, but left the arithmetic expression without drawing expression and solution explanation in the end. Many low achievers had the same behaviors with S14. Such phenomenon was changed gradually after the learning sheet of drawing examples was provided for them to rely on and imitate. Students started to try drawing expressions and saved them.

The teacher usually guided low achievers by monitoring their progress of math creation from the sharing-zone and reminding them to utilize clear marks and descriptions on their drawings expression and solution explanations. Some of them might thus modify the two parts; nevertheless, due to the abilities and time limitation, students might not always complete their drawing expression and solution explanations among the remaining time. However, they would still try to explain their solutions in the peer tutoring but focus on explaining how to calculate the mathematical equations instead of why they solved word problems in that way.

Contrary to the low achieving students, the high achieving students had different creating procedures. S15 preferred drawing first; she said “I think drawing expression is harder. I can't merely draw the arithmetic; I have to consider how to correspond to the problem and my solution. It would take more time to finish, so I usually draw first, and the following arithmetic expression and solution explanation will be finished very soon.” In addition, S1 chose the alternation of drawing and arithmetic in his math creation. S1 thought “drawing helps me think about how to solve the problem. I write my arithmetic expression after drawing, and then repeat the procedure [to my solution]”. Hence we knew

that high achieving students preferred to draw the mathematical representation first although they also felt that drawing expressions were more difficult. Besides, it seemed that the high achiever tended to use the drawing expression as an assistant approach for arithmetic expression rather than distinguished the two expressions as unrelated elements.

Overall, students spent more time on drawing expression and solution explanation rather than arithmetic expression. Most students tended to finish the arithmetic expression and then back to think about how to draw the mathematical representation and solution explanation except for the high achievers. Low achievers usually only completed the arithmetic expression without examples to rely on. Students had learning tension on withdrawing their drawing expression and solution explanation or not because they could not confirm the correctness of the two parts. Besides, compared with writing the solution explanation, students preferred to explain how to solve problems by oral presentation because their oral explanation was always provided more and sooner than the written explanation.

#### **4. Discussion**

This study intends to facilitate students' mathematical expression and explanation by integrating peer tutoring into math creation. Traditional mathematics education emphasizes on the correctness of repeated calculation, so that students may perform well in the arithmetic expression. However, the same procedure (e.g., subtraction) used to solve all problems within a chapter (Bonotto, 2013), students may not have the opportunity to distinguish among problems which need different solutions. This study tries to help students understand the meaning and structure of a problem and asks them to address their mathematical knowledge and solving processes by math creations. Students may fail to develop their mathematical expression and explanation at first, once they gain access to math creation to internalize mathematical concepts or relationships, their improvements, whether in drawing expression, arithmetic expression or solution explanation, were seen clearly.

Computers provide an easier and even instant access with a wider audience for students' math creations compared to similar activities with prepared papers. The sharing zone in the LMT supports not only students' mathematical written expression and explanation, but also oral explanation and feedback during the peer tutoring. The sharing zone demonstrates students' math creation and helps students reflect why they construct the expression and explanation in the ways. Besides, teachers can monitor students' progress, analyze students' problems, and examine the knowledge status of students. Subsequently, both teachers and peers can provide real-time feedback and recommend revisions. Students who share their math creations are able to take advantage of the availability of classmates' works to communicate with each other to get more perspectives and suggestions. Therefore they can draw on the strong points to offset the weaknesses for modifying and refining their math creations, and further expand their capacity to interpret their mathematical concepts.

In contrast, the second-grade students loved to draw creative expression. Many students drew a great deal of irrelevant details in their mathematical representations. Through sharing math creation, students may know more than one way to express their mathematical representations. However, after students chose more efficient and effective representations by observing classmates' artifacts in the sharing zone, they may thus become less creative. Their mathematical representation specifically changed from concrete materials mixed with default components to more abstract self-drawing pictures. Although this was a normal development and also an important goal for primary mathematics, this study still reflected that developing the ability of problem solving and creativity simultaneously from initial to the end was not easy in practical classrooms.

#### **5. Conclusion and Future Work**

The aim of this study was to improve students' mathematical expression and explanation by integrating peer tutoring into math creation. We analyzed students' math creation of the whole learning activity and compared the performance of second and final artifacts to identify students' advancement. The drawing expression and solution explanation achieved significant difference, except the arithmetic expression. In addition, this study carried out the interview and collected student's math creation in different activity sessions as learning evidences in terms of mathematical expressions and explanation. The low and high achievers' creating sequence in math creation were also explored. However, some questions still needed to be explored. For example, spending two classes to solve one word problem may be



considered time-consuming for many teachers. Therefore, how to spend less time on completing such learning activities is still a question. Besides, how students' mathematical representation advanced and how they mapped the details of the problem onto his drawing expression in different stages during the thirteen activities deserved further inquiry, which will need future studies.

## Acknowledgements

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# Providing Knowledge-Related Partner Information in Collaborative Multimedia Learning: Isolating the Core of Cognitive Group Awareness Tools

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**Abstract:** Cognitive group awareness tools support learners in dealing with specific challenges of computer-supported collaborative learning scenarios. This paper suggests three supporting functions underlying cognitive group awareness tools and proposes to disentangle them in three consecutive experimental studies with regard to multimedia learning. It focuses on one of those studies that systematically investigates whether providing knowledge-related partner information can improve collaborative learning with multiple external representations and with dynamic and interactive visualizations. Learning dyads ( $N = 120$ ) were compared in four groups that differed with regard to the presentation of knowledge-related partner information during two subsequent collaboration phases: (1) learning with multiple static representations and (2) learning with dynamic and interactive visualizations. Results indicate that providing partner information during collaboration can facilitate meaningful learning discourses and improve learning outcomes.

**Keywords:** computer-supported collaborative learning, cognitive group awareness, multiple external representations, interactive visualizations

## 1. Introduction

Collaborative multimedia learning is a promising but challenging scenario. Learning partners have to overcome individual as well as specific collaborative barriers simultaneously (Bodemer, Kapur, Molinari, Rummel, & Weinberger, 2011; Bromme, Hesse, & Spada, 2005; Dillenbourg & Bétrancourt, 2006). With regard to individual multimedia learning, research addressed various difficulties of learning with multiple external representations (MER; e.g., Ainsworth, 2006) or dynamic and interactive visualizations (DIV; e.g., de Jong & van Joolingen, 1998). Moreover, when learning collaboratively, learners have to additionally (1) establish references between external content and communication, (2) construct a common ground based on mental representations of their learning partners' knowledge, and (3) coordinate communication and interaction processes in a goal-oriented way (cf. Bodemer, 2011; Clark & Brennan, 1991).

This paper focuses on cognitive group awareness (CGA) tools that support learners in dealing with the specific challenges of computer-supported collaborative learning (CSCL). It has been shown that they can improve collaboration processes and learning outcomes while enabling self-regulated learning processes (cf. Bodemer & Dehler, 2011; Janssen & Bodemer, 2013; Ogata & Yano, 1998). Moreover, CGA tools are suited to be combined with instructional tasks well-proven in multimedia learning research. It was already shown that they can significantly support collaborative learning with both MER (e.g., Bodemer, 2011) and DIV (Scholvien & Bodemer, 2013).

As a core feature, cognitive group awareness tools provide knowledge-related information on learning partners (e.g., a learning partner's hypotheses, test scores, interests or opinions), which can facilitate grounding and partner modeling processes during collaborative learning. Group awareness tools usually provide further support in two ways. On the one hand, knowledge-related information on learning partners do not only comprise information on a person but also refer to specific and often preselected content (e.g. a learning partner's hypothesis regarding a single element of the learning

material), thereby cueing essential information of the learning material and constraining content-related communication. On the other hand, group awareness tools frequently provide information in a way that allows for comparing learning partners (e.g. adjacently presenting hypotheses of two learning partners), thereby guiding learners to discuss particularly beneficial issues (e.g. conflicting hypotheses as nudges for collaboratively elaborating divergent perspectives).

While all three tool features can potentially support learners in overcoming CSCL challenges, they are usually applied and investigated in combination. Thus, it is an open research question if the positive learning effects of providing group awareness information are based on only one, on two, or on all three features. In order to disentangle the effects of the underlying supporting functions in CGA tools, we propose three consecutive experimental studies that systematically vary only one of the tool features in each study (see Table 1).

Table 1: CSCL challenges and CGA tool support in collaborative multimedia learning.

| <b>CSCL Challenge</b>                          | <b>Tool Feature</b>                  | <b>Support/Function</b>                    | <b>Study</b> |
|--|--------------------------------------|--|--------------|
| connecting communication and learning material | information cueing                   | constraining content-related communication | 1            |
| establishing a common ground                   | providing partner information        | partner modeling                           | 2            |
| structuring the learning discourse             | visualizing knowledge constellations | socio-cognitive guidance                   | 3            |

Study 1 already showed that cueing relevant information in MER- and DIV-based learning material focuses learners' attention and communication to essential aspects and improves learning outcomes (Scholvien & Bodemer, 2013). This paper reports results of the second study that investigates the core feature of CGA tools (i.e., providing knowledge-related partner information). It is investigated if this feature is effective in addition to the beneficial effect of information cueing. It is hypothesized that providing partner information facilitates partner modeling, guides learning processes, and enhances learning outcomes during MER-based and DIV-based collaboration.

## 2. Method

### 2.1 Design and Procedure

In this experimental study, learning dyads were individually provided with interdependent learning material comprising either visual or algebraic information about the analysis of variance (ANOVA). Afterwards, learning partners collaborated in two subsequent phases in which they were instructed to collaboratively elaborate on statistics concepts and interrelations by means of different multimedia learning material:

During the first collaboration phase, learners are provided with static multiple external representations (MER), i.e. visualization (VANOVA; Oestermeier & Barquero, 2001) and formula components regarding the one-way analysis of variance such as observed values, experimental groups, means, sums of squares, mean squares, and  $F$  ratio.

During the second collaboration phase, this visualization was augmented by several dynamic and interactive components (DIV) that enabled participants to modify visual components (e.g., number of observed values and of experimental groups; size of observed values and group means) and to monitor the resulting effects on other components (e.g., sums of squares, mean squares, and  $F$  ratio).

Additionally, in each collaboration phase, partner information was provided in two of the four experimental groups, thus leading to four different experimental groups (MER0\_DIV0 vs. MER1\_DIV0 vs. MER0\_DIV1 vs. MER1\_DIV1; cf. Figure 1). Both collaboration phases were operated using a Samsung SUR40 multi-touch tabletop with Microsoft PixelSense that enabled face-to-face communication between learning partners as well as the synchronous manipulation of the ANOVA animation.

Prior to each collaboration phase, learners indicated their individual knowledge, i.e. assumptions on different elements and relationships within the ANOVA. Individual knowledge tests were conducted before (KT 1) and after each collaboration phase (KT 2 and 3; see Figure 1). Each knowledge test comprised three different subtests to measure conceptual knowledge, representational transfer (Bodemer, 2011) and intuitive knowledge (Swaak, de Jong, & van Joolingen, 2004). All test items were designed as multiple choice questions, including one correct answer and three distractors.

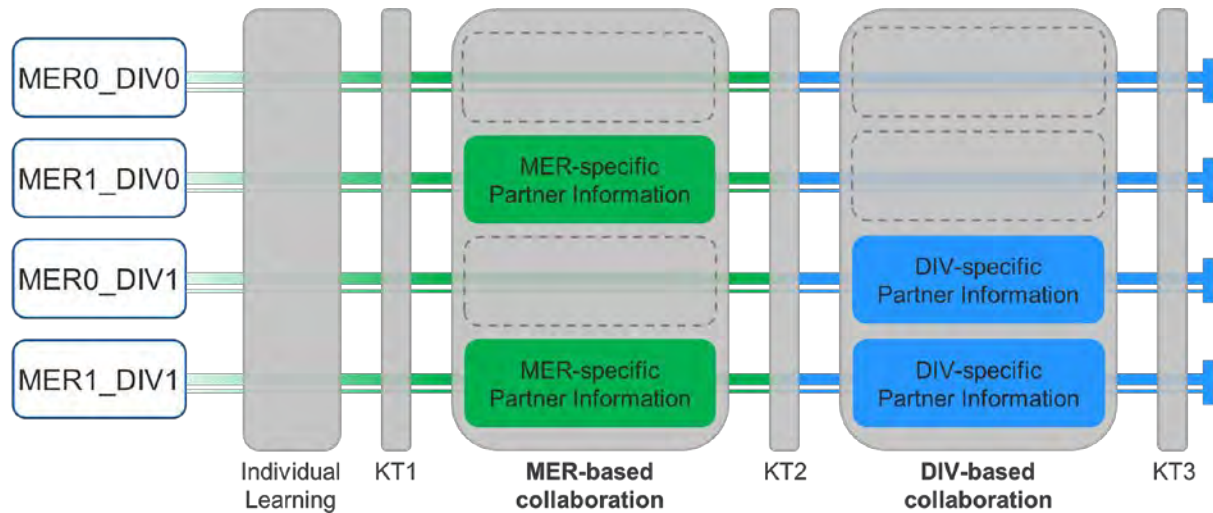


Figure 1. Experimental procedure differing with regard to four experimental groups.

## 2.2 MER-based Collaboration

Prior to the actual collaboration, each learner was requested to externalize her/his assumptions on MERs by individually integrating 13 formula-based elements into according parts of a static visualization via drag and drop. This integration task repeatedly proved to effectively support representational transfer and deep learning in individual MER-based learning scenarios (e.g., Bodemer, Ploetzner, Feuerlein, & Spada, 2004).

During the following first collaboration phase (15 minutes), learners were provided with differently coded learning material. The essential algebraic and visual elements were color-highlighted in all groups in order to keep the first CGA design feature invariant (see Figure 2a). To support partner modeling processes in two of the four experimental groups, each learner's prior assignments were presented to the respective learning partner (MER1\_DIV1 and MER1\_DIV0; see Figure 2b).

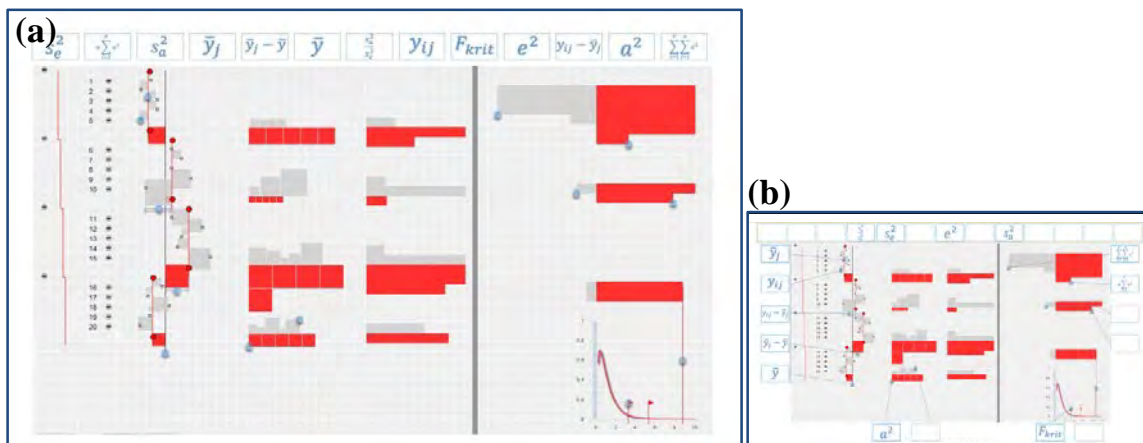


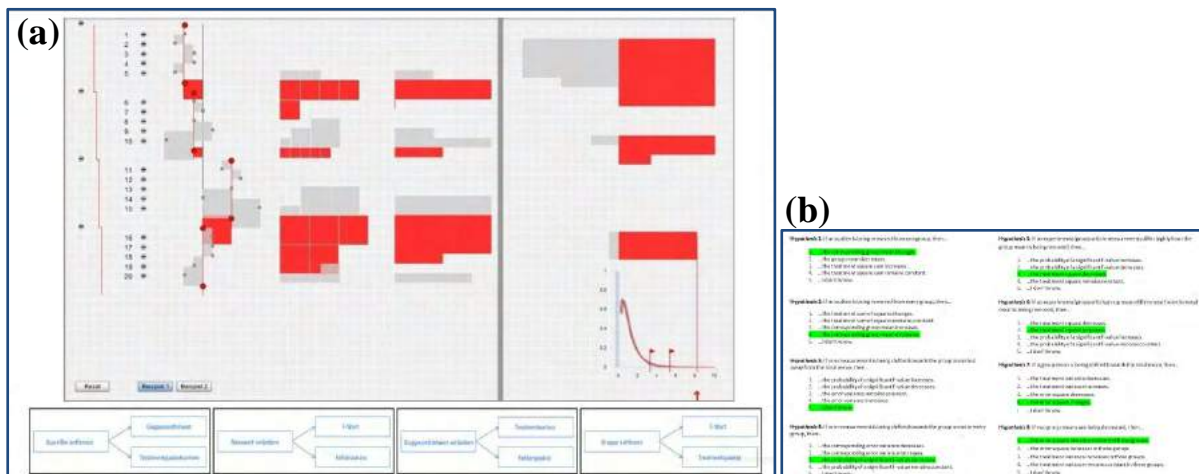
Figure 2. Screen captures of collaboration phase 1: (a) static multiple external representations (all experimental groups), (b) partner assignments (supported groups only).

As learners should not see their own assignments (enabling a comparison between own and partner information will be investigated in study 3), partner information was provided on additional laptops, which were arranged adjacently to the multi-touch tabletop.

### 2.3 DIV-based Collaboration

Analogous to the MER-based phase, learners externalized assumptions on the learning material in advance to the DIV-based collaboration phase. Each learner constructed eight hypotheses regarding interrelations of ANOVA elements using a set of predefined phrases (see Figure 3b). With respect to simulation-based discovery learning, a number of studies verified positive effects of supporting learners in generating hypotheses on collaborative processes as well as individual learning (e.g. Gijlers & de Jong, 2009; Scholvien & Bodemer, 2012; van Joolingen & de Jong, 1991).

In the following second collaboration phase (20 minutes), the visualization was enriched by several dynamic and interactive components, e.g. dragging a group mean to increase or decrease it. Essential causal relations between key elements of the ANOVA were provided beneath the animation (see Figure 3a), which, in a previous study, showed to beneficially affect learning partners' discourse as well as their individual learning outcomes (Scholvien & Bodemer, 2013). In addition, learners were provided with cognitive partner information in two of the four experimental groups. Each learner's prior hypotheses were presented to her/his respective learning partner (MER1\_DIV1 and MER0\_DIV1; see Figure 3b). Again, partner information was provided on additional laptops that were arranged adjacently to the multi-touch tabletop.



**Figure 3.** Screen captures of collaboration phase 2: (a) dynamic and interactive visualization (all experimental groups), (b) partner hypotheses (supported groups only).

### 2.4 Participants

In total, 120 university students (80 females and 40 males), aged 18-36 years ( $M = 22.38$ ,  $SD = 2.93$ ), were randomly paired into 60 dyads and subsequently randomly assigned to the four experimental groups. Participants were either paid or given a certificate needed for credits. All participants were recruited among students of a psychology-oriented degree program at the University of Duisburg-Essen, Germany, and had a basic knowledge of statistics concepts underlying the one-way analysis of variance.

### 3. Results

Due to the complex nature of the learning scenario, and to better comprehend the underlying individual and collaborative learning processes, a combination of qualitative and quantitative analyses has been applied to the data. Some analyses are still to be processed. However, essential results can be presented in the following.

#### 3.1 Learning Outcomes

To investigate the effect of providing partner information on learning outcomes, individual learning was measured by three knowledge tests, which had to be performed prior (knowledge test 1) and subsequent (knowledge tests 2 and 3) to the collaboration phases. Each knowledge test was designed to measure conceptual knowledge, representational transfer, and intuitive knowledge. As intra-class correlations (Kenny, Kashy & Cook, 2006) regarding both post-knowledge tests revealed no interdependence within learning dyads, knowledge test scores were analyzed on an individual level.

With regard to prior knowledge (knowledge test 1), a two-way ANOVA with the factors *MER-specific partner information* (with vs. without) and *DIV-specific partner information* (with vs. without) showed no significant differences between the experimental groups (MER:  $F(1, 116) = 0.58, p = .450, \eta^2 = .005$ ; DIV:  $F(1, 116) = 0.02, p = .900, \eta^2 = .000$ ; MER x DIV:  $F(1, 116) = 0.06, p = .801, \eta^2 = .001$ ). Equivalent ANOVAs were performed on knowledge tests 2 and 3 (for means and standard deviations see Tables 2 and 3).

After MER-based collaboration, particularly the main effect for providing MER-specific partner information is informative. As hypothesized, learners scored higher in knowledge test 2 (see Table 2) if they were provided with their learning partner's MER-assignments during the first collaboration phase ( $F(1, 116) = 4.55, p = .035, \eta^2 = .038$ ). According to expectations, means did not differ significantly with regard to the presentation of *DIV-specific partner information* ( $F(1, 116) = 0.02, p = .961, \eta^2 = .000$ ) and the interaction of both factors ( $F(1, 116) = 0.12, p = .729, \eta^2 = .001$ ).

**Table 2: Means and standard deviations for scores (%) in knowledge test 2 (after MER-based collaboration).**

|                                  |         | MER-specific partner information |             |          |             | overall  |             |
|----------------------------------|---------|----------------------------------|-------------|----------|-------------|----------|-------------|
|                                  |         | yes                              |             | no       |             |          |             |
|                                  |         | <i>M</i>                         | <i>(SD)</i> | <i>M</i> | <i>(SD)</i> | <i>M</i> | <i>(SD)</i> |
| DIV-specific partner information | yes     | 44.81                            | (19.24)     | 38.15    | (20.15)     | 41.48    | (19.82)     |
|                                  | no      | 46.30                            | (20.86)     | 37.04    | (21.51)     | 41.67    | (21.52)     |
|                                  | overall | 45.56                            | (19.91)     | 37.59    | (20.67)     | 41.57    | (20.60)     |

Complementary to MER-based collaboration and knowledge test 2, after DIV-based collaboration (knowledge test 3; see Table 3) particularly the main effect for providing DIV-specific partner information is informative. As expected, learners provided with their learning partner's hypotheses outperformed those learners without CGA support in this learning phase ( $F(1, 116) = 29.84, p < .001, \eta^2 = .205$ ). No significant differences occurred in this test regarding the factor *MER-specific partner information* (MER:  $F(1, 116) = 0.33, p = .565, \eta^2 = .003$ ) and regarding the interaction of both factors (MER x DIV:  $F(1, 116) = 0.03, p = .866, \eta^2 = .000$ ).

**Table 3: Means and standard deviations for scores (%) in knowledge test 3 (after DIV-based collaboration).**

|                                  |         | MER-specific partner information |             |          |             | overall  |             |
|----------------------------------|---------|----------------------------------|-------------|----------|-------------|----------|-------------|
|                                  |         | yes                              |             | no       |             |          |             |
|                                  |         | <i>M</i>                         | <i>(SD)</i> | <i>M</i> | <i>(SD)</i> | <i>M</i> | <i>(SD)</i> |
| DIV-specific partner information | yes     | 57.59                            | (12.07)     | 56.48    | (16.32)     | 57.04    | (14.24)     |
|                                  | no      | 43.15                            | (18.78)     | 41.11    | (11.36)     | 42.13    | (15.42)     |
|                                  | overall | 50.37                            | (17.26)     | 48.80    | (15.95)     | 49.58    | (16.57)     |

### 3.2 Partner Modeling

Providing partner information is expected to facilitate partner modeling, that is constructing a mental representation of the learning partner's assumptions. In order to estimate the modeling success, participants were asked to recall their learning partner's assumptions after each collaboration phase (MER-assignments after phase 1 and DIV-related hypotheses after phase 2). On this basis, the percentage of correctly memorized partner assignments could be determined. For means and standard deviations see Table 4 (assignments after MER-based collaboration) and Table 5 (hypotheses after DIV-based collaboration).

Analogous to the learning outcomes, learners performed better when they were provided with partner information in the respective collaboration phase (significant main effect for MER-specific partner information after MER-based collaboration:  $F(1, 116) = 14.17, p < .001, \eta^2 = .109$ ; significant main effect for DIV-specific partner information after DIV-based collaboration:  $F(1, 116) = 7.14, p = .009, \eta^2 = .058$ ).

Table 4: Means and standard deviations for correctly memorized partner assignments (%) after MER-based collaboration.

|                                  |         | MER-specific partner information |               |          |               | overall  |               |
|----------------------------------|---------|----------------------------------|---------------|----------|---------------|----------|---------------|
|                                  |         | yes                              |               | no       |               |          |               |
|                                  |         | <i>M</i>                         | ( <i>SD</i> ) | <i>M</i> | ( <i>SD</i> ) | <i>M</i> | ( <i>SD</i> ) |
| DIV-specific partner information | yes     | 52.67                            | (25.45)       | 34.00    | (21.11)       | 43.73    | (25.04)       |
|                                  | no      | 49.33                            | (30.51)       | 32.67    | (24.90)       | 41.00    | (28.86)       |
|                                  | overall | 51.00                            | (27.90)       | 33.33    | (22.90)       | 42.17    | (26.92)       |

Table 5: Means and standard deviations for correctly memorized partner hypotheses (%) after DIV-based collaboration.

|                                  |         | MER-specific partner information |               |          |               | overall  |               |
|----------------------------------|---------|----------------------------------|---------------|----------|---------------|----------|---------------|
|                                  |         | yes                              |               | no       |               |          |               |
|                                  |         | <i>M</i>                         | ( <i>SD</i> ) | <i>M</i> | ( <i>SD</i> ) | <i>M</i> | ( <i>SD</i> ) |
| DIV-specific partner information | yes     | 43.33                            | (31.74)       | 38.89    | (31.66)       | 41.11    | (31.51)       |
|                                  | no      | 31.11                            | (23.05)       | 23.33    | (26.48)       | 27.22    | (24.92)       |
|                                  | overall | 37.22                            | (28.19)       | 31.11    | (29.98)       | 34.17    | (29.14)       |

### 3.3 Interaction and communication behavior

To enrich the quantitative data on a deeper, more qualitative level, an insight into typical collaboration processes will be given. Therefore, the collaborative discourse of two learning dyads is illustrated and compared regarding prototypical interaction and communication patterns during their MER-based collaboration (with CGA support: Figure 4; without CGA support: Figure 5).

Figures show the communication and interaction sequence with regard to highlighted elements of the learning material (numbers in green circles) and the duration of each step of this sequence (circle size). For means of illustrating the collaborative discourse related to the learners' knowledge, all MER-assignments were added to the illustration even if they were not provided to the learners during collaboration. Assignments that were not visible to the learners are greyed out. Moreover, unequal MER-assignments (only one of the learners assigned a formula element to a particular visual element or both learners assigned different elements) are indicated by red dashed boxes.

The dyad provided with cognitive partner information (cf. Figure 4) interacted in a very structured way. First, the learning partners mainly searched for and addressed unequal assignments in the left part of the visualization (1-5), trying to clarify and solve knowledge-related conflicts. Then they continued with this systematic approach on the right and the lower right side of the visualization (6, 9-11) and thus managed to identify and discuss all unequal assignments during the first half of the

collaboration phase. After this initial work on unequal assignments, the two learners very briefly affirmed assignments they already agreed with each other. Finally, this learning dyad used the remaining collaboration time to revise the solutions regarding their initial unequal assignments (14-16), which led to a deep collaborative elaboration of involved concepts and high learning outcome.

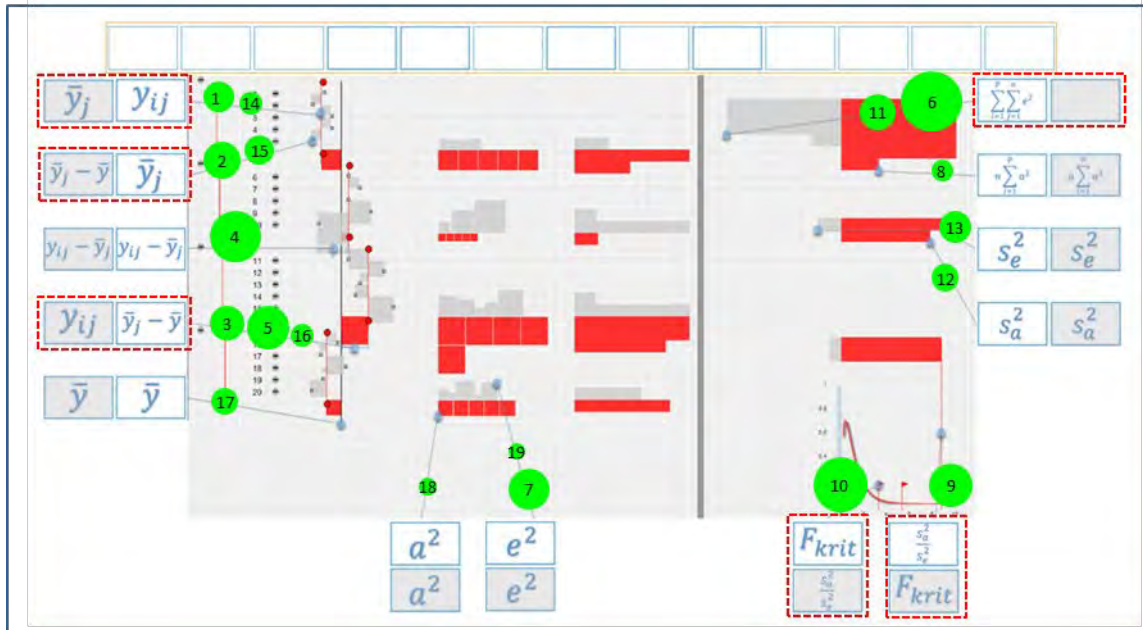


Figure 4. Prototypic MER-collaboration sequence *with partner assignments* (numbers indicate sequence of discussion, circle size indicates duration of collaboration, assignments not visible to the learners are greyed out, unequal assignments are indicated by dashed boxes).



Figure 5. Prototypic MER-collaboration sequence *without partner assignments* (numbers indicate sequence of discussion, circle size indicates duration of collaboration, assignments not visible to the learners are greyed out, unequal assignments are indicated by dashed boxes).



Learners in the unsupported dyad (cf. Figure 5) did not use the given time just as effectively. Their learning discourse was not structured in terms of knowledge constellations, that is they did not focus on searching for and discussing divergent knowledge. Rather, learning partners clarified higher-level concepts (1-2) before systematically discussing the visualization from its left part (3-6, 9-11) via its bottom part (7, 9, 12) to its right part (13, 14, 17, 18). Thereby, this learning dyad spent more time and effort on talking about assumptions they already agreed on. Consequently, they failed to identify and discuss all unequal assignments and were not able to use the learning potential of discussing controversial positions thoroughly.

#### **4. Discussion**

The presented study was the second in a series of three experimental studies that investigate functions of cognitive group awareness tools in a complex collaborative multimedia learning scenario. Overall, it confirms the expected beneficial effects of providing knowledge related partner information on learning.

Regarding learning outcomes, in both collaboration phases learners provided with learning partner assignments performed significantly better than learners without additional collaboration support. However, this benefit was found for the respective collaboration phases only, indicating that there is no transfer effect for group awareness support from one collaboration phase with CGA support to a subsequent unsupported phase. Thus, providing cognitive information on the learning partner can support conceptual learning but does not seem to instruct useful metacognitive knowledge about grounding processes. Moreover, in contrast to findings regarding individual multimedia learning scenarios (e.g., Bodemer, Ploetzner, Bruchmüller & Häcker, 2005; Swaak, van Joolingen, & de Jong, 1998), higher representational and conceptual knowledge of supported learners after MER-based learning did not lead to better learning during subsequent collaboration with dynamic and interactive material.

Furthermore, it was hypothesized that providing cognitive partner information directly facilitates modeling processes of constructing a mental representation of the learning partner's knowledge or assumptions. This hypothesis was supported by an increased ratio of correctly reminded assumptions of the learning partner when learners were provided with CGA support. Supported learners seem to have better detected partner information and to have used it for efficient grounding processes and better learning.

Finally, a first, qualitative analysis of typical learning dyads demonstrates how learners provided with knowledge-related partner information can collaborate in a very systematic and beneficial way. They can successfully and effectively identify knowledge-related conflicts and, on this basis, engage in deeper, more elaborated communication. Although these data need to be analyzed in a much more comprehensive way, these first indications are consistent with a number of studies which emphasize the importance of negotiating knowledge-related conflicts (e.g. Mugny & Doise, 1978; Webb, 1989; Weinberger, Marttunen, Laurinen & Stegmann, 2013).

Overall, the results indicate that providing cognitive partner information supports different types of collaborative multimedia learning in many aspects. In addition to overall effects of GA tools (cf. Janssen & Bodemer, 2013) and to the beneficial function of cueing relevant information (Scholvien & Bodemer, 2013), the core feature of CGA tools showed positive effects on essential learning processes and learning outcomes. The third experimental study in this series will reveal whether the third proposed design feature (visualizing knowledge constellations for comparing learning partners) is as effective for collaborative multimedia learning as the two already investigated have shown to be.

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# The appropriation of a representational tool in the second language classroom

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**Abstract:** This case study investigates the appropriation of a representational tool by students in small groups in the context of collaborative second language writing. The functions of inscriptional devices in second language classroom learning are identified: (1) referencing, (2) pinpointing, (3) accumulating, (4) prompting notice, (5) realizing parallels, and (6) promoting synergy. The study explores the beneficial affordances of the representational tool that supplement face-to-face communication for second language learning, and draws some implications for the design of collaborative L2 learning in networked classrooms.

**Keywords:** Representational tool, Networked Classroom learning, CSCL, Computer-supported language learning

## 1. Introduction

Computer-supported language learning has received attention since computers have been used for word processing, and has developed rapidly with the availability of online technologies. The use of computer-supported collaborative learning is more and more commonplace in language learning classrooms (Dooly, 2011). Technical artifacts can augment spoken and gestural communication between copresent collaborators (Roschelle, 1994; Suthers, Girardeau, & Hundhausen, 2003), and they can be embedded in classrooms where face-to-face communication is still a main channel for interaction (Lingnau, Hoppe, & Mannhaupt, 2003).

In recent years, a kind of generic representational tool—Group Scribbles (GS), which consists of a graphical shared workspace—has been codeveloped for enabling collaborative generation, collection, and aggregation of ideas through a shared space based on individual efforts and social sharing of notes in graphical/textual forms (for more information, see SRI International, <http://groupscribbles.sri.com/>). The educational benefits of representational tools have been recognized, such as when selecting relevant information, organizing information into coherent formats, or relating it to prior understanding (e.g., Liu, 2011; Stull & Mayer, 2007). Yet most of the studies focus on reporting the positive or negative effects of them on the students' learning performance or learning motivations (Hwang et al., 2014) or accentuate how to design or script a representational tool in online learning. Less attention (Overdijk & van Diggelen, 2008, as an exception) is paid to how groups of learners appropriate a representational tool in a classroom environment in which face-to-face communication is an integral part of the learning interactions, and to how technical artifacts mediate face-to-face communication.

Situated in a Chinese as second language (L2) learning classroom setting equipped with GS, the study aims to explore the beneficial affordances of the representational tool that supplement face-to-face communication for *group understanding development* (in this study, it is an operational definition of group's collective thinking for judging group performance, including both mutually and partially shared meaning) in L2 learning classrooms, and thus provides insights to task/script design and enactment of collaborative L2 learning in networked classroom environments where face-to-face and online interactions are intertwined.

## 2. Literature Review

## *2.1 Use of representational tools*

Prior research on CSCL has highlighted the importance of representational aids, such as dynamic notations, knowledge maps, and simulation for collaborative learning performance (Fischer et al., 2002; Janssen et al., 2008; Slob et al., 2010; Wegerif et al., 2010). Embedding representational tools in a CSCL environment can facilitate students' construction of multimodal representations of the domain knowledge and thereby guide their interactions (Slob et al., 2010). Through representing ideas and understandings on the shared work space, students' thinking is made public and exposed to critical scrutiny, during which cognitive development can occur (Liu & Kao, 2007). Suthers and Hundhausen (2003) have concluded that external representations play at least three roles that are unique to situations in which a group is constructing and manipulating shared representations as part of a cognitive activity. They are: (1) initiating negotiation of meaning; (2) serving as representational proxy for purposes of gestural deixis (reference to an entity relative to the context of discourse by pointing) rather than verbal descriptions; and (3) providing a foundation for implicitly shared awareness. Although the educational benefits of representational tools are widely recognized, some studies report mixed or even negative findings and thus question how students' interaction can best be guided (e.g., Bera & Liu, 2006; Elen & Clarebout, 2007).

In accordance with other computer-mediated communication tools used in education, the presence of a representational tool in the classroom alone does not automatically benefit students' learning (Slob et al., 2010). A given tool offers affordances that may influence how learners engage in knowledge construction (Kozma, 2003; Suthers & Hundhausen, 2003) but do not causally determine their learning outcomes (Hakkarainen, 2009; Medina & Suthers, 2012). Technology does not determine the nature of its implementation but coevolves with gradually transforming instructional practices (Tuomi, 2002). Learners can appropriate the multimodal resources for their own purposes, and this appropriation (as well as the influence of the technology) can develop over time (Medina & Suthers, 2012). Even though there are stable characteristics of tools that are generalizable over different settings, the tools can be appropriated in unexpected ways (Dwyer & Suthers, 2006; Overdijk & van Diggelen, 2008). Different groups evolve alternative approaches to representational practices with the affordances of representational tools (Larsson & Alterman, 2007). It is like what Carrol et al. (2002) pointed out that appropriation can be seen to be a process which combines technological determinism (that affords and constrains certain activities and partly determines the boundaries around the activities that are possible) with social shaping within these boundaries. Only when collaborative technologies (including representational tools) have been fully fused with social practices of teachers and students, are their intellectual resources genuinely augmented and learning achievements correspondingly facilitated (Hakkarainen, 2009). Therefore, this study focuses on analyzing how the GS representational tool was brought into use in a good lesson.

## *2.2 Analytic frameworks for investigating interaction in CSCL*

During the past decade, analytic frameworks and approaches for analyzing interaction in CSCL have been getting increasingly sophisticated. It is posited that the methodological uniqueness of CSCL research "is reflected in the several approaches that have been put forth to document and analyze collaborative interactions" (Puntambekar et al., 2011, p. ix). These frameworks/techniques are used for examining interactions in different representational formats (e.g., forum-based or mapping-based) and with different analytic foci and assumptions about what it means for participants to achieve a conceptually deeper level of interaction.

As whether only the temporal issue (or the chronological dimension) is taken into account, they can be classified into two major categories: (1) the nature of the function of participants' contributions in the dialogue and (2) patterns and trajectories of participant interaction. Besides, the bulk of the analytical frameworks/techniques are applied to examine interaction happening in a single dialogue-based interaction environment, and only a few revolve around interaction happening in dual-interaction spaces (e.g., Hmelo-Silver et al., 2011; Suthers & Rosen, 2011). Furthermore, none of them is specific for analyzing interaction in language learning. In the study reported here, open coding is adopted.

### 3. Methods

This case study was derived from a 5-year project that integrates GS in language learning for sustaining collaborative activities in language learning classrooms. The “ideal” case lesson was the last GS lesson of a semester. This lesson was selected in terms of the reflection from the teacher and students. As the teacher mentioned her post-lesson interview “today’s lesson is completed smoothly as we planned...”

#### 3.1 Participants

The subjects of this study were from a class of a secondary school (Grade 8). The class consists of 6 female students and 13 male students (aged from 14-16). In every GS lesson, these 19 students were separated into five groups based on their previous school examination scores for the Chinese language subject. A comparative high-ability group, a medium-ability group, a comparative low-ability group, and two mixed-ability groups were formed. In order to build and sustain the group culture, the group compositions remained unchanged from the beginning stage till the end of the implementation of this study. The last GS lesson was selected on the assumption that the teacher and students had developed familiarity with GS-based collaborative activities.

#### 3.2 Learning environment and the activity design

Figure 1 shows the GS classroom environment where 3-4 students sitting in groups, and each of them had their own laptop to access and use the GS tool. An Interactive Whiteboard was set up in front of the classroom to help the teacher to visualize and monitor the interaction processes of every single group.



Figure 1. GS classroom environment

The lessons were about collaborative L2 writing. The main learning objective of the lesson reported in this paper was to help students understand that an argumentative essay can be conceptualized and composed from exploring the contributing factors of a phenomenon, followed by finding its impacts and providing solutions if needed. In the GS tool, a template (Figure 2) was uploaded as the background in order to provide tangible scaffoldings for students to follow the teacher’s instruction (Wen, Chen & Looi, 2011) and to allow them to pay attention to the three elements (cause, consequence, and solution) necessary in writing an argumentative essay.

| 整容现象产生的原因: | 这一现象导致的后果:   | 解决方法:     |
|------------|--------------|-----------|
| Causes     | Consequences | Solutions |

Figure 2. A graphic organizer for the planning task

### 3.3 Data collection and analysis

The main data sources for this study were the video data of the face-to-face and GS-based interactions in the various groups. In addition to video cameras, the iShowU screen-capturing was installed on every student's MacBook to record all the actions of individual students on the computers, as well as their verbal talks and facial expressions.

For the data analysis, all the video data were first transcribed verbatim, synchronized and presented chronologically. Then all the interaction data were coded on the multiple levels with different dimensions. At the macro-level, the interaction data were coded back and forth with two dimensions: the medium and functions of interactions using the unit of "event". "Event" in this study referred to a series of uninterrupted interaction moves with the same semantic content that happened through the same medium. It could be a two minutes long conversation as long as the participants were talking about the same topic unceasingly. It also could be as short as one verbal sentence or a single GS posting.

This study aims to investigate students' interactions across face-to-face and online interactional spaces. Student's interactions in the unit of event were categorized into face-to-face-based and GS-based in terms of medium, and then these events were further categorized in terms of the *function* performed to complete the task: whether it is social-related or cognitive-related. Additionally, as the study is focused on exploring the trajectories of group understanding development, any events regarding off-task issues, such as technical problems, jokes, greetings etc., would not be included in the data analysis of this study. In view of these, all the events were classified into three categories related to functions performed to complete the task: cognitive-related, social-related, and off-task. In the study, the "social-related" category termed as "Regulation", refers to interactions about regulating and coordinating group work. Taking account of the characteristics of L2 learning, the "cognitive-related" interactions were further categorized into two sub-categories: Content-related and Language-related. These categories were established as the result of a repeated process of iterating back and forth between theory and data (Onrubia & Engel, 2012).

| Diagram Representation |              | Content   | Participants                 | Note & Interpretation   |
|------------------------|--------------|---|------------------------------|---|
| GS                     | Face-to-face |   |                              |   |
| 3G1                    | 3C4          | <ul style="list-style-type: none"> <li>➤ T: 这边呢? 分类怎么样了?<br/>[How about here? How about your classification?]</li> <li>➤ William: 我们用那个“五指山”来分类。<br/>[We classified based on “Five fingers”.]</li> <li>➤ T: 对, 五指山。对, 所以呢?<br/>[Yes, “Five fingers”. All right, then?]</li> <li>➤ William: 我们有对自己不满, 比如说对自己不满, 嗯, 还有家庭的原因。<br/>[We have “not satisfied with own appearances”. Eh, also have reasons from the family perspective.]</li> <li>➤ T: 家庭会有什么原因啊? 什么原因会是家庭的?<br/>[What kind of reasons from the family perspective? What kind of reasons belongs to the family's]</li> <li>➤ William: 嗯...<br/>[Eh...]</li> <li>➤ Sophia: 家庭也可以是兄弟姐妹的事。<br/>[It could be about brothers or sisters.]</li> <li>➤ T: 对, 可以写兄弟姐妹的影响。<br/>[Yes, can write something effects from brothers and sisters.]</li> </ul> | Teacher, William, and Sophia | <ul style="list-style-type: none"> <li>❖ When Group 3 was on the point of re-organizing their existing postings, the teacher intervened and asked the students about their work progress.</li> <li>❖ William responded to the teacher that they had contributed some ideas from “the personal perspective”, but it is worth noting that “reasons from the family perspective” never occur in this group's previous discussion. It seems that this a new idea that has popped up in William's own mind.</li> </ul> |
|                        | 3R4          | <ul style="list-style-type: none"> <li>➤ Sophia: 我来, 我写。<br/>[I do it, I write it]</li> </ul>   | Sophia                       |   |
| 3G7                    |              | <p style="text-align: center;">[Because people (friends or families) like to compare him with his brothers and sisters. E.g., saying the elder brother is more handsome than the younger.]</p> <p style="background-color: #e0f0ff; padding: 5px;">因为人(朋友/家庭)一直把他跟兄弟姐妹一起比。比如: 说哥哥比弟弟帅。</p>  | Sophia                       |   |

#### Legend:

3G1 refers to group 3's first GS posting (the small rectangle in broken link means the posting is not newly created).

3G7 refers to group 3's seventh GS posting

3C4 refers to group 3's fourth Content-related verbal conversation

3R4 refers to group 3's fourth Regulation-related verbal conversation

Figure 3. Diagram for analyzing across-media interaction at the micro-level

Coding on the macro-level provided an objectively “first pass” about the interaction distribution. Then on the micro-level, the interaction sequences and contextual information were taken into consideration in coding. A kind of diagram was created to visualize the sequence of interaction events and their relations (Figure 3). As shown in the figure, the flow from top to down denotes the time sequence. GS postings and verbal conversations are presented in two separated columns. Their content is shown in the central big column. The information regarding participants, media and functions of interactions could be obtained from the diagram directly. Two other concepts were proposed to help identify the medium transition (interactions happened across different media). One is “*cross-media adjacency events*”. These are represented in solid lines with arrow, to signify the adjacent cognitive meaningful events spanning different medium spaces. The other is “*cross-media responses*” which indicate that those cross-media interactional moves happened between GS postings and social-related/off-task events (represented in broken lines). They are represented by dotted in the diagram. In this study, we focused mainly on “cross-media adjacency events”.

In sum, this is a pre-dominantly qualitative case study. Quantitative information about interaction distribution in different small groups is mainly provided to help select and interpret the interesting excerpts for micro-level analysis.

## 4. Findings

### 4.1 Interactions with various content via different media

Table 1 shows the medium distribution of the interactions in different groups. In addition, the results noted that task management-related communication or coordination, and even off-task interactions, did not occur in the GS environment. That meant the GS environment mainly served as a shared external memory where the group kept a record of shared understandings. Face-to-face interactional event, however, could be classified into different categories of function (see Table 2).

**Table 1:** Description of group interactions in different media spaces

| Group \ Medium                           | Homogeneously high-ability group | Heterogeneously high-ability group | Homogeneously middle-ability group | Heterogeneously middle-ability group | Homogeneously low-ability group | Total      |
|--|----------------------------------|------------------------------------|------------------------------------|--------------------------------------|---------------------------------|------------|
| No. of face-to-face interactional events | 102 (25.95%)                     | 95 (24.17%)                        | 72 (18.32%)                        | 71 (18.07%)                          | 53 (13.49%)                     | 393 (100%) |
| No. of GS postings                       | 51 (34.23%)                      | 21 (14.09%)                        | 18 (12.08%)                        | 31 (20.81%)                          | 28 (18.79%)                     | 149 (100%) |

**Table 2:** The distribution of face-to-face interactional events in different groups (N =393)

| Group \ Function | Homogeneously high-ability group | Heterogeneously high-ability group | Homogeneously middle-ability group | Heterogeneously middle-ability group | Homogeneously low-ability group | Mean (SD)  |
|------------------|----------------------------------|------------------------------------|------------------------------------|--------------------------------------|---------------------------------|------------|
| Content-related  | 48 (47.1%)                       | 38 (40.0%)                         | 27 (37.5%)                         | 27 (38.9%)                           | 27 (50.9%)                      | 33 (9.628) |
| Language-related | 3 (2.9%)                         | 5 (5.3%)                           | 11 (15.3%)                         | 9 (12.7%)                            | 6 (11.3%)                       | 7 (3.535)  |
| Regulation       | 39 (38%)                         | 45 (47%)                           | 26 (36%)                           | 31 (44%)                             | 16 (30%)                        | 15 (8.031) |
| Off-task         | 12 (11.8%)                       | 7 (7.4%)                           | 8 (11.1%)                          | 4 (5.6%)                             | 4 (7.5%)                        | 7 (3.317)  |
| Total            | 102 (100%)                       | 95 (100%)                          | 72 (100%)                          | 71 (100%)                            | 53 (100%)                       | 78 (19.83) |

The quantitative data suggested that all the groups actively participated in completing the task (mean of Off-task =7, SD =3.317). The empirical data showed that group language competency influenced the way in which the representational tool was appropriated. The results indicated that group language proficiency restricted L2 learners’ involvement in verbal talk, especially when they were encouraged to communicate in the target language. Yet its influence on their involvement in online interaction was not so compelling (shown in Table 2). Groups with higher language proficiency tended to focus more on content-related knowledge talk than on language-related knowledge talk (shown in Table 2).

#### 4.2 Interplay between medium transition and group understanding development

Zooming in on the co-construction process of group inscriptions, the analysis of both cross-media adjacency events and cross-media responses helps to identify the semantic and temporal relationship among face-to-face and GS-mediated interactions and to understand the kind of situations in which group understanding development occurred more effectively. Beyond the understanding that the representational tool served as an external shared space where small groups kept a record of shared thinking (Suthers & Hundhausen, 2003), the role of inscriptional devices in group understanding development was further identified and demonstrated through the qualitative microanalysis of the interactions. In this sense, the findings revealed the fabrics of common ground in a classroom environment with representational tools. Table 3 shows a summary of the patterns of medium transition, their corresponding trajectories of group understanding development, and the role of inscriptional devices functioned.

Table 3: the summary of findings

| Pattern of medium transition | Trajectories of group understanding development  | The role of inscriptional devices |
|------------------------------|--|-----------------------------------|
| GS→CONT                      | <ul style="list-style-type: none"> <li>Provide comments towards the existing posting but without changing its content.</li> </ul>  | Referencing                       |
| GS→LANG                      | <ul style="list-style-type: none"> <li>Inquire about the pronunciation or meaning of specific characters/phrases relevant to the posting.</li> </ul>   | Pinpointing                       |
| GS→<br>CONT<br>(LANG)<br>→GS | <ul style="list-style-type: none"> <li>Read out the written content of an inscription.</li> <li>Promote verbal discussion by pointing out the improper content in the inscription or the content that could be better written, or providing a new idea relevant to the inscription.</li> <li>Pool knowledge to polish the sentence/idea, and reach a consensus. Language-related problems may emerge in content-related discussion, and they can be solved implicitly or explicitly.</li> <li>Complete/repeat the sentence verbally.</li> <li>Type out the sentence without any change in GS.</li> </ul> | Promoting synergy                 |
| CONT<br>(LANG)<br>→ GS       | <ul style="list-style-type: none"> <li>Attempt to start a topic with fragmented words or phrases.</li> <li>Assemble or link words/phrases into a complete sentence without explanations. (Language-related problems may be proposed and solved in this process as byproducts).</li> <li>Type out the sentence verbatim in GS.</li> </ul>   | Accumulating                      |
| CONT<br>(LANG)<br>→ GS       | <ul style="list-style-type: none"> <li>Verbalize individual ideas.</li> <li>Help one another to express ideas clearly and precisely, involving questioning, interpreting, exemplifying etc.</li> <li>Organize and summarize the ideas that have been co-constructed in verbal form.</li> <li>Translate the summarized ideas into text concurrently.</li> </ul>   | Realizing parallels               |
| LANG<br>→ GS                 | <ul style="list-style-type: none"> <li>Ask for help explicitly to complete the text, when a student needs to express an idea to start or continue his/her work.</li> <li>Collect informative linguistic knowledge to translate content, and reach a consensus once a “correct” answer is given. During this process, students are able to clarify the ideas that they would like to externalize and their understanding on the ideas from others.</li> <li>Transform the idea into an inscription.</li> </ul>  | Prompting notice                  |

According to the empirical data gained, when the inscriptional device functioned as *referencing*, *pinpointing*, or *accumulating*, the corresponding interactional moves were comparatively less cognitively demanding. Contrarily, when the role of inscriptional devices functioned as *promoting synergy*, *realizing parallels*, or *prompting notice*, the corresponding interactional moves were more cognitively demanding and more productive group interactions occurred, because students engaged in



searching information, explaining, elaborating, and summarizing. It has been widely reported in educational literature that such kind of cognitive engagement requiring higher-order-thinking skills is critical to meaningful learning (e.g., Zhu, 2006). Nevertheless, as observed, this is not always the case that groups with higher language proficiency more frequently draw upon the inscriptional device as *promoting synergy*, *realizing parallels*, or *prompting notice* in group understanding development.

The quantitative data above indicated that group language proficiency influenced the occurrence frequency of language-related talk. Theories of second language learning (e.g., the Noticing Hypothesis from Schmidt, 1990, and the Output Hypothesis from Swain, 1985) have emphasized that the learner's attention to language as an object while engaged in communication is beneficial for L2 learning. Two patterns of medium transition relating to language-related talk and their effects on a small group's L2 development were distinguished. Corresponding to the pattern of medium transition—LANG→GS—the role of inscriptional devices in group understanding development was *prompting notice*. The activity of producing the target language on GS space prompted students to consciously recognize some of their linguistic problems, and this triggered cognitive processes in which group members co-constructed or consolidated their existing linguistic knowledge and created a new posting that was accepted by all of them. Corresponding to the pattern of medium transition—GS→LANG—the inscriptional device functioned as *pinpointing*, which had an emphasis on prompting individuals to inquire about the pronunciation or meaning of specific characters/phrases on the posting. Since no subsequent improvement or creation of a new group inscription can be observed in this pattern, it is difficult to judge whether the mutual understanding is successfully established by all group members. In other words, when the role of inscriptional devices functions as *pinpointing*, group understanding development can be observed but its effectiveness cannot be guaranteed.

The qualitative microanalysis of interaction also revealed that language-related talk often intertwined with content-related talk. Once verbal talk went beyond language-related knowledge, the talk would not be dominated by the authoritative group members, and hence all the members could have comparatively equal opportunities to contribute to their group work. Instead of solely compensating for deficient language-related knowledge, students constantly ventured new ideas and updated their common ground. In such a process, more language-related problems might emerge. Along with this, they effectively constructed and consolidated understanding of both content-related knowledge (including understanding of the given topic and the writing strategy) and language-related knowledge. Nevertheless, it is also worth mentioning that even though corresponding to the same pattern of medium transition, the inscriptional device can function differently. As summarized in Table 3, they can function as accumulating and realizing parallels in the pattern of medium transition—CONT→GS. The data indicated that when the inscriptional device functioned as *accumulating*, the group understanding development seemed less productive. This is because students initially had no clear idea about what they intended to express and they did not seek to find out and fill gaps in their knowledge resources. However, in some cases, students co-constructed ideas from different perspectives through developing an intersubjective orientation toward one another based upon exploratory talk, and then rendered their individual ideas simultaneously. In doing so, productive group understanding development occurred and the role of inscriptional devices was *realizing parallels*. Besides, the role of inscriptional devices as *promoting synergy* in the pattern of medium transition—GS→CONT→GS, which contrasts with its role as accumulating in CONT→GS, put an emphasis on online inscriptions, which are more persistent and may be from other groups, rather than only ephemeral intragroup verbal talk.

The data drawn from cross-media adjacency events also indicated that the role of inscriptional devices was task sensitive. For example, at the first phase of the task, the students were encouraged to provide their own ideas in an initial text. In doing so, the inscriptional device mainly functioned as referencing or pinpointing. At the final phase of the task, however, the students were required to discuss with one another, modify existing inscriptions and create truly shared group inscriptions as products of their collaborations. Even though different small groups still appropriated GS in different ways, the inscriptional device functioned more as promoting synergy, realizing parallels, or prompting notice in more productive group understanding development in all groups. In other words, there was not just one way to utilize the tool to perform the task, and the students were required to make choices.

## 5. Discussion and Conclusion

Situated in a setting of L2 learning, this study focused on investigating the appropriation of a representational tool in the classroom at the level of the small group. A major concern of this study was to examine how small-group task completion is contingent on cross-media interactions, to explore the temporal scope of this contingency as mediated by persistent inscriptions. The case was selected and investigated when the participants have truly gone through the expansive learning that is required for cultivation of novel computer-mediated collaborative practices of working creatively with knowledge.

The study established a connection between the pattern of medium transition and the trajectory of group understanding development, what was investigated through cross-media adjacency events. The results indicated that using the representational tool—GS in L2 classrooms—is beneficial for collaborative language learning. Empirical data evidenced that different small groups evolved alternative approaches in carrying out the tasks; group language competency, and task design influenced the way in which the representational tool was appropriated. The inscriptional device had significant effects on the students' interactions and had different influences on group understanding development. Stated succinctly, this study provided empirical data to illustrate some of the mutual influences between the tool and the participants.

According to the findings, a number of beneficial features of the representational tool supplementing rather than substituting face-to-face communication within a single language learning class can be summarized. Here we need not elaborate any further on the obvious advantages of online representational effects on enlarging the bandwidth of resource sharing, compared to the traditional use of pen and paper (e.g., the convenience of intergroup interaction without physical movement). The beneficial features of the online representational tool are elaborated by emphasizing its complementary role in the improvement of L2 learning in a classroom environment.

First, *online interaction tends to feature more balanced participation than face-to-face discussion, and online interaction is juxtaposed with face-to-face interaction, and thus students with higher language proficiency are less likely to dominate the group work.* The observation made in this study indicated that all small groups, regardless of their language proficiency, were willing to externalize their ideas or to help improve postings from others, whereas group language proficiency restricted their involvement in verbal talk, especially when asked to communicate in the target language. This result is consistent with the literature on computer-assisted language learning which shows that L2 learners tend to participate more equally and take more risks to experiment with ideas (try more creative ideas) in online environments than in traditional face-to-face classroom environments (e.g., Warschauer, 1999).

Second, *embedding representational tools in classroom learning empowers students to notice their linguistic problems and incorporate knowledge from others to solve problems, and meanwhile the shared space for the co-construction of group output (inscriptions) gives way to discussion about and justifications of representational acts as well as inducing knowledge sharing.* The results indicated that the activity of producing inscriptions in the target language prompted students to consciously identify gaps in their own knowledge, and this triggered cognitive processes in which group members co-constructed or consolidated their existing linguistic knowledge and generated a new posting that was accepted by all of them through verbal discussion (e.g., in the pattern of medium transition LANG→GS, the inscriptional devices function as prompting notice). Therefore, in the context of language learning, the co-construction of inscriptions can be deemed as “writing to learn” (Williams, 2012), which promotes learning content knowledge as well as knowledge about the language (Hirvela, 1999). Previous literature has found that compared to other forms of language use, written record pushes learners to demand greater precision, which may encourage them to consult their explicit knowledge (Williams, 2012).

Third, *the contributed inscription reminds participants of previous ideas and initiates elaboration or negotiation on them, and possibly serves as resources for the emergence of new ideas/perspectives.* In this case study, we see the high frequency of occurrence of the medium transition from GS inscriptions to face-to-face discussions, and some of them are accompanied by the creation of new GS inscriptions. The qualitative microanalysis of interaction has suggested that group understanding develops productively in the pattern of medium transition—GS→CONT→GS, where the inscriptional device plays a role as promoting synergy. In semiotic terms, the inscriptions are representations not by reference to fixed concepts but by being in contextually defined relations to the situation at hand (Goodwin, 2003). Therefore, it is explained that the persistent inscription providing semiotic resource evokes and facilitates subsequent negotiations of meaning (Medina & Suthers, 2012;

Suthers & Hundhausen, 2003). On the contrary, when the group's verbal talk takes place without referencing to a prior inscription, the group understanding development is usually less productive as participants construct inscriptions without contextually making meaning (e.g., in the pattern of medium transition CONT→GS, the inscriptional devices function as accumulating).

In sum, the results of the study add to a growing research indicating the effects of representational tools on learning (especially on L2 learning). It is emphasized that the use of representational tools or the high frequent medium transitions does not necessarily imply that learning is effectively taking place. Exploring and understanding the specific functions of inscriptional devices in depth and in situ help us reflect on some of the practical implications of the findings and the discussion above for suggesting pedagogical design improvements by integrating a representational tool such as GS to facilitate language learning. However, this case study does not aim at predicting that all the identified functions will be played out in all the representational tool-supported L2 learning contexts. The scope of the study is limited to the examination of interactions that occurred among a class of small groups of students. As a result, the major limitation of the study is about the generalizability of the findings. In order to generalize the findings, there is a necessity to examine the appropriation of the representational tool in other lessons, with diverse task designs.

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# Using Content Analysis to Check Learners' Understanding of Science Concepts

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**Abstract:** The ongoing EU project JuxtaLearn aims at facilitating the acquisition of science concepts through the creation and sharing of videos on the part of the learners. For the specific learning targets threshold concepts are specified as key elements of knowledge. Content analysis techniques are used to extract learners' concepts manifested in textual artifacts and to contrast these with the anticipated domain concepts (represented as ontology). Deviations between student concepts and the ontology can indicate problems of understanding, which may trigger a revision of the original curriculum. In two studies we explore the potential of (semi-)automated artifact analysis to identify and characterize the students' comprehension problems around knowledge artifacts. In the first study, protocols from a "flipped classroom" style teacher-student workshop are analyzed. The second study analyses comments to videos from educational video platforms. Here, we have applied text analysis methods to identify potential problems of understanding. Also, we have used "signal words" and their relations to domain concepts to highlight potential information needs and problems of understanding.

**Keywords:** conceptual change, network text analysis, STEM learning, video based learning

## 1. Introduction

The on-going European project JuxtaLearn aims at fostering learning and curiosity in different fields of science (or STEM) by combining or "juxtaposing" the understanding of domain concepts with performing. Concretely, the students' performance is substantiated in the form of creative video making and editing activities. We see this way of learning by performing and presenting as a variant of Papert's "constructionism" (Papert & Harel, 1991) and as similar to learning by teaching (Gartner, Kohler, & Riessmann, 1971). In this context, we are interested in studying the role of video as a medium for learning in different (including passive) forms of usage.

The design of learning activities in JuxtaLearn is guided by previously identified threshold concepts (Meyer & Land, 2003). Threshold concepts are the basis for reinforcing deeper understanding and further creative production through scaffold reflections focused on essential elements. To identify such concepts and to explore how they are understood and appropriated by teachers and students, a series of face-to-face workshops has been conducted. Following an initial workshop with science teachers, a second workshop also involved a group of six A-level students. The workshop was structured employing a role reversal with students exposing central ideas from the domains as a first step. This enabled the teachers to elicit a deeper understanding of the gaps in the students' knowledge. In our study, this was the first target of applying Learning Analytics techniques to extract structured representations of the underlying conceptual relations.

Since at this point of development the project had not yet produced collections of student-created videos, we have also tried to identify processes of understanding around videos by analyzing existing web-based learning communities, namely from Khan Academy. Since videos from Khan Academy are hosted and therefore also available on YouTube as a less "educationally guided" environment, we were able to compare comments from both contexts. We only analyzed questions and answers, not the videos nor their contents.

We were particularly interested in extracting information from these texts to shed light on the following aspects:

- Associations of concepts (which may be adequate or inadequate from a scientific point of view);

- Concepts that are frequently addressed in questions as indicators of possible origins of problems of understanding;
- Associations between concepts often used in answers as indicators for missing relations in the original understanding

We used these indicators to infer possible misconceptions and “stumbling blocks”. As known from classical learner modeling (Wenger, 1987), we had to distinguish between missing knowledge about concepts and/or relations and misconceptions as often idiosyncratic constructions of incorrect knowledge. An example of a misconception (beyond missing knowledge) would be an in-correct association between two or more concepts.

## **2. A Network Perspective on Conceptual Models and Conceptual Change**

### *2.1 Application of text mining techniques on learning data*

In various scenarios of learning, knowledge building and knowledge production, humans externalize their knowledge in terms of “knowledge artifacts”, which are often represented in the form of texts and thus susceptible to being analyzed by text mining (Heyer, Quasthoff, & Wittig, 2006). Content analysis, as a form of artifact analysis, can be used to reduce qualitative textual data into clusters of conceptual categories aiming to unfold patterns and relationships of meaning (Julien, 2008). Although several (semi-)automated methods can be used to detect these patterns from content, e.g. statistical methods based on the Vector Space Model (VSM) or Latent Dirichlet Allocation (Blei, 2012) as a probabilistic method, these methods are barely used on learning data, so far (He, 2013). Content analysis in the context of learning data has primarily been used for clustering resources, e.g. the grouping of e-learning resources according to their similarity (e.g. Hung, 2012; Tane, Schmitz, & Stumme, 2004). Sherin (2012), however, found that even without using semantic background knowledge, a Vector Space Model (VSM) based clustering of spoken word transcripts is an adequate instrument to identify student’s concepts and the dynamics of their mental constructs. Additionally, He (2013) provided evidence that similar techniques are suitable for grouping learners’ main topics in student-to-teacher online questions and peer-to-peer chat messages related to online video learning lessons.

The aforementioned methods are based on the “bag of word” model, in which the given order of words in a text is of no relevance to the analysis (Blei, 2012). A method that takes the words’ positioning into account is the Network Text Analysis (NTA). NTA is a text mining method, which is based upon the assumption that knowledge can be modeled as a network of concepts (Carley, Columbus, & Landwehr, 2013). Against this background, a concept is a single idea, which is represented by one or more words in a network (nodes). The links representing semantic relationships between these words (edges) are differing in strength, directionality and type based on the words’ position to each other in the text (Carley, Columbus, et al., 2013). The union of all relations builds the semantic network (Carley, Columbus, et al., 2013), similar to the relational network of a concept map. Similar to text networks, concept maps are networks in which knowledge is represented by concepts and their relationships to each other. They differ from text-based semantic networks inasmuch as they are arranged hierarchically with the ontological root concepts at the top (Novak & Cañas, 2008). In the context of knowledge construction research, concept maps are often used to trace the student’s knowledge development (Engelmann & Hesse, 2010; Engelmann, Dehler, Bodemer, & Buder, 2009; Schreiber & Engelmann, 2010).

### *2.2 Representation of conceptual models as text networks*

Jacobsen and Kapur (2010) have suggested to conceive learners’ mental models or “ontologies” as scale-free networks, which would allow to apply known characteristics of such networks to theories of conceptual change. According to Barabási (2009) the evolution of scale-free networks can be explained by the mechanisms of “preferential attachment”. Applied to learners’ ontologies, preferential attachment means that newly learned concepts are most frequently associated or linked to those concepts that are already more densely connected than others. From this, Jacobsen and Kapur (2010) conclude that such “hubs” i.e. nodes with a relatively high degree centrality, represent root categories of knowledge domains. Hoppe, Engler and Weinbrenner (2012) support this theory in a study in which the volunteers had to create concept maps on the subject of global warming. This study clearly showed a scale-free nature of the maps in terms of an inverse power law degree distribution (a known structural characteristic of scale-free networks). This implies that there are more hubs than to be expected in a

randomly connected network. Also, Hoppe et al. (2012) could show that certain known graph-theoretical structural measures correlate with quality judgments of these maps by independent experts. Interestingly, the “density” measure is negatively correlated with the criterion of map “completeness”, which is significant. Again the scale-free model provides a clear explanation: In a growing scale-free network the density is anti-proportional to the size of the network, i.e. the smallest networks will show the highest density. Based on this characterization, the authors hypothesize that newly appearing hubs represent ‘hot spots of conceptual change’ (Hoppe et al., 2012, p 297), whereby this change describes a restructuring process, in which learners revise their false beliefs and misconceptions on the relational or ontological level (Chi, 2008). If the number of edges around a node is suddenly reduced, this may indicate a qualitative change of understanding or a paradigm shift (Hoppe et al., 2012). Viewing concept maps as networks allows for applying a variety of techniques known from Social Network Analysis (SNA - cf. Wasserman & Faust, 1994). As an example, the betweenness centrality measure is suggested as a possible indicator to identify “bridge concepts” that link different knowledge domains (Hoppe et al., 2012). It is important to note that the results of NTA (see above) are also networks that can be further analyzed in the same way as concept maps. This would also allow the comparison of textual input (e.g. from student essays, wikis etc.) with concept maps.

Our basic idea and approach is to use content analysis techniques to generate network representations from knowledge artifacts originally created by students or experts and to apply structural and differential (comparative) measures to these representations in order to detect similarities or mismatches. In this approach, expert maps or ontologies can be used as “normative” references for comparison, e.g. to indicate deviations from standard domain knowledge and possible misconceptions. Regarding the evolution of maps, certain structural features and anomalies can also be detected.

### **3. Text-based Content Analysis: Method and First Results**

#### *3.1 Network Text Analysis*

According to Carley and colleagues (2013), the NTA workflow consists of three main steps: (1) data selection and extraction, (2) text pre-processing and (3) network analysis. We have applied this technique using the AutoMap/ORAs toolset for NTA (Carley, Columbus, et al., 2013; Carley, Pfeffer, Reminga, Storrack, & Columbus, 2013):

As a first step, the data of interest will be selected, depending on the terms of reference, for instance the selection of comments belonging to a certain person or video. In the second step, the pre-processing functions are intended to prepare the textual data for subsequent analyses. Unneeded and unwanted concepts will be reduced through simple text cleaning functions such as the removal of extra spaces. Furthermore, this step serves to apply a) a stemming for reducing words to their root stem by removing suffixes from words, b) a delete list, which is required for the removal of non-relevant stop words (articles, auxiliary verbs etc.), and c) a manually generated thesaurus, used for replacing synonym concepts with the more standard form, for combining n-grams and to correct spelling errors. Next step of pre-processing is the identification and classification of concepts. Relevant concepts will be detected by analyzing the words’ frequencies based on the following principle: Words and n-grams that appear more than x-times are considered as relevant and will be included into further analyses, whereby x depends on the size of the corpus. The classification is done by the determination of categories based on the words appearing in a concept list that includes the frequency of all words and can be reduced to the most important key words using a threshold defined by the researcher. After specifying the categories, every single concept will be assigned to one of them. Therefore, an ontology-based meta-thesaurus will be created, which later is used for generating the network. As a result of the processes described before, multimodal networks will be created, whereby the modality of the network depends on the number of categories that can be identified by the researcher.

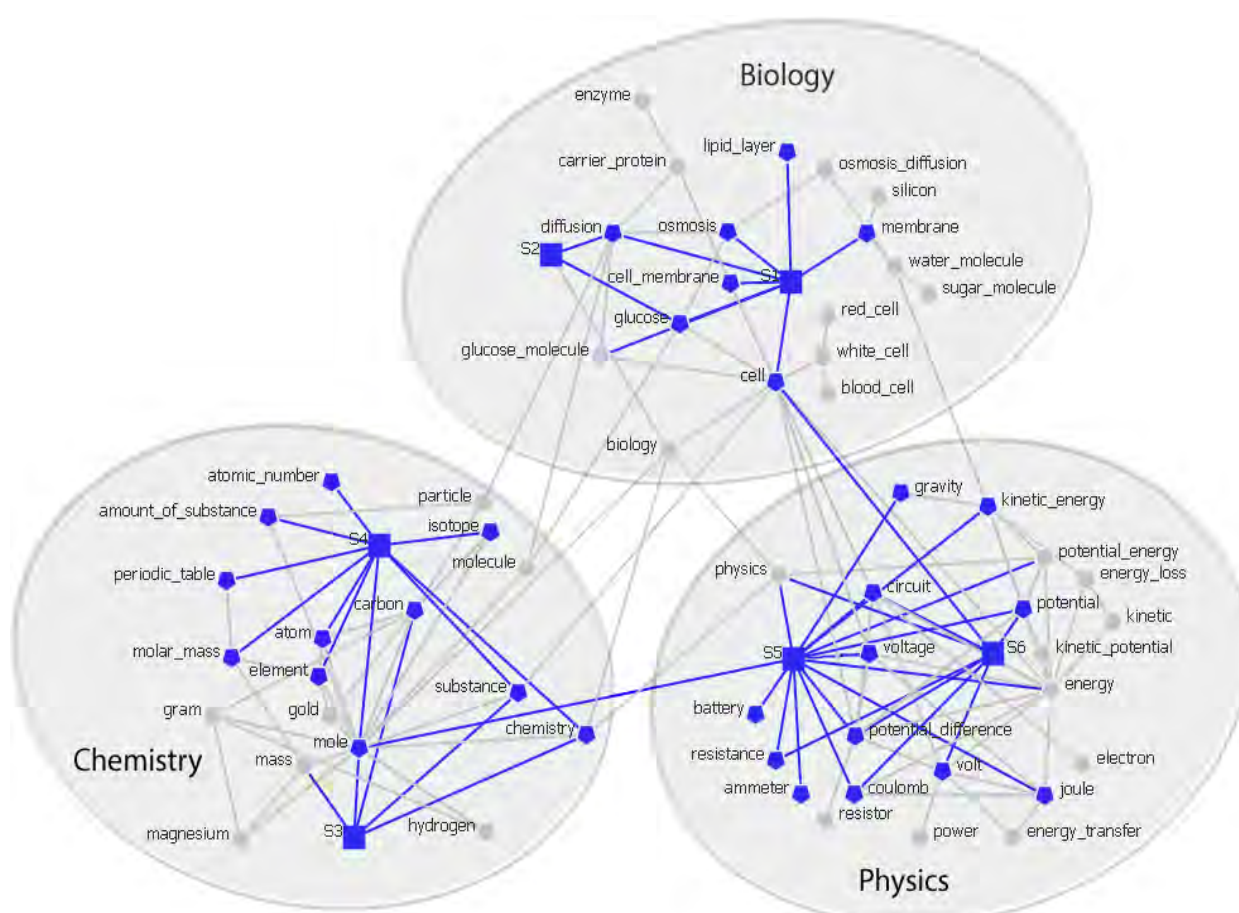
This analysis process has been applied on the transcripts of an initial role reversal workshop surrounding the STEM topics “moles” in chemistry, “potential difference” in physics and “cells” in biology. In each lesson, two students with different school marks (both excellent / mixed / both middle) taught two teachers. The transcripts were analyzed with the method described above.

#### *3.2 First results*

As a result of this analysis process, a multimodal network of categorized concepts was generated and visualized using ORAs. This network comprises the following concept categories: pedagogical concepts,

domain concepts, general concepts (i.e. concepts that are neither domain specific nor pedagogic concepts), tools, and actors. We have declared actors and domain concepts as the most relevant categories. These categories are represented in a meta-thesaurus. Within this thesaurus, the actor category represents all acting persons in the lessons; teachers have been labeled as T1 to T6, the researcher staff as R1 to R4 and students as S1 to S6. The domain concept category represents discipline-specific topics associated with the lesson subjects.

The number of connections between one actor and surrounding topics (also called “degree”) indicates the thematic richness of an actor’s contributions. Regarding the whole semantic network, the degrees reflect that both physics students (S5 and S6) as well as one of the biology students (S1), who score high in their school marks, have also a higher total degree in the network than the other students with middle school marks. Figure 1 depicts an excerpt of the net, a two-mode network of actors and domain concepts, which contains 16 actor nodes (blue square nodes) and 71 domain concept nodes (pentagonal). The excerpt only shows 6 student actors as well as the connected domain concepts (in blue) and the domain concepts surrounding the connected domain concepts (in grey). Additionally, every subject area and corresponding sub-activity in the workshop (chemistry, biology and physics) forms a cohesive cluster in the overall network, which are possibly interconnected by “bridge concepts”.



**Figure 1.** Partial view of a network generated from a teacher-student workshop, depicting connections of students (actors S1-S6) to domain concepts in blue (two-mode network) and relations between domain concepts in grey

Other relevant structural properties of the extracted network are nodes that represent hubs (high in total degree centrality) or nodes that bridge over between other concepts or between areas of discourse, here: the domains (high in betweenness centrality). Figure 2 shows the top six knowledge items ranked according to their total degree centrality and betweenness centrality in the uni-modal domain concept x domain concept network.

Concerning total degree centrality, we could find the three main topics of the workshops “mole”, “potential difference” and “cell” within the top 6 ranking. Furthermore, the nodes high in betweenness centrality seem to bridge over different ontological areas. Mole, for instance, builds a fundamental connection between the physics related cluster and the chemistry related cluster. Furthermore, cell, second highest in betweenness centrality, also connects the three discipline clusters with each other.



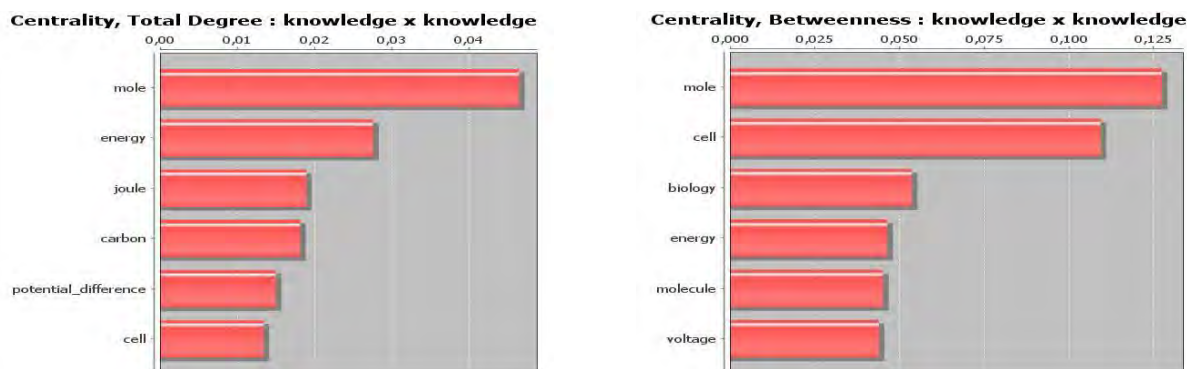


Figure 2. Domain concepts with the highest betweenness centralities (on the right) and highest total degree (on the left) in a domain concept x domain concept network.

Based on this first example, we claim that text networks can not only represent and characterize the specific foci of the JuxtaLearn workshops, but also provide ontological information, which is related to the student’s conceptualization of specific science topics.

Furthermore, NTA seems to be an appropriate method to analyze student generated textual content on the JuxtaLearn online platform to learn more about their conceptual models.

## 4. Analysis of Video Comments

### 4.1 Content Analysis

Since the NTA workflow described above was conducted on offline material and suitable data from the online platform was unavailable at this developmental stage of the JuxtaLearn project, we focused on material found outside our project for further research. The approach to content analysis presented here focuses on the attention given to a specific topic in an online discussion around learning materials, which in this case are represented by online discussions composed of comments in discussions around educational videos. This approach aims to extend the NTA workflow by focusing on the content of single comments instead of the complete discussion thread.

We used a quantitative approach implementing regular expressions based matching with the concept lists constructed during the NTA workflow and the preprocessed text base which was generated during this workflow. In principal this generates a sparsely populated feature vector for each comment based on the occurrence frequency of concepts from each list. We use these vectors to construct a measure we call “semantic richness” which tries to quantify the relation between the domain specific concepts and the general concepts occurring in each comment. This measure follows the assumption that a comment that contains more domain concepts than general concepts compared to a different comment which uses a lesser ratio of domain and general concepts is more “on topic” thus semantically richer. During our analysis of external data we derived different methods of evaluating this ratio and the following will present our results.

### 4.2 Khan Academy and YouTube Videos

As a starting point for our content analysis we have chosen Khan Academy’s learning videos and the accompanying discussion in the comments section. The Khan Academy website provides a significant amount of videos on different STEM topics and offers the option to enter into a learning dialogue with other students, a scenario which is similar to the one envisioned for the JuxtaLearn platform. The website offers message boxes below the videos to enter this dialogue through a scaffolded question/answer construct rather than an open comment section. The videos themselves are hosted on YouTube EDU, which enables users to comment on the same videos without assistive scaffolding. The library covers science topics such as biology, chemistry and physics on different levels ranging from junior high school to university and holds more than 4.300 videos with an average length of 10 minutes (Khan Academy, 2013). For this case study we used three videos with the following titles “The Mole and Avogadro’s Number”, “Diffusion and Osmosis” and “Voltage-Difference between electrical potential (voltage) and electrical potential energy”. In total, we have extracted 1.284 comments through Khan Academy’s web service. These textual artifacts have been used as a sample for our analysis. Khan Academy provides the aforementioned scaffolded discussion elements and encourages discussion on the

topic of the video, which means we can assume that artifacts extracted from the discussion will be about the topic of the video as well. Table 1 gives an overview of the amount of artifacts used in our study. It shows the number of questions and answers for each area the video topic can be assigned to, as well as their sum (# of comments) for easy comparison with other sources.

YouTube EDU is a subsection of YouTube that focuses on educational videos. The idea behind it is to provide everything related to education, spanning from short lessons for supplementing school learning to full courses from universities and other professional material from educators around the globe (YouTube EDU, 2014). As mentioned above, this includes videos from the Khan Academy. For a comparison with the Khan comments, we extracted video comments from YouTube EDU (using the appropriate Google API) for the same three videos. This resulted in another 1.201 comments distributed among the videos as shown in table 2. YouTube EDU does not provide any scaffolding for discussion resulting in a mixture of comments and smaller discussion compared to Khan Academy’s strict question/answer construct.

Table 1: Type and number of extracted comments on STEM videos at Khan Academy’s website.

| Type of artifact | Biology | Chemistry | Physics |
|------------------|---------|-----------|---------|
| # questions      | 184     | 279       | 70      |
| # answers        | 312     | 362       | 77      |
| # comments       | 496     | 641       | 147     |

Table 2: Subject and number of extracted comments on STEM videos from YouTube EDU.

| Subject of artifact | Biology | Chemistry | Physics |
|---------------------|---------|-----------|---------|
| # comments          | 487     | 628       | 86      |

### 4.3 Data Sampling and First Observations

The aforementioned strict construct of questions/answers seems to be enforced by a strong moderation through the Khan Academy staff, because the discussion artifacts have a very low amount of noise (e.g. spam comments). This is reflected by the high amount of very short and poorly written comments extracted from YouTube EDU. Additionally, the artifacts extracted from Khan Academy seem to focus on the video’s topic rather than on the video itself, while the opposite is true for comments from YouTube EDU, which mostly contain short comments that focus on e.g. the quality of the video. This observation can be confirmed by analyzing the content based on the list of domain and other concepts we constructed during the NTA workflow. Employing a quantitative approach we counted the occurrences of general and domain concepts in artifacts from both platforms, representing these values as feature vectors for general and domain concepts. Table 3 shows the results from this approach.

Table 3: Results from statistical computations for the “semantic richness” measure.

| Description   | Value                 |              |                  |             |
|---|-----------------------|--------------|------------------|-------------|
|   | Khan Academy (N=1284) |              | YouTube (N=1201) |             |
| Source from which the basis was extracted (N represents the number of comments extracted) | M                     | SD           | M                | SD          |
| sum of general and domain concepts (length of comment)                                    | 23.73                 | 28.04        | 9.78             | 11.03       |
| general concepts: with duplicates   only once   | 9.89   7.62           | 11.88   7.43 | 6.07   5.49      | 6.11   5.12 |
| domain concepts: with duplicates   only once  | 13.84   7.26          | 17.58   5.60 | 3.71   2.51      | 6.27   3.45 |
| 1. measure: domain concepts / length  | 0.54   0.38           | 0.23   0.20  | 0.26   0.22      | 0.26   0.22 |
| 2. measure: domain concepts / (general concepts + 1)                                      | 1.46   1.08           | 1.48   1.02  | 0.50   0.40      | 0.88   0.63 |

The two combinatory measures were introduced to create a value describing the semantic richness. We introduced two different formulas for both versions of feature vectors (those using all occurrences therefore with duplicates / those using only the first occurrence), the first normalizes the value to a range of 0-1 but favors shorter comments as a comment containing only one domain concept and no general concepts will have a semantic richness of 1. The second favors longer comments but the value is uncapped, meaning it can grow infinitely when only domain concepts are found (the +1 is needed to avoid division by zero).

The numbers clearly indicate both longer and “semantically richer” artifacts on Khan Academy, which might be a result of the platform’s focus on provision of educational content and discussion or simply the suspected strong moderation.

## 5. Introducing “Signal Concepts”

### 5.1 Idea

While scrutinizing the list of most frequent general concepts in an exploratory way, we found a subcategory of words within the comments (such as “help”, “explanation”, “difference\_between”) that seem to refer to students' problems of understanding. We decided to select the most frequent of these “signal words” in order to take a closer look at their relationships to adjacent domain concepts in the text network. These signal concepts occur in combination with domain concepts and indicate or “signal” a specific relationship either between the author and a domain concept or between two domain concepts. This distinction is reflected by using two types of signal concepts: unary and binary. Unary signal concepts reference only one domain concept and therefore represent the signal concepts that reference the author and one domain concept, while binary signal concepts reference two domain concepts. An example for a signal concept that defines a relationship between the author and a domain concept is “help\_needed”, which may indicate a problem the author has with the connected domain concept, while an example for the latter is “difference\_between” that may indicate that the author thinks or inquires about a difference between two domain concepts. Signal concepts provide a resource for teachers interested in learning about potential problems their students might have. Thus, our approach indicates a topic or a domain concept that may be worth focusing on in a future lesson.

Initially we used our NTA workflow to single out signal concepts and visualize this part of the network, Figure 3 shows an example network based on “dont\_understand”, “definition” and “difference\_between”. This network highlights the inherent problem with analyzing signal concepts through our NTA workflow as there are several connections between the signal concept “difference\_between” and different domain concepts without the possibility of identifying their original context. The missing original context means there is no way to identify which of these domain concepts were actually referenced using “difference\_between”, since the NTA workflow aggregates all occurrences of a signal concept into a single node. This node has connections to all domain concepts it was attributed to in the complete set of comments analyzed but lacks the original context of each individual comment.

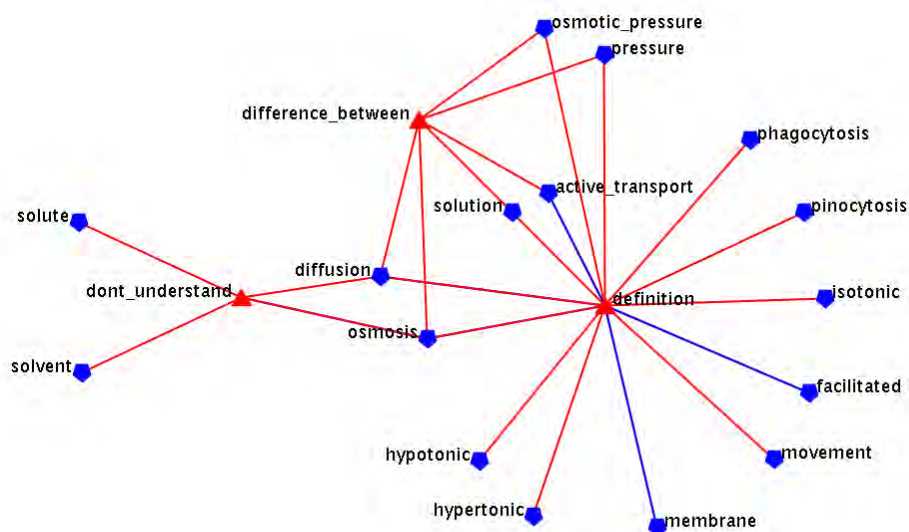


Figure 3. Network showing the neighborhood of “difference\_between”.

### 5.2 Approach

The basic idea behind our refined “signal concept” approach is to be able to correctly identify the original context and avoid the combinatorial blending seen in Figure 3. For this purpose, we generate a new network that is able to visualize the connections between the signal concept and the referenced domain concept(s) separately for each co-occurrence. Here, we did not search for co-occurrences in entire comments but in segments (windows) with a size of seven words in the pre-processed text, i.e. the signal concept and the domain concept(s) can have at most five words between them.

In a further refinement of the method we used a matching algorithm with predefined patterns of domain and signal concepts specified in the form of regular expressions. This algorithm transforms the

preprocessed text into a compact string representation by replacing each word with a single letter symbol. We used six letters (G, D, S, T, M and O) which represent general concepts (G), domain concepts (D), unary signal concepts (S), binary signal concepts (T), binary signal concepts that need to be in the middle of two domain concepts (M) and other (O). The patterns we used for the matching on these string representations are shown in Table 5 and can be broken down into two archetypes, for unary and binary signal concepts. The rules reflect different orders of occurrence in the text for these two types of signal concepts.

Table 5: Patterns used for digging up signal concepts from artifacts.

| Pattern                        | Description   |
|--------------------------------|---|
| (S)[OG]{0,5}(D)                | Matches a unary signal (S) and a domain concept with 0-5 general or other concepts between them.  |
| (D)[OG]{0,5}([MT])[OG]{0,5}(D) | Matches a binary signal concept (T or M) that's in the middle of two domain concepts with 0-5 general or other concepts separating the domain and signal concept.   |
| (T)[OG]{0,5}(D)[OG]{0,5}(D)    | Matches a binary signal concept (T) followed by 0-5 general or other concepts, a domain concept, another 0-5 general or other concepts and a second domain concept. |

These patterns were then used to highlight the signal and domain concept(s) in their original context as an additional way of visualizing possible problems in a human readable form.

### 5.3 Results

For the first approach we generated a new network around the signal concept “difference\_between” to illustrate the usefulness of our approach and specifically the introduction of the new combination nodes. Figure 4 shows this example network with the node for “difference\_between” in the middle surrounded by the combination nodes and the referenced domain concept nodes. The red node represents the signal concept this network focuses on while the purple nodes are the new combination. The size of these combination nodes represent their occurrence in all of the texts we analyzed by being larger the more often the combination of signal concept and both domain concepts occurred. Blue nodes show all the domain concepts that were mentioned along with the signal concept “difference\_between” in the data we analyzed.

The second approach resulted in a list of comments with co-occurring signal and domain concept(s), containing highlighting for the referenced concepts. An excerpt of this list is shown in table 6, illustrating the usefulness of this approach. It puts our preprocessed text with highlighting next to the original comment to indicate the detection of a signal and domain concept but also shows the original context both as a means of feedback for us showing the validity of our approach but also as a possible source of information for the teacher in a learning analytics context.

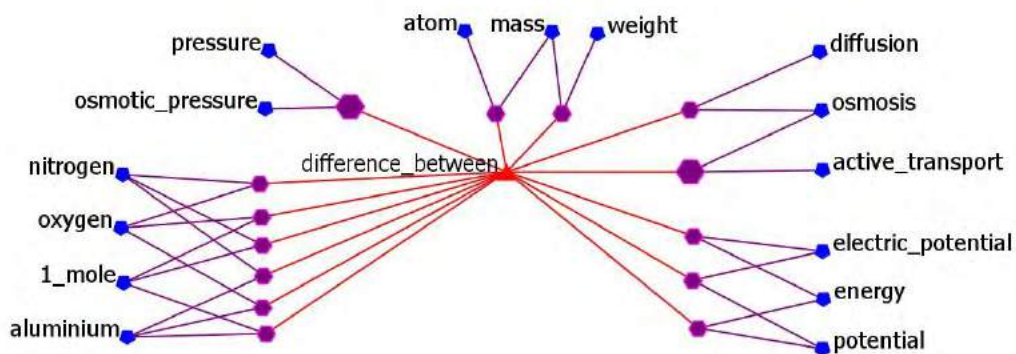


Figure 4. Network including blue combination nodes hovering around “difference\_between”.

**Table 6: Highlighting of signal and domain concepts next to their original context.**

|  |
|--|
| I finally understand osmosis. Thanks Khan!!<br><b>do_understand osmosis</b> thanks khan  |
| how I know if the membrane will allow sugar to diffuse or not? plzany body reply.<br><b>explanation</b> i know if <b>membrane</b> be allow sugar diffusion not plzany body reply |
| KhanAcademy helped me to review a unit on OSMOSIS AND DIFFUSION in my BIOLOGY class!<br>khan_academy <b>help</b> review <b>unit</b> on osmosis_diffusion in biology class        |
| Still confused about osmotic pressure :/ wasted a bit of time..<br>still <b>confusion</b> about <b>osmotic_pressure</b> / waste bite time  |
| What is the difference between osmosis and active transport<br>definition <b>difference_between osmosis active_transport</b>   |

## 6. Conclusion

In our first study, we aimed to find evidence that NTA is a useful instrument to identify and analyze students' conceptual understanding while learning a specific science topic. Similar to a student's self-created concept map, (semi-)automatically generated text networks provide information about the learners' conceptions belonging to the respective discipline. As theoretically expected, we could corroborate that hubs found in the ensuing concept networks indeed represent ontological root categories, e.g. the concept of "mole" that was the main topic of a role reversal lesson and consequently reaches a high value for total degree. Furthermore, given betweenness centrality values support the theory that nodes high in this measure indicate bridges between different ontological areas. Overall, we conclude that the analysis of a network's structural features provides important information on ontology development. This led us to a second study, in which we investigated the impact of differentiating between various categories.

In the JuxtaLearn context, this type of content analysis can serve as a source of diagnostic information regarding the students' understanding and potential misconceptions. Based on our refinement of the NTA approach, we aim to develop a tool for teachers and educational designers that supports them in optimizing the student's learning processes but also revising educational processes and possibly even curricular decisions.

While investigating general concepts of comments in a discussion around publicly available educational videos, we could identify an ontological subcategory of signal words among frequent general terms high in degree. These words (such as "explanation" or "difference\_between") indicate a certain type of concepts, which in conjunction with domain concepts can help identify problems of comprehension. Contrary to commonly used content analysis techniques, which are based on a "bag of words" assumption and hence ignore the word's position in a text (e.g. Sherin, 2012), NTA has proven effective in disclosing conceptual relationships of meaning. By means of extending the NTA by a tailored analysis, we receive indicators for drawing conclusions as to which (pre-)knowledge the students might miss or which concepts are particularly difficult to distinguish (such as "osmosis" and "diffusion").

As a next step on our research agenda, we will particularly look at the progression of concept networks over time. Particularly deviations from "normal" progression following the preferential attachment principle (i.e. disappearing hubs or new clusters of high connectivity) will be analyzed to better understand the evolution of the students' conceptual models.

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# Assessment of Developmental Stages of Generic Skills: A Case Study

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**Abstract:** Generic skills (GS) are meta-competencies necessary for acquiring knowledge from provided information in classes. This paper assumes that GS consists of a skill associated with the literacy for pulling information from the accessible contents in the classes, and a skill associated with the literacy for pushing knowledge stored in the students' brain for obtaining useful information from the instructors. Based on the assumption, we propose a method for assessing developmental stages of GS. Observational studies were conducted in a real classroom for testing this assumption. For preparation, we defined a micro-structure of GS. Using the structure, we identified three critical parameters that should characterise the students' performance on the micro-structure. Then, we selected elite monitors to verify whether micro-structure works in our study. The results suggested that the micro-structure of GS works well in classroom situations. We conclude that three critical parameters are good parameters for assessing developmental stages of GS.

**Keywords:** Meta cognition, Generic skills, Cognitive Chrono-Ethnography, Human behaviour

## 1. Introduction

There are a number of versions of the definition for generic skills. However, they commonly suggest that high-order, transferable skills are necessary for almost all complex endeavours. Particularly, the importance of these skills is clearly summarised in "Defining Generic Skills" as follows: "*Generic skills are important because jobs today require flexibility, initiative and the ability to undertake many different tasks. .... Internationally, there is increasing emphasis being placed on active citizenship and community capacity as reflected in the extensive work on learning communities. Generic skills feature prominently in this body of literature as fundamental to developing successful, progressive communities.* – adapted from *Defining generic skills: at a glance, 2003. 12*" Six common elements listed in "Defining Generic Skills" are as follows: Basic/fundamental skills, People-related skills, Conceptual/thinking skills, Personal skills and attributes, Skills related to the business world, and Skills related to the community.

Under the current state of the society, higher-educational institutions have begun to consider introduction of the skills in their education. In order to handle those skills in the education effectively and efficiently, it would be critical to establish reliable methods for assessing the state of developmental stages of generic skills, or assessing the six elementary skills that support generic skills, in the respective education fields.

A number of methods for assessing generic skills have been proposed. For example, in US, the case for generic skills and performance assessment was introduced by Roger *et al.* (2012). It adopted a batch of multiple-choice and short-answer tests for assessment, which have been the dominant testing regime for generic skills. Another example is Berwyn *et al.* (2003), which proposed assessment methods of generic skills. The assessment is done on the basis of skills and knowledge checklists. The checklist consists of the items such as the things that learners should know, what they should know in order for them to be able to access information, what they are able to do, and the documents that could provide them with evidence of their competence. In this case, learning materials are developed from the checklists, so generic skills are fully mapped to skills and knowledge, and are built-in from the beginning of the training development process. Assessing generic skills includes such activities as completion of workbooks, supervisors' reports, participation in professional networks, and so on.

As for the methods for developing generic skills, there are several propositions, but most of them are based on self-regulating learning. For example, Luca (2002) proposed an instructional design strategy that supports generic skills development, consisting of the following three key learning principles for designing effective learning environments – authenticity, self-regulation, and reflection. The framework was integrated with the ICT technologies. Thus, the pedagogical methods of developing generic skills are growing year by year. Especially, the methods are shifted their focus to integration of ICT technologies probably due to the rapid proliferation of e-Learning.

In this research, we propose a new assessment method for developmental stages of generic skills using trainee’s behaviour by implementing a set of controlled learning task sequences. The assessment is supposed to be applied to educational institutions, so the target is higher-education institutions’ classes. Hence, we focus on the generic skills characterised by the following features: collecting information, organising knowledge, and literacy, related to basic/fundamental skills and conceptual/thinking skills.

## 2. Methodology

To construct an assessment method, we need to focus on the target of generic skills, conformable to higher educational institution pedagogy. In this case, the place where assessment is done would be classes. Taking into account the constraint imposed on conducting observation at classes, however, we need to select the suitable items of the generic skills. And therefore, we focused on the collective notion of “key competencies”, suggested by Dawe (2002), which represents the important features of the generic skills within all education and training. One of the important key competencies is “collecting, analysing, and organizing information (Council *et al.*, 1992).” This competency includes the following capacities: (1) to locate information, (2) to shift and sort information in order to select what is required and present it in a useful way, and (3) to evaluate both the information itself, and the sources and methods used to obtain it. These three capacities define a basis for assessing developmental stages of generic skills. The results of measurement of these capacities in classes would provide the information where a specific student is located in the spectrum of developmental stages of generic skills.

### 2.1 Monitoring Students’ Behaviour

In this research, we adopted Cognitive Chrono-Ethnography (CCE). CCE is a methodology for

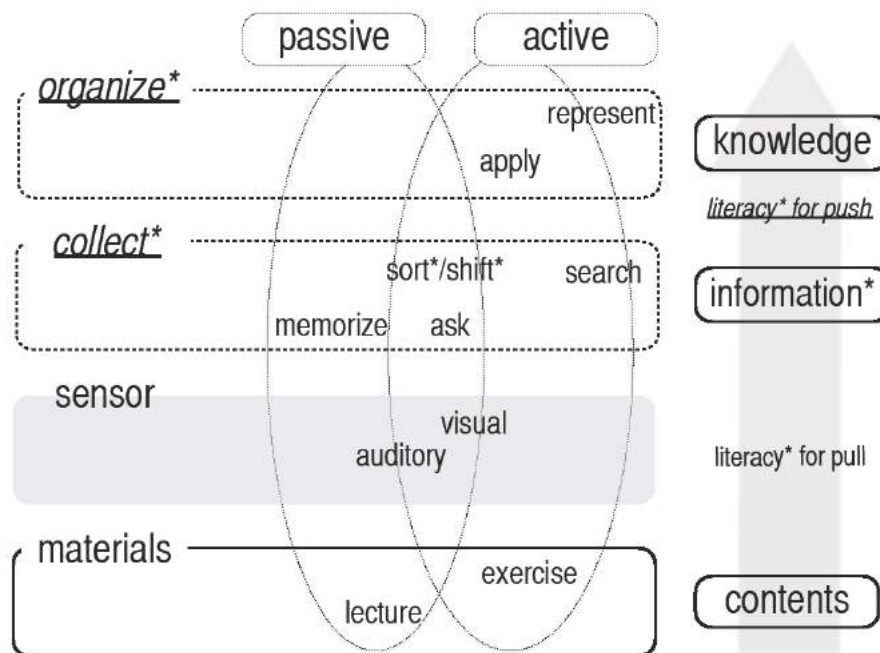


Figure 1. Micro-structure of Generic Skills. \*’s are the concepts introduced in Council et al.(1992).



understanding people's daily *in situ* behaviours (Kitajima *et al.*, 2010, Kitajima *et al.*, 2012, Kitajima, 2012), and has been successfully applied to a number of topics to understand people's behavioural changes such as "how some of baseball fans have become aficionados", *etc.* CCE consists of the following six steps; Choose the field of study, Define critical parameters, Recruit elite monitors, *i.e.*, representative subjects in the space defined by the critical parameters, Observe elite monitors' behaviour in the study field, Define a space for representing the observed phenomena, and Analyse the observed behaviour from the viewpoint of the critical parameters. In short, a CCE study would provide detailed descriptions for the representative people's behaviours in the study field, which is characterised by a set of important, or critical, parameters. The students' learning activities in classes would be characterized by a set of parameters, and they would be categorized into a number of activity patterns, each of which is associated with a particular combination of values of the critical parameters.

This paper defines critical parameters that should be associated with generic skills. Each of the critical parameters has values, e.g., high or low. Each student is located at one of the legal points in the parameter space. The students placing at the same point would show similar activities in the classes, providing concrete examples of students' activities with the generic skill level defined by the point in the parameter space.

## 2.2 Generic Skills

When students attend the class, they try to get some knowledge from the lecture. We assume that generic skills are critical determinant of the way how students organise their activities in the class.

Figure 1 shows the micro-structure of generic skills. It consists of four layers for representing students activities, *i.e.*, materials which the students pay attention to, sensing to convert the physical stimuli on the materials to the perceptual representations, collecting and organising the sensed data for comprehending them as meaningful information, and three layers that correspond to the depths of information processing, *i.e.*, physical contents (data), information (meaning), and knowledge (long-term memory of the students), and three layered framework to generate knowledge from contents material or information. The four layers' elements represent human behaviour; materials, sensor, two activities – collect and organise, which have strong relation to generic skills. The three layers' elements represent the processes of changing materials; contents, information, and knowledge.

**Materials :** The first layer, *materials*, represents the source where students get information for the subjects instructors are giving in their classes. When instructors make lectures, they construct several professional context and use technical words for explaining them. Sometimes, they make some exercises to give a chance to apply the information or knowledge which students have got through the class. Basically, *materials* are constructed by means of contents which include text, audio talking, figures, and so on, as physical signals or codes. The students pay attention to some materials but not all, depending on their developmental stages of generic skills.

**Sense :** Human receives these signals through some sensors, such as auditory or visual. The signals are converted to useful information in human brain. Again, the control of sensing, namely which channel to open, is dependent on the developmental stages of generic skills.

**Collect :** In this process, the brain requires the ability of *literacy for pull*. The collect layer includes some activities, and is divided in two domain modes – passive and active. The passive domain mode has the following features: (1) students get information and memorise it without any comprehension or thinking processes, (2) students ask the instructor for useful information without any deep thinking, and so on. The active domain mode has the following feature: (3) students have a desire to get useful information, and accomplish it by searching literatures by themselves with clear purposes. Each element in this layer is associated with one of the modes exclusively but it is not the case for the sort and shift elements because these elements can operate in either mode depending on the status of students. We assume sort and shift work in the both mode.

**Organize :** Once the *collect* layer is done, students move to the final layer, *organise*, to convert information to "knowledge". To do this, students make some activities, such as applying the information to several exercise or examples, and integrating the results of application in the form of organised information. Through the process, the mere information changes to knowledge stored in long-term memory, which can be used in the future as needed. In this process, a skill, *literacy for push*, is required. Using this framework, we can make a plan for observing students' generic skills via their behaviours in the real classes.

### 2.3 Cognitive Chrono-Ethnography

**Critical Parameters :** Comparing the focused generic skills and Figure 1, we can set reasonable critical parameters. In the figure, human behaviours arise in the processes of collect and organise layer, and *literacy for push*. And therefore, we can identify the following correspondences between them: locate information corresponds with collect process, shift and sort information in order to select what is required and present it in a useful way corresponds with *literacy for push*, and evaluate both the information itself and the sources, and methods used to obtain it corresponds with organise process. Thus, we identify the three items – collect, organise, *literacy for push* – as critical parameters. Then we need to define how to observe these parameters.

**Motivation :** The motivation of the study is to propose an assessment method of developmental stages of students' generic skill. To do this, we need to construct a model of students' cognitive activity. As shown in Figure 1, we have already done it. Using the frame, we studied it by analysing students' products such as reports or minutes note which summarise the contents of the lecture they attend and make comments or academic questions to the instructor. There are several ways for the analysis. This paper reports the first analysis has done for an exercise style class to which a small number of students attend, considering whether our frame is good for describing students' behaviour in the class or not.

**Elite Monitors :** In this practice, we chose an exercise style class to which attended nine second grader from the undergraduate course of the university. Each student knew how to search information using the search engines in the web, but they were poor at or did not know how to draw graphs. We used a consecutive 3 classes which took 135 minutes per class. The instructor set three themes for a statistical graph drawing exercise with a spreadsheet application whose difficulty levels were set to low, middle, and high. Through the exercise, the instructors did not provide any textbook or documents. If they wanted to finish the exercise and did not have the necessary skills for drawing graphs, they needed to search the available sources of information for ICT literacy for using the spreadsheet application, knowledge for handling data statistically, or raw data to do the exercise. In this situation, if students' generic skills were high and good for literacy for both push and pull, students would show active domain mode behaviour.

Our goal is to identify students' conditions whether they can acquire knowledge from the contents that were given to them or were found by their efforts. Table 1 shows the relationships between the students ability and what they finally acquired from the contents through a series of conversion processes. Although we tend to assume intuitively that students can always organise knowledge from clear and good information, there are complex processing steps that are necessary for converting such information to well-organised knowledge. Even if a student has high ability for collecting and organising information, he/she would not be able to construct knowledge from the information without high *literacy for push*. Or, if a student has low ability for collecting and/or organising information, he/she would not be able to give appropriate representation for the information unless enough time is available. This table shows the conditions of the states of students for characterising various manifestations of generic skills, including elapsed times, quality of products, activity logs which they check webpage, and so on.

Through this consideration, we set some critical parameters to evaluate students' generic skills; – activities for collecting information and organising knowledge, and *literacy for push*. To observe these critical parameters, we gathered students' behavioural data.

**Observation :** After preparation, we started to observe students' behaviour, in this case, "observe students' behaviour" means gathering students' behavioural data. We set the gathering data from students as: (1) searching activity logs which include the elapsed times per 15 minutes and the URLs students visited, and (2) products which students draw graphs with finished time. With the parameters and frame, we consider some important relationships -- *short elapsed time to solve exercise* and *long elapsed time to solve exercise*. After these considerations, we set three critical parameters for collecting, organizing, literacy. For literacy, we can assess just *literacy for push* because the ability of *literacy for pull* is the activity in human brain so we cannot check unless represented with language. We observed students' activities using these critical parameters. Through these observations, we found good

Table 1. the relation of students' behaviour and layers for constructing knowledge. The codes in table header are: "A" means active mode, "P" means passive mode, "AT" means human attitude for collecting/organizing information, "F" means the final reception form of contents. The codes in each cells are: "H" means high ability, "L" means low ability, ● means high level of knowledge, ○ means low level of knowledge, and ■ means just contents.

| Collect           | H             |   |   |     |   |   |   |     | L             |   |   |     |   |   |   |     |   |
|-------------------|---------------|---|---|-----|---|---|---|-----|---------------|---|---|-----|---|---|---|-----|---|
| Organize          | H             |   |   |     | L |   |   |     | H             |   |   |     | L |   |   |     |   |
| Literacy For pull | H             | L | H | L   | H | L | H | L   | H             | L | H | L   | H | L | H | L   |   |
| Literacy For push | H             | L | H | L   | H | L | H | L   | H             | L | H | L   | H | L | H | L   |   |
| AT                | A             | P | A | N/A | A | P | A | N/A | A             | P | A | N/A | A | P | A | N/A |   |
| F                 | ● information |   |   |     |   |   |   |     | ○ information |   |   |     |   |   |   |     | ■ |

relationships between these critical parameters, and found several patterns of students' types. Through these verifications, we conclude the three critical parameters are useful for generic skill assessment.

### 3. Apply The Method of Generic Skill Assessment For Mass Students

After showing the validity of the critical parameters, we would like to apply the method of generic skill assessment for mass class students. In this case, we cannot obtain detailed students' active logs. In place of active logs, we used "minutes notes", which are generated by students at the end of five to ten minutes in each class. The note consists of two questionnaire: (1) please write new knowledge you have got in this class, (2) please make comments or questions for this class.

We applied this assessment method to a lecture to which attended up to 60 graduate students of the university. From the registered students of the class, we selected 28 students, who attended 10 to 12 classes. The following pieces of information are included in the minutes note: (1) technical term(s) which were used in the class, (2) question(s) which students had, (3) narrative impressions which students felt. We extracted the values of the critical parameters as follows:

**for collecting :** We counted the number of technical terms in the first question of the minutes notes. When students got new technical terms in the class, we assume they felt the word conveying important information. It is regarded as just "collect" information.

**for organizing :** After collecting new technical terms in the class but just "collecting", technical terms keep "information" status. They are not converted information to knowledge unless being "organised".

**for literacy :** We counted the number of nouns, verbs, and adjectives for the first question in the minutes notes to observe students' literacy. Writing process of minutes note, the students had to use their ability of literacy. Here, we focus on *literacy for push*. Though the students got good information or not in the class, they represented their thinking or new information with terms, such as verbs, nouns, and so on. If students' had rich vocabulary, they would have ability to represent their thinking by selecting appropriate words in their vocabularies.

Figure 2 shows a part of results of the generic skill assessment. Results of assessment are represented by numerical conversion, so we can make visualisation for these results.

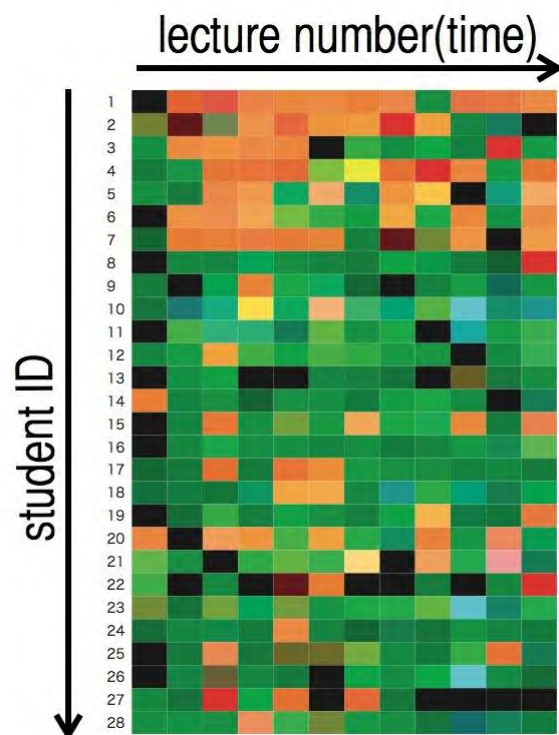


Figure 2. Generic skill assessment applied to 28 student attended classes.

Here, we assigned RGB colour for each critical parameter: blue colour is assigned to collecting information, green colour is assigned to literacy, and red colour is assigned to organisation. The upper group of student IDs in the figure show the red end of the spectrum. It means they might have rich organization generic skills; the ability of converting information to knowledge. The middle ones show the blue/green end of the spectrum. It means they might have rich collecting generic skills or just represent several impressions; the ability of collecting information and *literacy for pull*. From the left side to right side of the figure shows the elapsed time. Most students have not changed their ability – represented almost in the same colour – but several students such as students ID 10 transformed their ability – changing their colour spectrum –. Thus, we conclude the method of generic skills assessment seems to work well.

#### 4. Conclusion

In this paper, we proposed an assessment method for partly generic skills in higher-educational class. The feature of the method is that it is based on “observing” students’ activity, and the results of observation is easily quantified by means of visualisation and assessment process is facilitated. For constructing the method, we used the CCE methodology for understanding people’s daily in situ behaviours. Most important point of the proposed assessment method is that it defines the critical parameters – collect, organise, and *literacy for push*. Through interpreting the critical parameters, we implemented an observational method for collecting students’ information that is related with the parameters. After defining critical parameters, we assessed the method for its effectiveness for the students who attended the university class. Tracking the students’ behaviours, we conclude the assessment method is effective. We think one of the supports is to understand students’ study style whether they do just collecting new information, tend to organise knowledge which is collected in class, or other type. If we identify the student’s study style properly, we can customise the e- Learning contents sequence in such a way that they are fully optimised to the skills of each student.

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# ‘Does it Make Sense’ or ‘What Does it Mean’?

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**Abstract:** This conceptual paper problematizes a distinction between *meaning-making* and *sense-making* as activities that support learning. In framing this distinction, various theoretical perspectives on sense-making are introduced from a range of disciplines that have direct implication for the ongoing development of the digital environment designed specifically to support learning. The digital environment is replete with choices that enable communication, information-seeking, knowledge sharing, computation, and learning – all made possible by a diversity of technologies. Semantics have a significant computational role in this environment and making sense of it, amidst constantly emerging capabilities, represents opportunities for innovation as well as challenges for digital learning. While meaning-making has a pivotal role in knowledge construction in this environment it is argued that sense-making often precedes it, thereby indicating a specific role for *sense-making technologies*.

**Keywords:** sense-making, sensemaking, meaning, semantics, sense-making technologies

## 1. Introduction

Human beings have been making sense of things for a very long time – no doubt, long before language was invented. While the milieu might be vastly different, making sense of things is as routinized today within digital learning contexts as it likely was in the Stone Age. It is a conscious human act that supports meaning-making, learning, and the development of understanding and reasoning skills – whether as a young child interacting with the world they have been born into or as a researcher immersed in analysis of disparate datasets and the received wisdom of relevant theory.

Despite its historical roots the term *sense-making* (also *sensemaking*) appears to have only entered academic discourse in recent times, finding traction as a construct across a broad range of disciplines. Some researchers trace its recent roots to the work of Bush (1945) in his visioning of the “Memex” (Chi and Card, 1999, p. 18). More explicitly, from the field of communications and information science, Dervin (1983; 1998; 2003) has described it as “a mandate of the human condition” (2005, p. 27); in human-computer interaction (HCI) Russell, Stefik, Pirolli, and Card (1993) define it as “the process of searching for a representation and encoding data in that representation to answer task specific questions” (p. 269), while in the context of intelligent systems development “the basic sensemaking act is [described as the] data-frame symbiosis” (Klein, Moon, and Hoffman, 2006, p. 88); in organizational development, Weick (1993) describes it as “structur[ing] the unknown ... grounded in both individual and social activity” (pp. 4-6); and, in knowledge management, Snowden (2002) presents it in terms of a framework or model for dealing with complexity. It is also a term that has begun to appear in mainstream e-learning discourse such as *The Horizon Report* (Johnson *et al.*, 2010, p. 3).

This paper draws upon all these perspectives while problematizing a distinction between *sense-making* and *meaning-making* for the following reasons. Firstly, it is often the semantic dimension of digital innovation (the Semantic Web and *semantic technologies* generally) that has captured the imagination of those visioning the next iteration of the digital revolution (Hendler, 2009). Secondly, it is arguable that “(t)he concept of meaning is every bit as problematic as the concept of mind” (Tiles, 1987, pp. 450-454). Thirdly, from a pedagogical perspective, constructivist theory highlights the role of meaning-making in the construction of knowledge but says little about sense-making. It is argued here that while sense-making is important in knowledge construction it does not necessarily invoke meaning-making and is an activity that has a prominent role in human-computer interaction.

## 2. Distinguishing Key Terms

A practical rationale for why this distinction is made is that making sense of things has utility as a turn of phrase (just as common sense has) while finding meaning in something is somewhat more problematic and can raise issues of subjective semantics and philosophy (such as vexed questions concerning the meaning of life). In many contexts *sense-making* and *meaning-making* are interchangeable. For example, in understanding how to respond when driving a car and approaching a red light: making sense of this situation and understanding the meaning of a red light are one and the same. In situations involving more complexity, such as understanding statutory legislation concerning carbon pricing, making sense of documentation may require reasoning, reflection, and analysis while the meaning of such a document might simply be understood as a mechanism to ameliorate climate change. Such meaning could be inferred prior to making sense of the documentation or after having done so but is not necessarily ascribed in the process/es of sense-making or essential to it.

### 2.1 Information and meaning

“we live in a universe where there is more and more information and less and less meaning” (Baudrillard, 1988, p. 95). Such an observation raises questions concerning the contemporary situation, such as whether web technologies ameliorate or exacerbate this. It also suggests that with less meaning-making perhaps there may be a clearer appreciation for the role of sense-making.

A key feature of information is that it can be described in terms of its semantic properties – for example, its context, subject matter, and provenance. Describing information this way is an essential practice for librarians when they catalogue it according to various classification schemes, the core of which can be reduced to generic semantics of *who*, *what*, *when*, and *where*. This core set of semantics has been described as the “primitives of information retrieval” (Mason, 2012) as they constitute the basis of most metadata schemas. The information contained within such metadata schemas is also largely factoid in nature and not subject to interpretation (Verberne, 2010) – and therefore, any associated meaning is not contestable. In learning contexts, however, content contains more than information – such as data, declarative knowledge, procedural knowledge, rich media, argumentation, and explanation. It is these dimensions of content that require both sense-making and meaning-making for learning to proceed (Mason, 2014; 2012; Mooney, 2011).

### 2.2 Linguistic perspectives

Linguistic perspectives also assist in making this distinction. As activities, both meaning-making and sense-making are verbs; however, the former is also primarily associated with the semantics of content, which is typically describable in terms of nouns and properties, or as propositions (as in the Resource Description Framework). As such, it is indicative of an end result or outcome – a naming, or “*nouning*”. In contrast, Dervin’s (1999) articulation of her “Sense-Making Methodology” gives particular emphasis to the role of “verbing” and “Sense-Making is described as a verbing methodology ... a methodology for communication practice” (pp. 731-736). Dervin (1998) also explains that her “approach to studying human sense making ... has from its inception conceptualized knowledge and information as a verb” (p. 36). Dervin’s later work also carries this strong emphasis where “Leadership 2.0” is described in terms of “knowledging” (Cheuk and Dervin, 2011).

### 2.3 Constructivism and meaning

As a term within educational contexts, such as constructivist discourse and “meaning-centered education” *meaning-making* is a pivotal construct (Kovbasyuk and Blessinger, 2013; Whiteside, 2007; Jones and Brader-Araje, 2002; Hein, 1999; Jonassen et al., 1999; Jonassen et al., 1995; Driver and Oldham, 1986). While there is variation in emphasis within the constructivist literature there is evidence to suggest that meaning-making and constructivism are terms that have sometimes been conflated:

Is meaning making constructivism? Is constructivism meaning making? Short answers to these two questions are ‘No’ and ‘Yes’, respectively. The two terms, although frequently confused, are not synonymous ... All discussions of constructivism include meaning making; but

meaning making (although often appropriately called ‘knowledge construction’) does not necessarily imply constructivism. (Hein, 1999, p. 15)

What is arguably most important within constructivist theory, however, is the independent (though socially-situated) construction of knowledge – and both meaning-making and sense-making can be seen as contributing to this. The issue here is not whether the discernment or inference of meaning plays a major role in knowledge construction; it is whether it is intrinsic to it. Discernment or inference of meaning can be understood as sense-making activities but they do not define the scope of sense-making. The following discussion probes this distinction further.

## 2.4 Human-Computer Interaction and sense-making

*Sensemaking* has been a key consideration of Human-Computer Interaction (HCI) for over two decades (Russell, et al., 1993). HCI is a field of study that addresses diverse elements of interface design, semiotics, semantics of messaging, dialogic cues, usability and user control, media specifications, layout, navigation, and consistency, etc (Russell, et al., 2008; Russell, et al., 1993; De Souza, 2005; Rogers, Sharp, and Preece, 2011). Sensemaking in HCI spans all these topics as well as being a concern in its own right because it is a topic concerned with how the user can optimally interact with a computer and to achieve this the user needs to make sense of the interface as well as the content.

Recent HCI literature reveals a growing interest in sensemaking (Pirolli and Russell, 2011; Faisal, Simon, and Blandford, 2009; Paul and Morris, 2009; Klein, Moon, and Hoffman, 2006). Even so, it would appear that in a similar way that meaning-making and constructivism sometimes get conflated so does meaning-making and sensemaking in HCI. In paraphrasing Weick (1995) and Pirolli and Card (2005) Faisal et al. (2009) write that in broad terms “Sensemaking ... is the process of *finding meaning from information*. As such, it is intrinsically linked with *information seeking* as both an outcome and a driver.” (p.1) [emphasis added] Such a generalization may indeed be true for many situations that demand the parsing of information, but it also masks the underlying complexity and diversity of sense-making in which activities focused on gaining understanding do not necessarily produce meaning. A simple example is in processing the reasoning of an explanation. Nonetheless, Faisal et al. (2009, pp. 2-6) have proposed a practical (non-exhaustive) classification and “design methodology” of the variety of representations of sense-making used in HCI:

- Spatial – depicting objects and their spatial relationships
- Argumentational – representing proposition(s) and the logical operations that might link them
- Faceted – properties of an entity or entities within a domain
- Hierarchical – showing asymmetrical, one-to-many relationships
- Sequential – depicting a time series or chronology
- Network – depicting arbitrary, many-to-many relationships

From this scheme it can be seen that representations used in HCI sense-making involve a range of abstractions; however, at least two commonplace sense-making representations are missing from this list: firstly, symbols used in signs; and secondly, linguistic representations (textual or ideographic) in which semantics, syntax, morphology, and grammar all play important roles. It is also arguably the case that design innovations such as *infographics* also belong in this list as a *hybrid* or *aggregate* type.

## 2.5 Intelligent Systems and sense-making

Some concerns of HCI are shared by artificial intelligence (AI) – a field often referred to in recent years as *intelligent systems*. The application of AI within digital learning has typically been in the form of intelligent tutoring systems, although elements of intelligence can be seen in many common web and office software applications (such as suggested search terms or word corrections) and embedded into the design of the smart phone. It is within AI that the construct of the *frame* has been used for over four decades as a data structure that represents a viewpoint or set of assumptions (Minsky, 1974). The capability of representing everyday *common sense* as a manifestation of intelligence has been a fundamental problem for the AI community to solve from its beginnings. This problem of representing common sense continues today despite significant advances in the understanding and representation of context for any iteration of common sense representation (Lieberman and Havasi, 2012).

Of specific relevance to this paper is the presence of the frame as a pivotal construct within the “Data/Frame theory of sense-making” proposed by Klein, Moon, and Hoffman (2006b), in which it is the relationship between these two entities that matters most: “A frame functions as a hypothesis about the connections among data” (p. 88). In this theory, sense-making is presented as a cyclical process that *can* (though not necessarily *must*) involve assimilation, elaboration, questioning, doubting, and reframing. At various moments a hypothesis becomes plausible and this plausibility builds understanding. But is it the *meaning* of the hypothesis or its *reasonableness* that is preeminent when something becomes plausible? While it is the case that a frame(work) will likely have semantic content, sense-making is an activity conceived here as recognizing and postulating connections or relationships between data and frame and has an impact upon conceptualization and re-conceptualization. To characterize this process, or its goals, only in terms of meaning-making seems to diminish not only the process of sense-making but cognition itself.

## 2.6 *Connectivism*

The work of Klein, Moon, and Hoffman (2006a) has also found resonance for Siemens (2012) in his elaborations of his theory of connectivism since its first articulation (Siemens, 2004). It is not hard to see why: Klein, et al., suggest that “Sensemaking is a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively” (Klein, Moon, and Hoffman, 2006a, p.71).

Siemens (2004) has proposed “connectivism” as a “learning theory for the digital age” in which technology networks are conceived as enabling new and rich connections to a diversity of entities all linked to continual learning and activities in which “the pipe is more important than the content within the pipe”. The distinguishing characteristic of Siemens’ theory is the prominent role of networks in creating connections between disparate learning sources and events (Siemens, 2005). Siemens’ central insight regarding the role of networks is consistent with the sociological work of Castells (1996, 2001) in outlining the “rise of the network society” and in the work of Benkler (2006) on the “social production of intellectual capital”. In some respects it also represents a re-articulation of connectionist theory grounded in mathematics that was first developed by Thorndike (1932) and later in the field of artificial intelligence (Pinker and Mehler, 1988). In presenting a recent, concise summary of connectivism, Downes (2014) states: “According to connectivism, learning is the formation of connections in a network.” In the context of this paper, there is some alignment between connectivist (and connectionist) perspectives and sense-making although there are differences in conceptualization.

In the initial articulation of connectivism Siemens (2004) connects “meaning making” with learning but does not use the term sensemaking until some years later. But while the term “sensemaking” has found its way into the later discourse on connectivism (Siemens, 2012; Downes, 2011) it would appear that it is still very closely aligned with meaning-making: “Meaning-making is the foundation of action and reformation of viewpoints, perspectives, and opinions” (Siemens, 2006).

In recent work Siemens (2012) suggests “Sensemaking, then, is essentially the creation of an architecture of concept relatedness, such as placing ‘items into frameworks’.” This shows some similarity with the Data/Frame theory of Klein et al., but the definitive character of this statement can be seen as counter to Dervin’s (1999) “verbing” perspective which gives emphasis to process rather than outcome. There is, however, a more important distinction to be made in terms of how “sensemaking” is used in connectivism and Dervin’s work. For Dervin (1999), Sense-Making Methodology represents a research tool that is not aligned with any particular learning theory and is instead conceived as a “metatheory”. In terms of this paper Siemens’ representation of sensemaking primarily as “concept relatedness” also privileges the semantic domain and is not as richly presented as in the HCI discourse where mental representations are not necessarily in the form of concepts (such as scripts, models, and symbols).

Despite the differences in conceptualization, however, connectivism represents a plausible theory of how learning proceeds in some contexts – that is not being contested here. Its emphasis upon connections and connecting can also be seen as consistent with sense-making activities despite its limited depiction of sensemaking. As Downes (2014) argues “A connectivist account ... look[s] well beyond rules and meaning.”



### 3. Conclusion

This paper has been explicitly theoretical in addressing the distinction between sense-making and meaning-making. In determining the complexity of relationships between these two constructs it has been instructive to consider that semantic content represents just one of the functional components of natural language. Communicating in natural language would not be complete – or make much *sense* – without syntax, morphology, phonology, pragmatics, and grammar.

In very general terms the semantics of meaning-making suggest the formation of concepts and conceptual relationships. The semantics of sense-making suggests connection, causation, process, analysis, and probing. In learning, both activities are complementary. Yet it is also the case that both activities can function independently. This distinction suggests scope for developing technologies specific to supporting sense-making – as such, they might be identified as *sense-making technologies*.

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# Fostering change of views of the nature of scientific theories in a CSCL environment

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**Abstract:** This study investigated whether engaging students in knowledge-building help them develop more informed views regarding the nature of scientific theories. Findings indicated that students' views of the nature of scientific theories became more constructivist-oriented toward the end of the semester. A relationship was also observed between students' online activities and their changed views about the nature of scientific theories.

**Keywords:** Knowledge building pedagogy, Computer supported collaborative learning, Nature of scientific theory.

## 1. Introduction

Recent educational research shows that promoting students' understanding of the nature of science can help them understand science more deeply (Songer & Linn, 1991; Tsai, 1998; Lee, 2002). However, research in the investigation of students' perspectives of the nature of science showed that many students, even teachers, still see science as absolutely objective and definite; as such, they believe learning science is equivalent to memorizing a bunch of scientific facts. The teaching of science also emphasizes rote-learning rather than deep understanding. Consequently, students often do not know how to apply what they learned and eventually lost their interest in, and motivation to learn, science. Researchers need to investigate how to create a learning environment that can better encourage students to learn in a more autonomous and self-directed manner, and to guide them to construct their knowledge through learning-by-participating in various educational and cultural activities, rather than just highlighting knowledge telling and acquiring. To this end, this study adopted an instructional approach called 'knowledge building'. Knowledge building theory and pedagogy was originally proposed by Carl Bereiter and Marlene Scardamalia (2006), and it is manifested by twelve knowledge building principles that highlight intentional, self-directed learning and are different from conventional instructional approaches in Taiwan that emphasize knowledge-telling. For example, the principle of "real ideas and authentic problems" argue for the importance of using real-life related problems to engage students in working with their own ideas as a start of self-paced learning; and this is different from the kind of learning usually involved learning based on textbook knowledge. Other principles are such as improvable ideas; constructive uses of authoritative source, and epistemic agency (see Scardamalia, 2002, for details). Building on these principles, this study employed a knowledge building environment called Knowledge Forum, as an online forum for open-ended discussion and inquiry, where students could bring up issues or inquire topics they were interested in and responded to other peers with their own experiences or knowledge they learned in the past. The instructional goal is to guide students to work through a process similar to how scientists work with ideas by means of exploring a better explanation for an observed natural phenomenon. It is posited that engaging student in knowledge building process can help them develop a more informed and constructivist-oriented views of the nature of scientific theories.

## 2. Method

Participants were fifty-two college students in Taiwan who took a course titled "Introduction of Natural Sciences". The duration of the course was eighteen weeks. At the beginning of the semester, the participants brought up issues they were interested in inquiry in the discussion forum and then they used

the design features in the forum to conduct their inquiry (e.g., using scaffolds such as “I need to understand...”, “My theory...”, “This theory cannot explain...”, “New information...”, “A better theory...”, and “Putting our knowledge together...”), and to advance their knowledge in the community. Figure 1 shows a snapshot of students’ online discussion.

The data collected in this study included participants’ activities in the discussion forum and a survey. The survey was administered at the beginning and the end of the semester and used five open-ended questions as following: 1) What is scientific theory? 2) Are there good and bad theories? Why? 3) Where does a scientific theory come from? 4) Are scientific theories invented or discovered? Why? 5) Why do we need scientific theory? The survey was administered to assess participants’ views of the nature of scientific theories.

For the purpose of analysis, the pre and post survey was examined using a coding scheme emerged from a process of reading and re-reading the raw data. Five coding themes emerged were as follows: theory-independent vs. theory-dependent, single research method vs. diverse research methods, non value-laden vs. value-laden, discovery vs. invention, and permanent vs. temporary. Theory-independent means that students consider theories as objective presentation of a phenomenon without personal interpretation or inference; vice versa, theory dependent means that students think theories can be influenced by social factors, previous theories, and prior research results, and can further influence other research/theory. The second “single research method vs. diverse research methods” category assesses whether students consider that the generation of a theory involves repetitive validation using a or mixed single research methods. The third category of “non value-laden vs. value-laden” assess whether students think that theory could be judged as good or bad according to some specific standards. The fourth “discovery vs. invention” category assesses whether students consider theory as resulted from imagination and interpretation. The last category of “permanent vs. temporary” assesses whether students think that theory could be changed or replaced by better theory. The pre and post surveys were then further rated with a five-point Likert scale for each code. Take “permanent and temporary” as example, point one indicated that the participant tended to see scientific theory as infinite existence and unchangeable, whereas point five referred to a perspective that sees a scientific theory as replaceable by a better theory. The results of coding were statistically examined with t-test to see if there were any changes in the views of the nature of scientific theories over time.

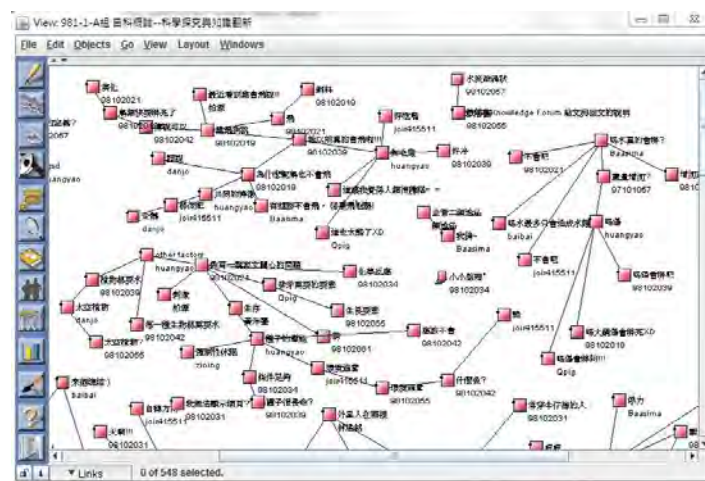


Figure 1. An example of the discussion activities in Knowledge Forum

Further, participants’ activities in the forum was analyzed by a tool called Analytic Toolkit (ATK) that was built-in in the forum for a purpose of obtaining quantitative data regarding online activities (e.g., their interaction). The content of online inquiry and discussion was content-analyzed using a coding scheme modified based on Zhang’s (2007) coding categorization of scientific concepts. There are six levels ranging from less-developed to well-developed scientific concepts. They are non-scientific concept, pre-scientific concept, hybrid concept, basically-scientific concept, scientific concept, and theory construction. Take non-scientific level for example, students’ note content is such as: “I don’t really remember... but this is a good way. So I’ll dry it (my jeans) inside out from now on!” or “It’s (plastic bags) not good to eat! Does this represent the feelings of germs? Though I think it’s kinda cute.”

Such content contains information (e.g., social chat) that is not very useful for or relevant to the development of scientific concepts. To elaborate further, pre-scientific concept (and hybrid concept) mean that students try to address questions mainly based on their personal experiences. Basically-scientific concept or scientific concept means that students can use constructive or proven scientific concepts to address questions. A key difference between these two categories is if students can provide better explanations. The highest level of theory construction means that students can further propose higher-level assumptions to develop a topic or to refute/challenge previous scientific concepts with higher level thinking and understanding.

In addition, the analysis of online activities in the forum was conducted with “week” as the unit of analysis, focusing on a given topic and its corresponding discussion. The entire semester was divided into two periods with mid-term (week 9) as the cutoff point to observe changes from the first half to the latter half of the semester. To understand the relationship between online forum activities and participants’ changes in their views of the nature of scientific theory, participants’ online activities were categorized based on the following characteristics: contribution activity, reading activity, improvement activity, and collaborative activity (see Table 1). Then, correlation analysis and a pair-sample t-test were conducted to observe whether there was a relationship between the number of each coding category and activities in the forum. Last, this study analyzed what participants inquired in the forum, and whether these inquiring activities were also related to participants’ changes of views of the nature of scientific theories. Due to the large amount of data, only half of the inquiry topics were selected for this analysis.

**Table 1. Coding table of the activities in the forum**

| Types of activity      | Item  | Description   |
|------------------------|---|---|
| Contribution activity  | - Number of notes contributed   | - Note contribution as a fundamental online activity in the discussion forum.   |
| Reading activity       | - Nnumber of notes<br>- total times for all notes read                                | - Reading others’ notes indicates community awareness (i.e. whether a participant cares about others’ ideas or not).<br>- The total number of times of all notes read indicates the intensity of reading activity.  |
| Improvement activity   | - Number of notes revised<br>- number of times scaffolds used                         | - Number of note revisions indicates that to what degree a participant reflects on his/her ideas.<br>- Number of scaffolds used represents the degree of higher-order thinking in relation to idea advancement by a participant.  |
| Collaborative activity | - Percentage of notes connected with others’ notes,<br>- Percentage of build-on notes | - Connecting with others’ notes indicates that a participant collaborates with others to improve the ideas and discuss about related issues.<br>- Build-on notes (i.e. replying to other’s notes) show that a participant responds and discusses by working with others’ ideas. |

### 3. Result

#### 3.1 Changes in the views of the nature of scientific theories

As shown in figure 2, the results indicated that there were significant changes in the five aspects as assessed at the end of the semester. The detailed statistics are as follows: (1) “Theory-independent vs. Theory-dependent” ( $t=-4.77$ ,  $p<.001$ ); (2) “Single research method vs. Diverse research methods” ( $t=-6.53$ ,  $p<.001$ ); (3) “Non value-laden vs. Value-laden” ( $t=-3.05$ ,  $p<.05$ ); (4) “Discovery vs. Invention” ( $t=-3.80$ ,  $p<.001$ ); and (5) “Permanent vs. Temporary”, ( $t=-4.35$ ;  $p<.001$ ). In brief, participants’ views of the nature of scientific theories were initially inclined to a more uniform view that sees theory as objective and permanent truth. Toward the end of the semester, their views became more

informed and diverse; they tended to see theory was tentative explanation for certain observed phenomenon and could be modified or falsified.

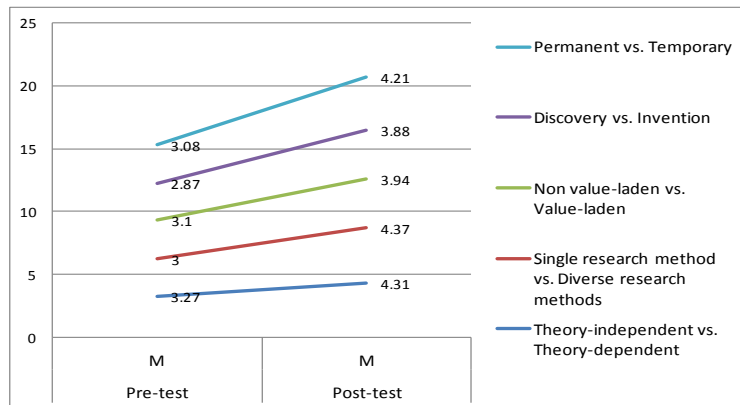


Figure 2. Students' pre- and post-survey results regarding their views of the nature of scientific theories

### 3.2 Relationship between forum activities and view changes

First, as baseline information, participants' basic online activities and the correlations among these activities were described as follows (see Figure 3 & Table 2). Furthermore, regarding correlations between participants' online forum activities and their changes in views of the nature of scientific theories, Table 3 shows the results. In this analysis, participants were divided into two groups based on the degree of changes in their views of the nature of scientific theories, with 50% as the cutoff point. Moreover, each category of the activity was divided into high- and low-frequency activities. A crosstab analysis was conducted to examine the relationship. Overall, the results showed that the range of participants' changes towards more diverse views of the nature of scientific theory at the end of the semester was highly related to the amount of activities on the computer-supported collaborative learning forum in this study: (1) the number of students with low pre-post change scores and low online activities is 58; (2), the number of students with high pre-post change scores and high online activities is 62; (3) the number of students with high pre-post change scores and low online activities is 42; and (4) the number of students with high pre-post change scores and low online activities is 46 ( $X^2 = 4.93, p < .05$ ).

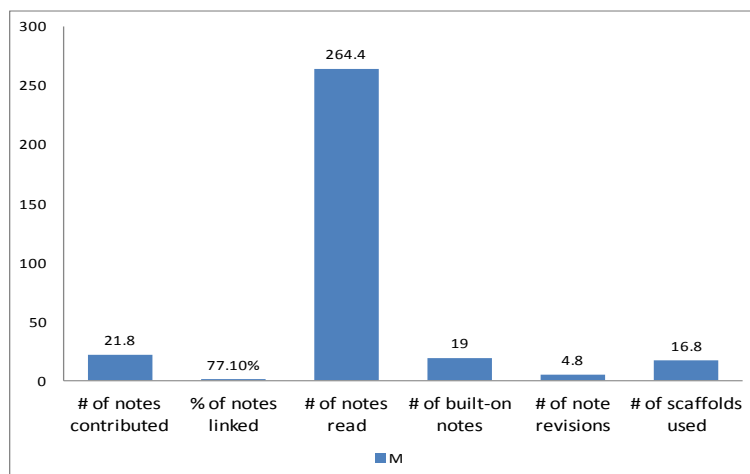


Figure 3. Descriptive analysis of participants' activities in the forum

Table 2. Pearson correlation among forum activities

|                           | 1 | 2      | 3      | 4      | 5      | 6      |
|---------------------------|---|--------|--------|--------|--------|--------|
| 1. # of notes contributed | 1 | 0.46** | 0.37** | 0.86** | 0.69** | 0.47** |
| 2. % of notes linked      |   | 1      | 0.19   | 0.38** | 0.46** | 0.95** |
| 3. # of note revision     |   |        | 1      | 0.47** | 0.29*  | 0.20   |

|                        |  |  |  |   |        |        |
|------------------------|--|--|--|---|--------|--------|
| 4. # of scaffolds used |  |  |  | 1 | 0.69** | 0.38** |
| 5. # of notes read     |  |  |  |   | 1      | 0.43** |
| 6. # of built-on notes |  |  |  |   |        | 1      |

\*<.05, \*\*<.001

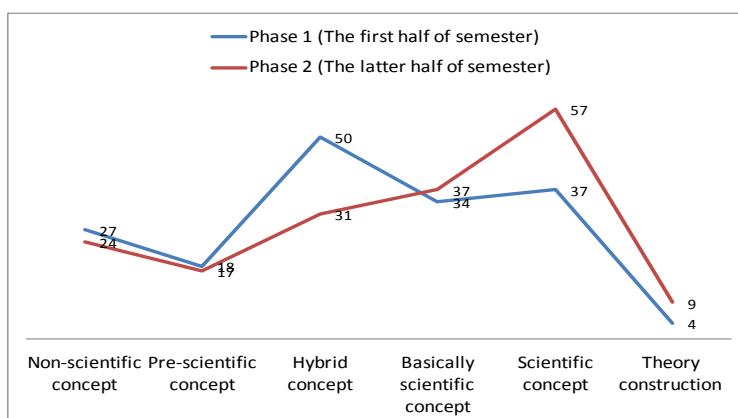
**Table 3. Crosstab analysis of participants' change and online activities**

| Types of activity/<br>Views      |             | Contribution |      | Reading |      | Improvement |      | Collaboration |      |
|----------------------------------|-------------|--------------|------|---------|------|-------------|------|---------------|------|
|                                  |             | Low          | High | Low     | High | Low         | High | Low           | High |
| Change between<br>pre-post tests | Low scores  | 17           | 8    | 14      | 11   | 14          | 11   | 13            | 12   |
|                                  | High scores | 9            | 18   | 12      | 15   | 12          | 15   | 13            | 14   |

\*<.05

### 3.3 Relationship between participants' online inquiry activities and their view change

Further, we analyzed the overall topics discussed within groups. Because class members were randomly assigned to one of the two groups and there was too much data, we only randomly selected one group for further analysis. There were fifty-eight topics and eleven sub-topics inquired in the discussion of this group (Group A) over the whole semester. Each topic lasted for an average of 5.26 weeks (SD=3.31), had 7.89 participants on average (SD=4.97), included 11.55 notes on average (SD=9.7), and had been read by 20.3 students on average (SD=7.92). Moreover, the results indicated that in the first half of the semester, participants' discussion tended to involve social and evaluative languages (non-scientific concepts), and pre-scientific concepts. They tended to use their personal experience and conjecture without providing any scientific evidence. But in the latter half of the semester, participants started to use more structural scientific concepts, including hybrid concepts, basic scientific concepts, and scientific concepts. They brought scientific theories, scientific knowledge into their discussion of the topic and then debated or proposed new ideas for future development. Regarding relationship analysis, the results of Chi-square showed that during the first half of the semester, participants didn't provide convincing information in the discussion. After participating in the forum activities for nine weeks, they started to use more persuasive theories or scientific information to support their arguments, and they also discussed or debated more with others. Using Chi-square analysis, there is a significant change from phase 1 to phase 2 in terms of the (high vs. low) level of scientific concepts students discussed in their inquiry ( $X^2=7.50, p<.05$ ).



**Figure 4.** Assessment of the quality of online inquiry between Phase 1 (weeks 1-9) and Phase 2 (weeks 10-18)

## 4. Conclusion

The purpose of this study was to investigate whether a computer-supported collaborative learning environment that was designed based on knowledge building pedagogy and principles could guide students to develop more informed and diverse views of the nature of scientific theories. First, the results indicated that participants' views of the nature of scientific theory changed significantly after they participated in the forum activities. Second, the results showed that forum activities were

positively correlated with participants' view change. Finally, it was also found that participants used more structural scientific ways to discuss and debate with others towards the latter half of the semester than in the first half. This was similar to how scientists conduct scientific investigation. In addition, it was found that more structural ways of inquiry was also related to participants' view change. Through the use of a computer-supported collaborative knowledge building environment that provided students with more autonomy and flexibility to inquire and discuss online, students were able to change from using more subjective personal opinions and experience to support their arguments, to using more structural and explanatory scientific ways of inquiry to support their knowledge work. As a result, they also developed more constructivist-oriented and diverse views of the nature of scientific theories, which help them to see theories as improvable and falsifiable, instead of unchanged and authoritative.

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# MuPeT: A Framework for Enabling Multi-Perspective Problem Elaboration

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**Abstract:** Creativity techniques gain importance in education and business areas day by day. Beyond the well-known brainstorming, which focuses on divergent thinking, lateral thinking will encourage the individual to regard the situation from a variety of perspectives by breaking old mind patterns and forming new connections and perceptions. Examples like „Six Thinking Hats“ or „(Walt) Disney Method“ consist of group discussions, where specific roles are assigned to the participants to enforce a discourse with different perspectives. Electronic group discussion systems can compensate the deficits of verbal (face-to-face) discussions through motivating passive discussants to participate. Furthermore, a system can provide a persistent logging of contributions and an explicit representation of a contribution according to the perspective of the participant. We present a novel approach, which allows both authoring and performing such multi-perspective creativity methods. In addition, the participant’s user interface is optimized for mobile devices. Finally we show first results of usability evaluations covering authoring and performing of a created method.

**Keywords:** Creativity techniques, group discussions, critical thinking, web-based learning

## 1. Introduction

Nowadays, internet and communication technologies (ICT) are present in nearly all areas of life in our society. The easy access to digital libraries and a variety of sources of information leads to a higher complexity, as the use of these knowledge sources turns into a requirement for individuals. The increasing complexity of this information and knowledge society inhibits the risk of uncertainty and personal overload as a consequence.

To accommodate to this knowledge society, there is a need to foster so-called 21<sup>st</sup> century skills. Abilities for problem-identification and problem-solving become more and more important in our daily life. This encompasses both the educational sector and business areas. Especially the movement from instructional to constructivist teaching methods demands critical thinking and active construction of knowledge from the students.

A solution to this dilemma will be the reduction of the information and knowledge society’s complexity. This can be achieved through abstraction, modelling, the use of tools and cognitive scaffolds. A key to problem-identification, problem-solving and decision-making is critical thinking, which elicits metacognitive skills to establish evidence on observation in order to judge on a specific problem. When performed in groups, such tasks include discussion and evaluation of others’ ideas. Former research has shown that collaborative learning enhances critical thinking (Gokhale, 1995, Johnson, Johnson, & Smith, 1991) and planning skills (Gauvain & Rogoff, 1989).

Electronic meeting systems can compensate some of the deficits of verbal (face-to-face) discussions (Nunamaker, Dennis, Valacich, Vogel, & George, 1991). In virtual teams it is easier to motivate passive discussants to participate, because the given anonymity reduces the barrier to contribute. Beyond that, such systems could provide moderation support

and explicit representations of contributions according to the context and perspective of the participants.

We propose a framework system for the authoring of creativity methods in the notion of multi-perspective problem-elaboration called MuPeT (“Multi-Perspective Thinking”). Prominent examples of methods applying to this category are the “Disney Method” (Dilts, Epstein, & Dilts, 1991) and De Bono’s “Six Thinking Hats” (De Bono, 1985). These methods are two examples, which can be applied in groups using MuPeT. The system provides means to add new creativity methods by *authors*. A dedicated interface for *moderators* allows for orchestrating a collaborative session. Finally, *participants* contribute in a collaborative session by adding cards to a shared space. A card represents ideas and concepts, and can relate to other cards. This relation is expressed by attaching a card to another, forming a pile of cards. The result will be a semi-structured space, reflecting the whole group discussion.

The structure of this paper is as follows: Section 2 provides a short overview about the background and related work. In section 3, an overview of the framework and implementation is given, emphasizing the three different roles in using the system. Section 4 summarizes two usability evaluation pilots focusing on the *author’s* interface. Finally, section 5 summarizes our findings and presents our future work concerning the MuPeT system.

## 2. Background and Related Work

The MuPeT system can be used to create methods for multi-perspective group discussions. There is a strong intersection between these kinds of group discussion and creativity-techniques, which can be applied to groups. A very prominent creativity technique is De Bono’s “Six Thinking Hats” (De Bono, 1985) in which participants wear hats in different colors representing different perspectives or ways of thinking in a group discussion. The goal is to foster a more efficient discourse about a topic without missing important viewpoints. A second prominent creativity technique is the “Disney Method”. The Disney method has been developed by (Dilts, Epstein, & Dilts, 1991). It is similar to the Six Thinking Hats and can be seen as a simpler version of it, consisting of three perspectives (*Dreamer, Realist, and Critic*) in a parallel thinking setting.

MuPeT supports both creativity techniques and is designed to foster collaborative and metacognitive skills. Former research has shown that collaborative learning enhances critical thinking (Gokhale, 1995). MuPeT furthermore follows a specific type of collaborative activities, namely Think-Pair-Share. This process has some benefits on the learning of the participants: In sharing their ideas, students take responsibility of their own learning. They negotiate meanings, discuss ideas, and do not rely solely on the teacher's authority, which forces critical thinking (Cobb, et al., 1991). Although this learning strategy has its foundations in non-electronic collaborative learning, it can also be applied to CSCL (Gallupe, Dennis & Cooper, 1992, Aiken, 1992). In MuPeT, cards represent ideas or concepts, the pairing appears in the system’s shared space and in a follow-up discussion, and participants share their ideas and solutions. The novelty of the presented approach is in the flexibility of the framework, which enables to author the underlying methods for group-discussions and the creativity techniques. In contrast to this, several systems exist, which focus on very specific creativity methods (Six Thinking Hats in *De Bono Thinking 24x7*<sup>1</sup>) or very general supporting group discussion or idea generation without putting emphasis on preserving or highlighting different perspectives (*MindMeister*<sup>2</sup> or *Daedalus InterChange*<sup>3</sup>).

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<sup>1</sup> De Bono Thinking 24x7: [http://www.debonoconsulting.com/de\\_Bono\\_Thinking\\_24x7\\_Software.asp](http://www.debonoconsulting.com/de_Bono_Thinking_24x7_Software.asp), retrieved May, 26<sup>th</sup> 2014.

<sup>2</sup> MindMeister, MeisterLabs GmbH: <http://www.mindmeister.com/>, retrieved May, 26<sup>th</sup> 2014.

<sup>3</sup> Daedalus InterChange, The Daedalus Group: [http://www.daedalus.com/products\\_diwe\\_overview.asp](http://www.daedalus.com/products_diwe_overview.asp), retrieved May, 26<sup>th</sup> 2014.

### 3. MuPeT System

With the goal of fostering critical, lateral and divergent thinking, we apply a modified Think-Pair-Share approach to create such system. We developed a framework to create methods for problem elaboration and group discussion with some degrees of freedom: Groups, parallel or non-parallel thinking, the number of perspectives and participants and possible recurrences and multiple iterations of the processes. To achieve this, we syndicate the requirements that come from related work and similar systems. This has been implemented in a web-based system, which will be presented in this section. After an overview of the system, technical details concerning the architecture will be shown briefly.

#### 3.1 Multi-Perspective Group Discussions

An example for a creativity technique that is usually applied in a group is the well-known brainstorming. The participants collaboratively produce ideas, which are not only built on their own thinking. They also reflect on others' ideas and rephrase, abstract or mash-up concepts to create more ideas. Such techniques and tools only cover the divergent phase of a problem-solving process, masking emotions, positive and negative aspects. Other techniques incorporate multiple perspectives and more structured information spaces, extending this minimalistic approach to enable group-discussions.

#### 3.2 Requirements

Considering the mentioned creativity methods and the related work, we derive the following requirements for such a system for authoring and performing multi-perspective group discussions:

- Method management: Allow for creating, removing and selecting methods.
- Session management: Sessions need to be recorded to enable persistence of the information, and also to pause them and continue later.
- Multiple perspectives: Following the mentioned creativity techniques, handling of different perspectives is needed.
- Perspective sequences: Methods consist of a queue of perspectives with a dedicated order.
- User management: More general than in the described methods, discussion can also benefit from different perspectives at the same time. Therefore, sequences need to be assigned to different users.
- Roles: Besides the participants, there is the need for a moderator with specific needs.
- Concurrency: Multiple users access the system concurrently when creating concepts and ideas, requiring data consistency.
- Idea representation: A potentially great amount of incoming ideas need to be represented adequately in the system. These ideas might be related and come from different perspectives. This requires a clear and functional visualization.

#### 3.3 Overview of the System

Derived from the requirements, we give a brief overview of the system. Mainly it consists of two different user interfaces, one for the moderator (and author) of methods, another one for the participants. When creating a new method, initially all perspectives need to be created. As a next step, the author can define a sequence of perspective (queue). By default, a queue of all previously defined perspectives is being created. Custom sequences might be useful to create

multiple iterations or custom schemes, as demonstrated in Figure 3. A use case for having more than one queue could be if a custom method consists of different groups of participants, where each group has its own set of perspectives. This can be applied in more controversy group-discussions, e.g. when learning to debate in schools. Such examples would not count as parallel thinking.

In order to facilitate the method, the moderator has to create a session. A session consists of a method on which it is based on and groups of participants. To these groups, queues of perspectives need to be assigned. Having one group for all participants will enable parallel thinking, while several groups can be used for the non-parallel version. After these assignments, the session is ready to accept connections from participants.

The participation mode gives the users the possibility to facilitate a created technique. The participants' interface gives an overview about the current perspectives including the instructions, e.g.

the description of the worn hat in terms of Six Thinking Hats. The interface provides the possibility to attach cards to a shared view, and to contribute to the discussion. It supports different representations of cards and reflects which participant created the card from which perspective. The card content can be text entered with a keyboard, or freehand text from a stylus. This can provide an additional benefit of natural input, especially when working on tablet PCs with such digitizer devices. Figure 5 demonstrates the whiteboard mode of the system, which could be easily used to provide a better overview of the current discussion, and to support the convergent or reflection phases at the end of a session.

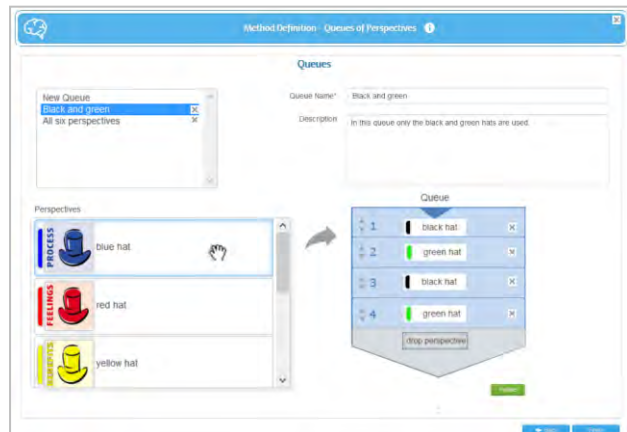


Figure 3. Creation of perspective queues. Different queues consisting of any order of perspectives can be defined for each method. This enables a flexible moderation and adaptation of methods.



Figure 4. The whiteboard mode of MuPeT. In the top bar, the queue of perspectives is displayed highlighting the current one. The canvas contains all cards (color from the perspectives) that have been added to the shared space. A pile of cards visualizes the relation between ideas.

#### 4. Evaluation

The system has been evaluated with focus on the authoring of creativity techniques as first trials indicated that the system is relatively simple for executing the methods in groups. However authoring in general is a complex task and the development of own creativity techniques is quite unnatural and uncommon. Therefore we will describe three evaluation studies that focused on the authoring part of the system.

In the first evaluation, a group of five experts discussed a real world topic (“extending the university with a new building”). Before the actual discussion, the participants had to create a method for the problem elaboration. The experts evaluated most of the functionalities of the system *for authors and participants*. The results are based on Jakob Nielsen’s ten heuristics for user interface design (Nielsen, 1994), performed with a think-aloud protocol. The overall impression of the experts was quite good. However, there were some aspects of the system that can be improved. Most of the usability problems concerning user control, freedom, and error prevention were encountered in the authoring process, when creating new methods. The suggestions have been used as an input for the first redesign iteration, shifting the focus for further evaluations to the moderators view.

The next iteration consisted of two studies. The usability improvement of the interface was further evaluated, focusing on the authoring of methods and orchestration of groups. The Ergonomics of Human System Interaction formed the basis of the evaluation criteria (ISO 9241-110 for dialogue principles and ISO 9241-210 for user experience). Two questionnaires have been used to evaluate these criteria: The User Experience Questionnaire (UEQ) (Laugwitz, Held, & Schrepp, 2008) is used to measure the perceived user experience and the dialogue principles are tested through the ISONORM 9241/110 (Pataki, Sachse, Prümper, & Thüning, 2006) survey. A protocol for the evaluation has been developed to check the user workflow for the authoring and moderation. Initially, 16 users tested the version of the system. Afterwards, the participants were asked to fill out the questionnaires. This output regarding ideas from the think-aloud technique has been used to create further improvements, later evaluated by another 16 participants. Table 1 shows the results of the UEQ questionnaire. The ratings range on a 7-point Likert-scale (-3 , +3).

Table 1: Average and standard deviation of the UEQ evaluation. Group 1 tested the previous version (iteration 1) and group 2 the improved version of iteration 2.

| Dimension      | Group | AVG  | SD   |
|----------------|-------|------|------|
| Attractiveness | 1     | 0.78 | 1.20 |
|                | 2     | 1.11 | 0.77 |
| Perspicuity    | 1     | 0.11 | 1.56 |
|                | 2     | 1.14 | 1.12 |
| Efficiency     | 1     | 1.05 | 0.71 |
|                | 2     | 1.34 | 0.81 |
| Dependability  | 1     | 0.50 | 1.10 |
|                | 2     | 1.17 | 0.95 |
| Stimulation    | 1     | 0.98 | 0.88 |
|                | 2     | 1.08 | 0.86 |
| Novelty        | 1     | 0.98 | 1.01 |
|                | 2     | 1.28 | 0.64 |

Table 2: Results of the IsoNorm questionnaire for both groups. The values have a range from -3 to +3 on a 7-point Likert-scale.

| Dimension                         | Group | AVG   | SD   |
|-----------------------------------|-------|-------|------|
| suitability for the task          | 1     | 1.23  | 1.11 |
|                                   | 2     | 1.54  | 1.33 |
| self-descriptiveness              | 1     | -0.90 | 1.33 |
|                                   | 2     | 0.90  | 1.17 |
| conformity with user expectations | 1     | 0.98  | 1.31 |
|                                   | 2     | 1.42  | 1.29 |
| suitability for learning          | 1     | 0.77  | 1.32 |
|                                   | 2     | 1.44  | 1.53 |
| Controllability                   | 1     | 0.69  | 1.11 |
|                                   | 2     | 1.06  | 1.17 |
| error tolerance                   | 1     | 0.48  | 0.85 |
|                                   | 2     | 0.98  | 1.06 |
| suitability for individualization | 1     | 0.13  | 1.16 |
|                                   | 2     | 0.63  | 0.82 |

In all dimensions of the questionnaire, an improvement can be measured. The evaluation of the IsoNorm questionnaire (cf. Table 2) has proven the positive effect of the usability engineering. The most significant improvements are made on the UEQ Perspicuity and the IsoNorm self-descriptiveness. The results of the second group show that the overall perception of the systems usability is very good, though there is still space for improvement. Future studies will envisage a larger-scale use of the participant’s interface.

## 5. Conclusions and Future Work

In this paper, we presented a framework for enabling multi-perspective problem elaboration. The implemented system is capable of authoring of new creativity methods and their facilitation in a web-based application. The evaluations showed that the system is well received. For the future, additional experiments are planned to evaluate the participation interface in online-learning scenarios. It will be interesting to see, if such tools can be used to support inquiry-based learning, especially in the context of online labs in the STEM fields (“Science, Technology, Engineering, Mathematics”). Such learning scenarios usually demand activating and supportive teaching techniques. Moreover, the analysis of learning traces and the application of methods of learning analytics can be of interest. How do students create hypotheses, construct their knowledge or reflect on their learning process in discussion phases?

A typical weak aspect of such tools for idea generation is the lack of support for the convergent phase, where the concepts, ideas and solutions are evaluated. A borderline example is the brainstorming, where the result is a collection of unrelated ideas. For such tools, a “post-processing” phase that provides both visual support and also content-analysis would be of interest. This can be a timeline visualization of the idea generation, but also a network built from relations that are extracted on a semantic level.

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# The motivational underpinnings of using wikis for collaborative group work

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**Abstract:** This study aims to investigate the role of goal orientations on students' engagement in using wikis for collaborative writing. Hong Kong secondary school students (N = 422) participated in the study and answered questionnaires about their goal orientations and their level of engagement when using wikis for collaborative project work. Results showed that students who pursued mastery and social goals were more engaged in their collaborative projects. However, it was students who pursued performance goals who achieved higher grades. Implications for synergizing research on IT in education and motivational psychology are discussed.

**Keywords:** achievement goals, social goals, wiki, collaborative group work

## 1. Introduction

In recent years, there has been rapid growth in the use of Web 2.0 tools (also known as Web-based collaboration ware) such as wikis, blogs, podcasts, and RSS feeds (Boulos, Maramba, & Wheeler, 2006; Byron, 2005; Ebner, Kickmeier-Rust, & Holzinger, 2008). The success of Wikipedia is a testament to the widespread dissemination of Web 2.0 technology. Web 2.0 technologies offer a wide range of unique and powerful information sharing and collaboration features.

Educators have begun to harness the potential of Web 2.0 in the school setting (Chu, Chan, & Tiwari, 2012; Fu, Chu, & Kang, 2013; Parker & Chao, 2007; Woo & Chu, 2013). In this paper, we particularly focus on the use of wikis to foster collaborative group work. The word "wiki" comes from the Hawaiian phrase "wiki-wiki" which means quick. It is a system that allows users to create and edit web pages collaboratively (Leuf & Cunningham, 2001). Much of the research on wikis have been conducted by learning technology specialists who were interested in harnessing the affordances of the wiki technology in enhancing the student learning experience (e.g., Chen et al., 2005; Pifarre & Starman, 2011). As such, these studies have usually focused on the technical features of wikis, and how students and teachers use these features in collaborative group work.

A shortcoming of this literature is a lack of attention to the deeper motivational processes that underpin the effective use of the wiki technology for collaborative group work. Different students facing the same wiki tool would exhibit varying degrees of motivation and engagement. Given that all students are exposed to a similar wiki platform why do some students display a greater degree of engagement, while others seem to be more indifferent. What could account for these individual differences in motivation and engagement?

In this paper, we attempt to answer this question by looking at how individual differences in student motivation could account for the differential engagement with the wiki for collaborative learning. Educational psychologists who have studied motivation usually focus on the role of goal orientations as crucial motivational constructs (Covington, 2000). Therefore, in this paper, we examine the role of goals in predicting engagement and achievement when using wiki for collaborative learning.

## 2. Literature Review

Educational psychologists who study motivation have usually focused on the role of goals on learning and achievement. Goals refer to desired end states and have been shown to predict a wide range of educational outcomes (Huang, 2012; Hulleman, Schragger, Bodmann, & Harackiewicz, 2010).

Early research has focused on two types of achievement goals: mastery and performance goals (Elliot, 1999). Students who endorse mastery goals focus on improving their level of competence and are intrinsically interested in the task. On the other hand, students with performance goals are interested in demonstrating their superiority to others and showing their normative competence. Mastery goals have been shown to be associated with deep learning strategies, intrinsic motivation, effort, persistence among others.

Later researchers have argued that social goals are also important predictors of learning and achievement (King & McInerney, 2014; King, McInerney, & Watkins, 2012, 2013; King & Watkins, 2012). Social goals refer to the pursuit of social outcomes in school (Wentzel, 1994, 1996). There are two main types of social goals: prosocial and social responsibility goals. Students with prosocial goals focus on trying to help their classmates and peers. They are keen to share what they know with others. Students with social responsibility goals are focused on keeping interpersonal commitments to their peers and complying with classroom norms. Research has shown that both prosocial and social responsibility goals were associated with a wide range of adaptive educational outcomes (Wentzel, 1996; 2000).

In this study, we examined the association between the different types of goals that students pursued and their level of engagement in the collaborative wiki group work. Engagement has usually been conceptualized as having three dimensions: behavioral, emotional, and cognitive (Fredricks, Blumenfeld, & Alison, 2004). Behavioral engagement refers to effort, persistence and mental effort such as attention and contribution to class discussion. Emotional engagement covers the energized emotional states such as enthusiasm and interest, while cognitive engagement refers to the use of deeper forms of learning strategies. Cognitively engaged students are not afraid to exert effort to master difficult skills.

Engagement is a crucial construct in student learning given that engaged students learn more in school and achieve higher grades. They are also less likely to drop out of school. Engagement is a malleable construct and has been shown to be influenced by a wide range of factors. The goals that students pursue have been shown to exert an important impact on students' levels of engagement. In particular, mastery goals have been shown to be positive predictors of engagement.

Research examining the link between social goals (prosocial and social responsibility) and engagement are more sparse. However, the few existing studies would suggest a positive linkage between social goals and engagement. Studies have shown that students who try to help their peers (i.e., those who pursue prosocial goals) learn more in the process. Those who try to comply with classroom norms and rules are more likely to have a better overall learning experience (Wentzel, 2000; Wentzel, Filisetti, & Looney, 2007)

The present study examined the relationship between different types of goals (mastery, performance, prosocial, and social responsibility goals) and engagement in collaborative wiki writing. In this study we focused on a group of students who were using wikis to co-create their final group project.

## 3. Methods

### *Procedures*

The wiki platform PBworks (<http://www.pbworks.com>) was used in this study. Students used this platform for their collaborative inquiry group project in Liberal Studies (LS). A standard PBworks template was created. Using this template, students could add or edit the files and pages. On each page, they could leave comments for internal group discussions. The widget "Recent Activity History" could help group members keep track of the changes on the wiki pages.

On average, each group had four students. The students took 4-5 months to complete the online project. At the end of the project, students responded to a questionnaire which measured their goal orientations and engagement. The final grades for the group work was also obtained.



### *Participants*

There were 422 secondary school students from Hong Kong who participated in the study. All students were from a co-education government secondary school, and their age ranged from 13 to 15.

### *Instruments*

To measure students' goal orientations, the goal questionnaire devised by Wentzel (1994, 1996, 2000) was used. It measures four types of goals: mastery, performance, prosocial, and social responsibility goals. The definitions of these constructs as well as sample items are given below. Note that all questions were modified to pertain to the LS class.

To measure cognitive engagement, we used the deep learning strategies subscale of the Revised Two Factor Study Process Questionnaire (Biggs, Kember, & Leung, 2001). To measure behavioral and emotional engagement, we used the relevant subscales from Skinner, Kindermann, and Furrer's (2009) Engagement and Disaffection Questionnaire. All these scales were modified to pertain to the liberal studies class which was the domain we chose to study in this paper. Questionnaires were answered on a 5-point Likert scale with higher scores indicating a greater endorsement of the construct.

Table 1: Goal constructs, definition, and sample items.

| <b>Goal construct</b>      | <b>Definition</b>   | <b>Sample items</b>  |
|----------------------------|---|--|
| Mastery goal               | Wanting to learn as much as possible for intrinsic reasons      | How often do you try to learn something new for LS class even if you don't have to?  |
| Performance goal           | Wanting to outperform others                                    | How often do you try to show you have learned more than your classmates in LS class? |
| Prosocial goal             | Wanting to help classmates and peers                            | How often do you try to share what you've learned with your classmates in LS class?  |
| Social responsibility goal | Wanting to keep interpersonal commitments to peers and teachers | How often do you try to do what your LS teacher tells you to do?                     |

## **4. Results**

### *Preliminary results*

We first looked at the descriptive statistics and internal consistency reliabilities. Results showed that all the scales had good psychometric properties with Cronbach's alpha reliabilities ranging from .74 to .84 (see Table 2). Table 3 shows the correlations among the variables.

Table 2: Descriptive statistics and internal consistency reliabilities

|                            | <b>Mean</b> | <b>SD</b> | <b>Cronbach's alpha</b> |
|----------------------------|-------------|-----------|-------------------------|
| Mastery goal               | 3.36        | .66       | .83                     |
| Performance goal           | 3.10        | .72       | .83                     |
| Prosocial goal             | 3.21        | .62       | .79                     |
| Social responsibility goal | 3.47        | .64       | .74                     |
| Behavioral engagement      | 3.62        | .58       | .82                     |
| Emotional engagement       | 3.59        | .58       | .84                     |
| Cognitive engagement       | 3.37        | .59       | .79                     |
| Grades                     | 3.09        | .72       | n/a                     |

**Table 3: Zero-order correlations among the variables.**

|                               | 2       | 3       | 4       | 5       | 6       | 7       | 8       |
|-------------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1. Mastery goal               | .650*** | .610*** | .606*** | .513*** | .535*** | .543*** | .235*** |
| 2. Performance goal           | 1       | .598*** | .479*** | .341*** | .338*** | .424*** | .272*** |
| 3. Prosocial goal             |         | 1       | .487*** | .357*** | .431*** | .442*** | .175*** |
| 4. Social responsibility goal |         |         | 1       | .463*** | .442*** | .455*** | .191*** |
| 5. Behavioral engagement      |         |         |         | 1       | .791*** | .707*** | .218*** |
| 6. Emotional engagement       |         |         |         |         | 1       | .755*** | .214*** |
| 7. Cognitive engagement       |         |         |         |         |         | 1       | .180*** |
| 8. Grades                     |         |         |         |         |         |         | 1       |

Note:\*\*\* $p < .001$ .

*Predictive relationships*

To examine the relationship between the different types of goals and engagement in wiki collaborative writing, four separate regressions were conducted. The independent variables were the four types of goals: mastery, performance, prosocial, and social responsibility goals. The criterion variables included behavioral engagement, emotional engagement, cognitive engagement, and grades in the wiki project. Table 4 shows the results of the regression analyses.

**Table 4: Goals as predictors of engagement and achievement.**

|                            | Behavioral engagement | Emotional engagement | Cognitive engagement | Grades  |
|----------------------------|-----------------------|----------------------|----------------------|---------|
| Mastery goal               | .369***               | .396***              | .328***              | .075    |
| Performance goal           | -.034                 | -.100                | .055                 | .178**  |
| Prosocial goal             | .036                  | .167***              | .127*                | -.019   |
| Social responsibility goal | .239***               | .168***              | .168**               | .052    |
| R <sup>2</sup>             | 30.1%***              | 32.4%***             | 33.4%***             | 6.5%*** |

Note: \*  $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

Results indicated that mastery goal was a consistent positive predictor of the three different types of engagement: behavioral, emotional, and cognitive. Social goals were also important predictors. Prosocial goals positively predicted emotional and cognitive engagement, while social responsibility goals positively predicted the three types of engagement. Interestingly, grades on the wiki project was only predicted by performance goals.

**5. Discussion**

In general, the results of this study suggest that knowing the goals students are trying to achieve in school can explain, in part, how engaged they are when doing collaborative group work on a wiki platform. In particular, it was shown that mastery, prosocial, and social responsibility goals predicted engagement, while performance approach goals predicted actual achievement.

When students come into the classroom, they already bring with them a certain psychological baggage. Part of this baggage are the goals that they pursue in school. Psychological research has shown that different types of students would pursue different types of goals. It would be naive to assume that all students will be equally engaged when doing collaborative group work in wiki. Thus, teachers are advised to attend to the types of goals that students bring with them. Studies have shown that these goals are highly malleable and that teachers have an important role to play in shaping the types of goals that students would pursue (Jang, Reeve, & Deci, 2010; King & Ganotice, 2014).

Results of our study indicated that mastery, prosocial, and social responsibility goals were important predictors of behavioral, emotional, and cognitive engagement. Mastery goals have been

associated with a wide range of positive outcomes in previous research. Thus, it was not surprising to find mastery to positively predict all the three types of engagement

An interesting feature of our study was the inclusion of prosocial and social responsibility goals. Most educational psychologists fail to investigate the correlates of these goals and focus exclusively on mastery and performance goals. We thought that social goals would be especially important in collaborative settings. When students work with each other, goals aimed at helping each other (prosocial goal) and trying to keep promises and commitments to each other (social responsibility) would facilitate the cooperative learning process. Therefore, it is likely that social goals are especially important in collaborative group work. This assumption received support in the current study. We found that both types of goals positively predicted engagement.

Another interesting finding was that of all the four types of goals investigated only performance goals positively predicted grades in the wiki project. Performance goals have been associated with both positive and negative outcomes in previous research. For example, performance-oriented students have been found to use more superficial learning strategies and were anxious. However, performance approach goals have been consistently associated with higher levels of academic achievement (e.g., Huang, 2012; Hulleman et al., 2010) and these results were replicated in our study. This

## 6. Conclusion

Taken together, results of the current study showed that goals were important predictors of engagement in a collaborative wiki environment. This study has important theoretical implications for bridging research in educational psychology with the literature on IT in education.

IT in education researchers have traditionally been interested in the use of information technologies for improving the student learning experience. However, they have paid insufficient attention to the role of motivational factors in influencing the quality of learning in technologically-enriched environments.

On the other hand, educational psychology researchers have conducted a number of studies on the role of goals in traditional classroom settings where the learning structure is mostly individualistic. They have not investigated how these goals would play out in a collaborative and technologically-enriched learning environment.

This study showed the possible synergies that could emerge by linking information technology research with educational psychology theorizing. It also has important practical implications. To facilitate learning, teachers are encouraged to cultivate students' mastery and social goals. Mastery goals could be encouraged by designing interesting and meaningful tasks. The use of norm-referenced assessment and evaluation could also be decreased. Collaborative group work has been shown to increase students' prosocial and social responsibility goals. Therefore, teachers could encourage the use of collaborative strategies to improve student learning (Johnson & Johnson, 2009).

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# Learning about Reflection Processes: An Analysis of Learners' Observation of Experts

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**Abstract:** Both reflection-in-action and reflection-on-action are important, especially in creative design work. Although school curricula teach the technical side of design, they do not teach the psychological side, represented by the reflection process. The goal of this research is to support learners to understand experts' reflection processes in relation to design. This paper describes experts' reflection-in-/on-action processes in design, and how learners observe this from video data on the design process, and on eye-tracking of an expert designer. The findings are helpful for designing environments that support students to learn about experts' reflection processes.

**Keywords:** reflection-in-action, reflection-on-action, design process, student learning, eye-tracking

## 1. Introduction

The goal of this research is to help learners understand experts' reflection processes in the context of design.

Schoen describes design as a reflective conversation with the material of a situation, and distinguishes two types of reflection: reflection-in-action and reflection-on-action (Schoen 1983). Reflection-in-action is the reflective process that takes place while externalizing representation, while reflection-on-action occurs when a designer views a result of representation. Both types of reflection are important, especially in creative design work.

Although school curricula teach the technical side of design, they do not teach its psychological aspects, which is represented by the reflection process. For this reason, the student has to establish his/her style over many long years, or has to learn it practically through on-the-job trainings of a company.

This paper describes experts' reflection-in-/on-action processes in design, and how learners observe these processes from video data.

## 2. Reflection-in-/on-Action in Design

In addition to physical sketches, supportive computer-based tools are useful to designers. Nakakoji et al. describe the approach of using two-dimensional spatial positioning of piece of document as a representation that is useful for reflection in the early design of documentation (Nakakoji et al. 2000). They argue that position as a state is closely related to reflection-on-action, while positioning as an action is closely related to reflection-in-action. In other words, reflection on the results of a previous action is regarded as reflection-on-action, and reflection while taking the action is regarded as reflection-in-action. The approach taken by Nakakoji et al. guides the present research.

## 3. Preliminary Study

For the purpose of examining students' interest in learning from experts' processes of creation, we used two tasks: we conducted a questionnaire survey and we asked the students to list their awareness of

expert behavior based on video viewing. The participants consisted of a total of 14 first- and second-grade college students. All participants were majoring in media design.

### 3.1 Questionnaire Survey

A questionnaire survey was conducted in order to examine students' interest in learning about media design. The questionnaire items are listed in Table 1, and the results relating to question 1 and question 2 are shown in Figure 1 and Figure 2, respectively. As shown in Figure 1, the students feel that watching video representations of the design process is an effective form of learning. Figure 2 indicates that all the students are interested in both the technical and psychological aspects of experts' creation processes.

Table 1: Question items for the survey

|    |  |
|----|--|
| Q1 | Which types of media are most effective in learning about experts' creation processes?<br><books, images, videos, Web, dialogue, others> (Multiple answers allowed)        |
| Q2 | What is your level of interest in the technical/psychological aspects of experts' creation processes?<br><None: 0 pt, Very little: 1 pt, Some: 2 pts, A great deal: 3 pts> |

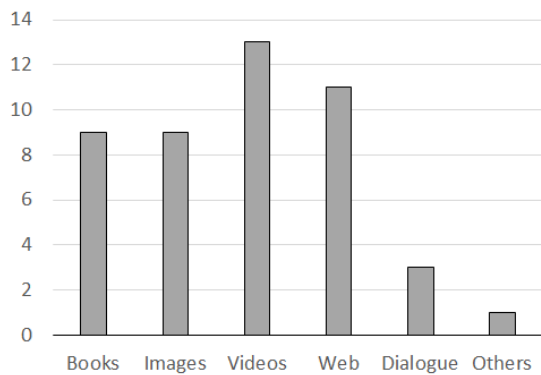


Figure 1. Results for Q1. Which types of media are most effective in learning about experts' creation processes? (N=14, multiple answers allowed)

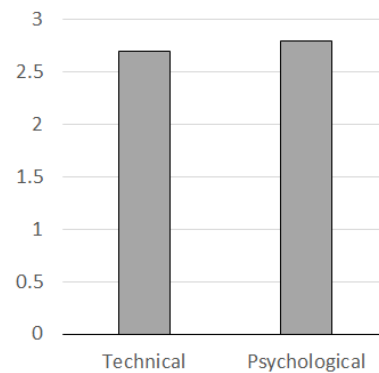


Figure 2. Average results for Q2. What is your level of interest in the technical/psychological aspects of experts' creation processes? (N=14)

### 3.2 Observation of Experts' Design Processes by Students

Based on the result of the questionnaire survey, a user study was conducted with the aim of revealing how learners observe experts' design processes. As a learning material, we used two video clips from a documentary film on the drawing processes of a famous manga artist, Inoue Takehiko (Inoue, 2006). The details of the videos are described as V1, V2 and typical behaviors considered as part of the reflection process are listed as R1, R2 and R3 in Table 2. The students were asked to report their awareness of the expert's technical and psychological aspects through watching the videos.

R2 was clearly regarded as a reflection-on-action process because the expert declared it to be so; however, it is not obvious that R1 and R3 are reflection processes because the artist did not mention them. R1 is likely to be reflection-in-action process, and R2 is unequivocally a reflection-on-action process.

As a result of the observation, the students reported their levels of awareness: 42.9%, 28.6% and 85.7% of the students mentioned R1, R2 and R3, respectively.

Table 2: Videos for the observation

|    |   |  |
|----|---|--|
| V1 | A documentary film focusing on Inoue's hand, which draws scenes from a very famous manga comic, <i>Vagabond</i> . 38 min.   |  |
|    | R1  | The expert said "Hmm..." while he was drawing the face of a character.                                     |
| V2 | A video that shows the drawing processes of other scenes from the same comic as that shown in V1. This includes dialogues between Inoue and an interviewer. 55 min. |  |
|    | R2  | The expert reversed a sheet of paper in order to examine whether the body of a character is balanced well. |
|    | R3  | The expert corrected the eyes of a character using correction fluid.                                       |

#### 4. Reflection-in-/on-Action in Experts' Design Processes

##### 4.1 Analysis of Results using the Retrospective Think Aloud Protocol

Since the target videos used for the preliminary study were in the commercial DVD (Inoue, 2006), the reflection processes were not immediately obvious. For the purpose of linking some of the artist's behaviors with reflections, an audio commentary of another expert's design process was recorded, along with eye-tracking data. The expert is a professional designer and also a part-time lecturer at several colleges. His work centers on logos, typefaces, posters, flyers, and so on. For this experiment, the artist was instructed to create a logo as part of a real logo design competition for a botanical garden in Japan. The tools he selected were Adobe Illustrator, Adobe Bridge, and Google Chrome. In order to track his eye movements, Tobii X2-30 Eye Tracker was used. This device can record eye-movement data without goggles. Figure 3 shows an image of the recording session.

The design process by the expert was initially recorded using his eye-tracking data (Figure 4 shows a screenshot of this data). The design was finished in three hours.

After the design process was complete, an audio commentary for the video containing the eye-tracking data was recorded through the Retrospective Think Aloud Protocol (Guan et al. 2006). Table 3 provides details on this video, and the behaviors that correspond to the reflection processes mentioned by the expert.



Figure 3. The environment during recording of the expert's design process



Figure 4. Eye-tracking data, which indicates that the expert was paying close attention to the character spacing

Table 3: Details on the audio commentary video and mentions of the reflection process

|    |   |  |
|----|---|--|
| V3 | An audio commentary video that includes eye-tracking data on designing a logo for a botanical garden in Japan. 170 min. |  |
|    | R4  | The expert fine-tuned the position of the kanji characters using the arrow keys on the keyboard. |
|    | R5  | The expert fine-tuned the size of the leaves using the arrow keys on the keyboard.               |
|    | R6  | The expert compared several logos made with different fonts.                                     |
|    | R7  | The expert zoomed out and considered the logo for a while.                                       |

The reflection processes listed in Table 3 are all recognized as reflection activities by the expert. R4 and R5 can be regarded as reflection-in-action processes, because the expert was reflecting while taking the action (i.e. fine-tuning using the arrow keys). On the other hand, R6 and R7 are reflection-on-action processes, because the artist was reflecting on the results of the previous action.

In addition to this awareness of reflections, the expert was surprised at his behavior because while he was adjusting the characters (R4) he paid close attention to the character spacing (Figure 4). This shows that even the expert himself could learn from his own design process. In other words, he “reflected on reflection-in-action”.

#### 4.2 Observation of Expert’s Design Process by Students

In order to examine whether the college students were able to understand or learn about the expert’s creation processes by just watching the audio commentary, an observation was conducted with the same student participants as in Section 3.

In focusing on the reflection processes, R4 and R5 did not capture the student’s attention to the same degree as R6 and R7, which were recognized as meaningful behaviors by the expert. Only one student (7.1%) had some awareness of R4, and stated, “This manipulation is a delicate adjustment”. A total of 14.3% of the students mentioned R5, for instance: “The expert is continuing to look for a satisfying size”; “it is not so easy for me to understand the slight differences...”. In addition, 35.7% of the students showed some interest in the expert’s comparison of several fonts (R6), stating, for example, “I cannot decide which is the best”; “Comparing a lot of fonts makes me confused...”; “This font is better”; and so on. R7 was recognized as a meaningful behavior by 28.6% of the students. Several comments, such as “I think that he is checking the arrangement”; and “Zooming in and out is important!” were received.



## 5. Conclusion and Future work

This paper describes experts' reflection-in-/on-action processes in design, and how learners observe this from video data. Since the number of participants in these studies was small, the results from the quantitative data were limited; however, we discovered a new perspective from the students' written comments.

The findings from the observations and analysis are as follows:

- College students majoring in media design have an interest in both the technical and psychological aspects of the creative design process.
- Videos are preferred as learning materials related to the design process.
- Behaviors related to reflection-in-/on-action were observed through the experts' design process.
- Reflection-on-action processes are relatively recognizable, whereas reflection-in-action processes are not.

How, then, can students learn about design processes used by experts? One key element is "reflection on reflection-in-/on-action," as described in Section 4.1. Giving some cues that indicate instances of reflection-in-/on-action during recorded design process would be useful in this regard, as would providing cues to indicate instances in which the expert is reflecting on their reflection processes. The fact that even experts continue to reflect on their behavior should enhance learners' interest in the reflection processes.

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# A Relationship between the Pair Effect and the Learner Characteristic at Pair Work in Computer Literacy Education

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**Abstract:** We have introduced pair works to university-level computer literacy education as opposed to the traditional one, standalone teaching. In this paper, in order to extract the learner characteristics factors that influence the pair work effects such as test-score improvement level, pair-work activity level and pair-work satisfaction level, we conducted two experimental pair work classes in computer literacy exercise courses. For the investigation, we used two main questionnaire surveys, TEG II and GAMI as personality indexes. The result showed that the personality index has clear strong correlation with the degree of activity and degree of satisfaction in TEG II and also to the degree of score elevation in GAMI. The personality score, obtained from the result, is useful for more effective pair combination.

**Keywords:** Computer literacy education, pair work, pair combination, personality

## 1. Research Background and Objective

Following the global educational trends of recent years, active learning, wherein students discover a problem and attempt to find a solution on their own, has been increasingly required. To implement active learning, gaining and increasing information literacy, which serve as the basis of information collection and transmission, are also necessary. To address these issues, we implemented lessons for university freshmen, incorporating pair work into information literacy education, and confirmed its effectiveness. Subsequently, we concluded that pair work can be very effective for the education.

For effective pair work, the method of forming pairs is important and fundamental. In many cases, however, pairs are determined randomly, e.g., according to the order of students' ID numbers or seating arrangement. Moreover, research specializing in pair formation is almost nonexistent.

Hence, since 2008, we have continued a survey to establish a pair formation method that optimizes student combinations. Thus far, we have clarified the following: 1) Problem solving by a pair exceeds that by an individual, and pair achievement is generally significantly higher than individual achievement; 2) the most effective pair combinations included those with a small difference in basic scholarship, and mixed gender (Uchida and Oya, 2011). However, our experience also shows that the personality of student must influence the pair effect.

Thus, this paper focuses on the personality traits that have been reported to affect cooperative learning and aims to improve the pair-work effectiveness by devising pair combinations according to quantitative scale scores.

## 2. Personality and Pair Effect

We investigated the learning motivation closely related to the class and the personality traits according to egrams, effective in diagnosing tendencies of interpersonal communication.

Used to measure personality traits, the egram is widely used in the medical field, but also in education—to examine university curriculum that considers students' characteristics and their awareness of information morals. There are many types of egram. In this study, TEG II (Tokyo

University Psychosomatic Medicine TEG Association, 2006), widely and generally used, was administered. To measure learning motivation, we used GAMI (the Gakugei Academic Motivation Inventory, Shimoyama, 1985), a widely used scale with criteria for classifying learners' characteristics. To develop e-learning materials suitable for different learning motivation types, relevance verification of learning motivation, and Internet usage, GAMI is a psychological scale that standardizes learning motivation measurement.

For the pair effect, we used three values: 1) test-score improvement level, 2) pair-work activity and 3) pair-work satisfaction level. The test-score improvement level represents the extent of increase or decrease in the score deviation value of the pair test, compared with the individual test deviation value. To measure pair-work activity, we used the number of utterances during pair work. Because, the amount of utterance is effective in the state estimation of cooperation working. Furthermore, the students' satisfaction level will be considered as an important factor for effective pair work. The post-questionnaire measured two values for satisfaction level: the overall pair work satisfaction level and the pair-combination satisfaction level.

### **3. Method**

In 2013, we conducted experimental classes using pair work. The participants were approximately 160 students participating in computer literacy courses in four classes at two private universities in Japan. In April, we conducted a preliminary survey on the pair combination indicators which are basic academic ability and gender. Following nine computer literacy lessons based on a simultaneous method, an individual test was conducted to calculate the pair effect. Our experimental pair work classes were conducted once a week for two weeks in June. Each pair comprised a male and female with similar academic abilities, which was confirmed to have a significant impact by a previous study. In the first pair work test (Test 1), a 15-minute practical test based on the word processing qualification examination was conducted. At the same time we conducted a 10-minute survey of personality (TEG II). In the second test (Test 2), a 25-minute assignment to create a sample document for a display poster and a 10-minute survey of personality (GAMI) were allocated. Before the pair work, a 5-minute free talk period was provided to develop smooth conversations between pair members who were meeting for the first time. We recorded the exchanges from the free talk to the end of the pair work with an IC recorder. After the pair work, we conducted a 21-item questionnaire survey on problem solving in pairs.

The procedure of analysis is as follows: First, we performed a basic analysis of the pair effect from test-score improvement level and activity level of Test 1 and Test 2, results of the overall pair work, and the pair-combination satisfaction level. Next, we attempted to find the correlation coefficients among TEG II and GAMI, the test-score improvement level, activity, and satisfaction level in an effort to select the elements involved in the pair effect from the significance probability.

### **4. Personality Score and Estimation**

To examine whether a relationship exists between TEG II, GAMI and the pair effect, we analyzed its correlation with the result test-score improvement level, activity, and satisfaction level. The result showed that the personality's characteristics has clear strong correlation with the degree of activity and degree of satisfaction in TEG II and also to the degree of score elevation in GAMI.

On the basis of these results, we summarized the scales of GAMI and TEG II that show relationships with the test-score improvement level, pair-work activity, and pair-work satisfaction level (see Table 1). A single asterisk (\*) refers to points with 5% significance and a double asterisk (\*\*) refers to points with 1% significance. There is a clear strong correlation between five items of GAMI regarding the test-score improvement level, four items of TEG II and two items of GAMI regarding activity, and four items of TEG II and seven items of GAMI regarding satisfaction level. From these results, we believe each effect of pair work—mixed gender with small basic academic ability difference—could be improved by devising pair formation using TEG II and GAMI.

Then, we proposed a pair formation improvement method using the values obtained from TEG II and GAMI: First, on the basis of these results, we calculated the individual personality score (PS) using the scale scores of GAMI and TEG II. Next, we divided the students into three groups, L, M, and H, using the quartile method. Then, the LL pair with the personality trait of low mutual pair effect was

**Table 1: Relevance between personality factors and each pair effect.**

|                                | test-score improvement level |          | pair-work activity level |         | pair-work satisfaction level |                  |
|--------------------------------|------------------------------|----------|--------------------------|---------|------------------------------|------------------|
|                                | Test1                        | Test2    | Test1                    | Test2   | pair work                    | pair-combination |
| TEG II                         |                              |          |                          |         |                              |                  |
| ①CP(Critical Parent)           | -.057                        | -.092    | .113                     | .156    | .221 **                      | .193 *           |
| ②NP(Nurturing Parent)          | -.118                        | -.121    | .149                     | .278 ** | .375 **                      | .161 *           |
| ③A(Adult)                      | .054                         | .067     | -.181 *                  | -.178 * | -.047                        | -.017            |
| ④FC(Free Child)                | .021                         | -.034    | .166 *                   | .263 ** | .353                         | .176 *           |
| ⑤AC(Adapted Child)             | .018                         | .008     | -.169 *                  | -.136   | -.128 **                     | -.003            |
| GAMI                           |                              |          |                          |         |                              |                  |
| ①Voluntary learning attitude   | -.224 **                     | -.261 ** | .134                     | .017    | .073                         | .202 **          |
| ②Achievement-oriented attitude | -.034                        | -.042    | -.036                    | .062    | .287 **                      | .158 *           |
| ③Sense of responsibility       | -.113                        | -.189 *  | .194 *                   | .219 ** | .303 **                      | .240 **          |
| ④Amenability                   | -.118                        | -.140    | -.055                    | .013    | .298 **                      | .182 *           |
| ⑤Self-assessment               | -.208 **                     | -.162 *  | .100                     | .095    | .228 **                      | .037             |
| ⑥Tendency to avoid failure     | -.001                        | -.002    | -.084                    | .004    | -.074                        | -.189 *          |
| ⑦Lack of persistency           | .150                         | .230 **  | -.097                    | -.055   | -.138                        | -.175 *          |
| ⑧Lack of learning values       | .285 **                      | .282 **  | -.177 *                  | -.106   | .006                         | -.149            |

\*\* p<.01 \* p<.05

extracted, after which we swapped partners in order for them to be paired with those having personality traits with high mutual pair effect. In addition, we also tried to evaluate this change’s possibility by simulating the effect when rearranging the pair using PS.

Using the TEG II and GAMI scale scores, we examined various formulas for the PS calculation method. Finally, we decided to use the formula in which the total number of asterisks in the Table 1 was multiplied by each scale score presents normality.

In order to verify the effect of the pair combination using PS which we propose, we performed the experiment class for verification from June to July in 2014. We rearranged the partner of the pair with low PS (LL pair) and compared the pair effect of a recombination groups and non-groups. As a result, the value of the group which rearranged the degree of results rise, the test-score improvement level, the pair-work activity level and the pair-work satisfaction level became high.

In conclusion, it became clear that the pair combination method using PS raises the pair effect of the whole class work.

## 5. Summary

Pair work using the pair combination indicators was introduced in the information literacy course. We mainly examined the learners’ personalities as it is a major factor impacting pair effect. We clarified that personality traits extracted by TEG II and GAMI are strongly involved in the test-score improvement level, activity, and satisfaction level. Therefore, it is suggested that even in pair formation, we can improve the effectiveness of indicators by incorporating some TEG II and GAMI items in addition to the two confirmed ones (gender and basic academic ability difference). Moreover, we performed a pair rearrangement using PS calculated in this study. Test-score improvement level, activity, and satisfaction level were simulated. As a result, the class’s overall pair-effect level improved through elimination of pairs in which both personalities were with low effect.

The investigation in 2014 shows that this method improves the class’s overall pair effect level.

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# A Study on Teaching Debugging Strategies for Digital Circuit

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**Abstract:** It is essential for educators to identify the student's reading ability when learning debugging strategies. Forty-five senior high school students (average 17.6 years old,  $SD=0.35$ ) participated in this study. The participants were divided into three groups to examine the effect of three teaching materials including 1) normal reasoning, 2) a debugging process model, and 3) a debugging process model and three debugging strategies, namely, forward strategy, backward strategy, and CLOCK-based strategy. While the participants debugging a digital circuit question, the eye tracker recorded the eye movement data for analysis. The results indicated that participants receiving a debugging process model and three debugging strategies improved their debugging skills significantly by: 1) increased percentage of the participants finding bugs correctly, 2) increased percentage of the participants using debugging strategies correctly, and 3) reduced time spent on debugging in average. The findings may help educators and researchers understand the benefit of debugging strategies on digital circuits to design better teaching materials, methods, and learning strategies.

**Keywords:** Digital logic circuit, timing diagram, debugging strategy, reading process, eye movement data

## 1. Introduction

Digital circuit, especially digital integrated circuit is one important electronic product. Engineers design and test digital circuit functions using software development tools such as tools for FPGA, ASIC, and CPLD. Debugging is a term to describe the engineers identifying system errors by observing a simulation software or logic analyzer. Since debugging is inevitable in system development process and required repetitive checks, one of the key capabilities of electronics engineers is to read digital circuits and timing diagrams efficiently and strategically. However, there is a lack of complete textbooks introducing debugging strategies on digital and integrated circuits. The authors identified three consistent debugging strategies based on most practices electronics theories including: 1) forward (from inputs to outputs), 2) backward (from outputs to inputs), and 3) CLOCK-based. By using eye tracker, the purpose of this study is to understand students' debugging processes and the influence of three strategies on students' debugging capability.

## 2. Literature review

Many research findings have identified the importance in understanding domain knowledge (Dochy, Segers, & Buehl, 1999), reading technology (Voss & Silfies, 1996), and reading strategies (Cottrell & McNamara, 2002) for general scientific knowledge. However, reading strategies on digital circuits and timing diagrams are rarely discussed and limited training are provided for engineers.

Araki, Furukawa, and Cheng (1991) proposed a theory of debugging process model, which is a repeat procedure including initial hypothesis, hypothesis modification, hypothesis selection, hypothesis verification, and inspection process on correct bug finding. Initial hypothesis refers to an aspect of error report. If there is no error report, the engineers need to find out where the error is in order to continue the

initial hypothesis. Xu and Rajlich (2004) explained the cognitive process of knowledge, comprehension, application, analysis, synthesis, and evaluation in program debugging. The eye reading scan path recorded by eye trackers as objective evidence can examine the initial hypothesis on correct bug finding related to Bloom's six cognitive categories.

### 3. Research framework and process

Teaching materials and test materials were designed based on the debugging process model and three types of debugging strategies: forward strategy, backward strategy, and CLOCK based strategy (four subtypes of CLOCK triggering including high-level, low-level, positive-edge, and negative-edge). Before the experiment, the study provided readily available prior knowledge resources based on the needs of learners to avoid the sample bias on various prior knowledge and memory among participants. The detail research framework is shown in Figure 1; the participants followed the experimental procedures by pre-test, course modification, and post-test. The complete interactions were recorded in the computer eye tracker for research analysis.

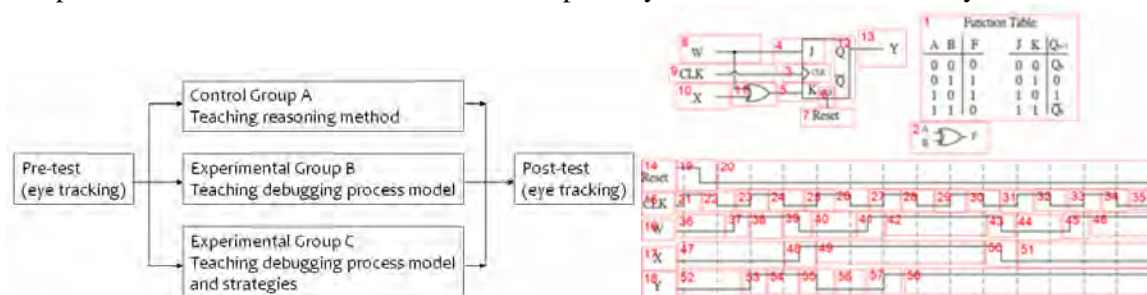


Figure 1. Research framework and process. Figure 2. Defined ROIs on the digital logic circuit.

To explore the different debugging strategies taught by the same instructor on the effect of debugging capabilities among the participants, following research method was conducted.

## 4. Method

### 4.1 Participants and Materials

Participants were volunteered from HsinChu Kuang-Fu high school; all participants had experience, and gained credit points in digital circuits. A total number of 45 senior students (average 17.6 years old,  $SD=0.35$ ) received parental consent to participate in this study. The participants were divided into groups based on the original classes they were attending:  $N_A=15$ ,  $N_B=14$ ,  $N_C=16$ . The participants had normal or corrected eyesight.

**Test Materials:** each participant undertook four eye tracking experiments including two pre-test and two post-test questions on digital logic circuit (J-K flip-flop), timing diagram (with one bug), and function table. Three teaching materials included: 1) normal reasoning, 2) a debugging process model, and 3) a debugging process model and three debugging strategies named forward, backward, and CLOCK-based strategy. CLOCK-based strategy has four subtypes relating to digital circuits CLOCK trigger models including high-level, low-level, positive-edge, and negative-edge triggering.

### 4.2 Design, Procedure, Instrument, and Data Analysis

This study is a 3x9 factorial quasi-experimental design comprised of three major experimental steps including pre-test, course modification (by the same instructor), and post-test. Independent variables included teaching materials (A: normal reasoning, B: debugging process model, C: debugging process model and debugging strategies), and Region of interest (ROI in short)(nine ROIs shown in Figure 2). Dependent variables included 1) the number of bugs found

correctly, 2) the number of times participants used debugging strategies been taught, 3) average time-spent in finding bugs correctly, and 4) eye movement variables (including scan paths and LCS of scan paths). The procedure is shown in Figure 1. EyeNTNU-180 eye tracker presented with a collection of experimental stimuli and record information on the participant's eye movements.

The average percentages of finding correct bugs were calculated based on participants' answers. Because the large eye movement data output from the eye tracker, the manual analysis became difficult to determine if the scan path contain equivalent eye movement data when the participant utilizing debugging strategies. The longest common subsequence (LCS) algorithm (Bergroth, Hakonen, & Raita, 2000) was then used to determine the scan path if a participant used the debugging strategies.

## 5. Results

Results of the analysis are shown in Table 1.

Table 1: Results on participants correctly debug digital circuit questions.

|                  |                           | Control group A<br>( $N_A=15$ ) | Experimental group<br>B ( $N_B=14$ ) | Experimental group<br>C ( $N_C=16$ ) |
|------------------|---------------------------|---------------------------------|--------------------------------------|--------------------------------------|
| <b>Pre-test</b>  | # of Found bugs           | 16.67%                          | 13.33%                               | 16.67%                               |
|                  | Used debugging strategies | 3.33%                           | 3.33%                                | 3.33%                                |
|                  | Average time-spent        | 236sec                          | 277sec                               | 244sec                               |
| <b>Post-test</b> | # of Found bugs           | 13.33%                          | 26.67%                               | 36.67%                               |
|                  | Used debugging strategies | 3.33%                           | 10.00%                               | 60.00%                               |
|                  | Average time-spent        | 242sec                          | 182sec                               | 113sec                               |

## 6. Findings and Implications

The results showed participants undertaking classes of debugging process model and debugging strategies had significant improvement in debugging ability and performance by: 1) increased percentage of the participants finding bugs correctly, 2) increased percentage of the participants using debugging strategies correctly, and 3) reduced time spent on debugging in average. The proven effectiveness of the debugging strategies will support and further to develop teaching software in electronic strategies.

## Acknowledgements

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# Design of Embodied Learning in 3D Virtual Worlds for Pre-service Teachers

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**Abstract:** This study intended to design embodied learning in 3D virtual worlds (ELVW) for the development of real-world problem solving competencies. The strengths and weaknesses of the ELVW model were explored in pre-service teacher education in South Korea. Through ELVW, elementary school pre-service teachers (n = 35) significantly improved their self-efficacy in preventing and addressing school-bullying behaviors. From interviews, this study identified strengths of ELVW in pertaining to embodied experience, collaborative learning, and instructional supports. To improve the ELVW practice, more efforts are needed to overcome technical and time constraints and to investigate the role of embodied experience in the 3D virtual world.

**Keywords:** Virtual world, embodied cognition, collaborative learning, teacher education

## 1. Introduction

Literature of embodied cognition has revealed that the body, which dynamically interacts with the physical world, plays a crucial role for knowledge construction and reasoning (Black, Segal, Vitale, & Fadjo, 2012). Embodied learning can occur not only through direct interaction with the physical world but also through an avatar, which represents a learner, in 3D virtual worlds (i.e., augmented embodiment; Black et al., 2012). The embodied experience and interaction, which are crucial for physical and social presence, have been considered as key affordances of virtual worlds (Dalgarno & Lee, 2010). The current study aims to develop the model of embodied learning in 3D virtual worlds (ELVW) for improving real-world problem solving competencies of pre-service teachers. Particularly, this study is interested in the development of classroom management competencies in pertaining to school bullying, which is a serious problem in South Korea. The research questions of this study are as follows:

- What are the strengths of ELVW for improving real-world problem solving competencies of elementary school pre-service teachers?
- What are the limitations of ELVW in the context of Korean pre-service teacher education?

## 2. Embodied Learning in 3D Virtual Worlds

The ELVW model is designed to improve real-world problem solving competencies in complex and ill-structured domains. Particularly, this model can be beneficial for learners who do not have enough opportunities for learning by doing in the physical world. Through ELVW, learners can use their perceptual and embodied experience in 3D virtual worlds for developing an in-depth understanding of a complex problem situation and collaborative problem solving skills. Although a small number of studies presented instructional models based on embodied cognition (e.g., Han & Black, 2011), little attention is paid to embodied learning in complex and ill-structured domains. Based on literature of embodied cognition, problem-based learning, and collaborative learning, this study created the ELVW



model that fosters real-world problem solving competencies through learning by doing in the virtual world (see Figure 1).

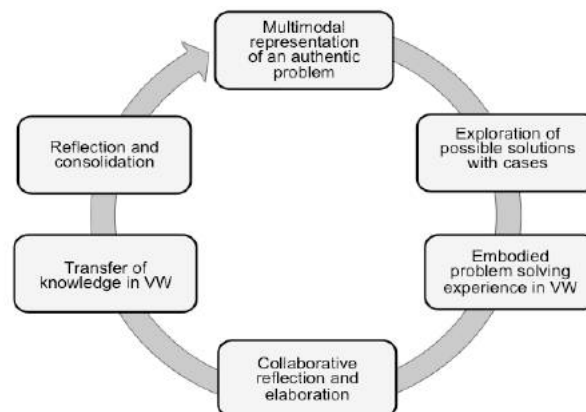


Figure 1. Model of embodied learning in a 3D virtual world (VW)

The ELVW model consists of collaborative problem solving and reflection activities in blended learning environments. The ELVW activities are developed and implemented on the basis of the following design principles:

- Real-world problems are presented with multimedia that support multimodal representations.
- Multiple cases (or perspectives) are compared and contrasted to support problem solving.
- Learners collaboratively create and evaluate solutions through argumentative discourse.
- Learners solve real-world problems through embodied experience in the virtual world.
- Learners have autonomy in interacting with the virtual world through avatars.
- Virtual world enables learners to express their ideas in both verbal and nonverbal ways.
- Embodied experience should be followed by reflection and consolidation activities.
- Instructor should provide appropriate instructional supports when they are necessary.
- Learners are encouraged to transfer their knowledge to different problem situations.

### 3. Methods

In the study, 35 (11 male and 24 female) elementary school pre-service teachers participated as part of the school-counseling course in South Korea. According to the ELVW model in Figure 1, participants had collaboratively solved a school-bullying problem in blended learning environments for four weeks. They discussed a real-world problem, conducted a role-play (i.e., embodied problem solving), and reflected on their embodied experience at a 3D virtual classroom in Second Life (see Figure 2). Instructional supports including scaffolding and feedback were mainly provided in a classroom.



Figure 2. Avatars in a 3D virtual classroom

The survey of self-efficacy (Cronbach's  $\alpha=.93$ ) in preventing and addressing school-bullying behaviors was conducted before and after the ELVW activities. In addition, the survey of perceived achievement (Cronbach's  $\alpha=.91$ ) was implemented right after the ELVW activities. The surveys used a five-point Likert scale. In addition, 10 participants were interviewed in terms of strengths and

weaknesses of ELVW. The grounded theory approach was applied to analyzing interview data through constant comparison and discussion among three researchers.

#### 4. Findings

This study found a positive influence of ELVW for self-efficacy about school bullying. A paired sample t-test showed that pre-service teachers' self-efficacy significantly improved through the ELVW activities ( $M = 2.84$  vs.  $3.58$ ),  $t(34) = 4.74$ ,  $p < .001$ . Their perceived achievement was somewhat positive ( $M = 3.4$ ,  $SD = .75$ ). Consistently, the interview analysis revealed more strengths than weaknesses, which were mainly related to technical problems and time constraints. The strengths of ELVW were summarized as follows:

- Verbal and non-verbal communication through avatars contributed to the presence and situational interest of pre-service teachers in the virtual world.
- Embodied experience in the virtual world helped pre-service teachers to take diverse perspectives of stakeholders in a school-bullying problem.
- Collaboration with group members encouraged active participation.
- Success and failure cases of experienced teachers were helpful in understanding a problem situation and exploring possible solutions.
- Collaborative reflection was helpful for making sense of embodied experience in the virtual world.
- Pre-service teachers had sufficient autonomy in deciding their activities in the virtual world.

The strengths above were closely related to the pedagogical principles of the ELVW model. This study also identified the weaknesses of ELVW as follows:

- Due to the Internet speed, pre-service teachers had difficulty in interacting with others through avatars in the virtual world.
- Pre-service teachers did not have enough time to carry out a role-play in the virtual world.
- Verbal and non-verbal communication should be enhanced for more natural interaction in the virtual world.

#### 5. Conclusion

The current study designed the ELVW model based on the literature of embodied cognition, problem-based learning, and collaborative learning. In teacher education, this study found that the ELVW activities significantly improved pre-service teachers' self-efficacy in preventing and addressing school-bullying behaviors. In addition, this study found a few strengths of ELVW in pertaining to embodied experience in the virtual world, collaborative problem solving and reflection, and appropriate instructional supports (e.g., success and failure cases, autonomy support). To improve the ELVW activities, future research is recommended to prevent technical problems and time constraints and to enhance verbal and non-verbal communication with advanced technologies (e.g., motion sensing input devices). In addition, more attention should be paid to the role of augmented embodiment in the virtual world for learning process and outcomes.

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# Development of Predict-Test-Revise Modeling Abilities via a self-study Learning Environment

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**Abstract:** In addition to developing students' content knowledge, an important goal of science instruction is to improve students' ability of modeling, such as, the ability to create and use simplified representations to describe and explain phenomena, and predict outcomes of new phenomena. It has been shown that students face difficulty in developing these abilities unless they are explicitly addressed in the curriculum. ICT-based solutions to this problem have been developed, such as the WISE and MARS, have mostly been implemented at the middle and high school levels and the teacher facilitates the process. In this paper we describe the design of LEMA, which addresses modeling abilities in college level science topics. LEMA is a self-regulated learning environment in which students are given various activities and customized formative assessment to achieve the above goals. We tested the effectiveness of LEMA through a two-group post-test controlled experiment. Students who learnt with LEMA performed significantly better on abilities of prediction, testing and revision of models. We also identified student perceptions of which features of LEMA helped them develop these abilities.

**Keywords:** predict-test-revise abilities, modeling, learning environment, self study

## 1. Introduction & Related Work

The goal of traditional classroom instruction in science and engineering has typically been that students develop certain other science *process-related* abilities in addition to their content knowledge. One such ability is that of modeling which refers to the use of models or simplifications to create faithful representations of the processes of science by providing satisfactory explanations of the phenomena in the world as experienced and predict outcomes of new phenomena (Gilbert, 2004). Studies have shown that under traditional instruction, students have difficulty in understanding and using models (Gilbert, 2004), especially in the understanding the predictive nature of models (Grosslight, et.al., 1991). There have been instructional interventions such as WISE (Linn & Slotta, 2000; Linn & Hsi, 2000), MARS (Raghavan, et.al., 1993; Raghavan & Glaser, 1995) and ISLE curriculum (Etkina & Van Heuvelen, 2007) which are two week to a semester long interventions which integrate a computer supported environment with classroom activities and have succeeded in developing students understanding about the interpretive and predictive nature of models. But in all these methods, the teacher plays an important role by facilitating the process, giving prompts or grading the student's efforts at a later stage (Raghavan & Glaser, 1995; Treagust, et.al, 2002; Verschaffel & De Corte, 1997) and these curricula have been implemented mostly at the middle school and high school levels, and to some extent in introductory college courses. In this paper, we introduce the rationale for the design of a Learning Environment for Modeling Education (LEMA) which is an ICT-based solution made specifically for the context of self study wherein each topic has a learn time of 45-60 minutes. We have performed a two-group quasi-experimental study to determine whether LEMA helps students in developing abilities of using models, prediction, testing and revision. Students' perceptions using reflection questions were used to ensure that LEMA features are consistent with our design rationale for including these features.

Students make sense of the world around them, and what they are taught, by means of conceptual models that they form in their minds. If these models are incorrect, it leads to flawed reasoning and misconceptions (Gilbert, 2004). An important aspect of modeling is to explain the macroscopic outcome of a given situation by applying a model at a microscopic level. Research shows that students have difficulty transferring from a macroscopic level of representation to the microscopic level (Gabel, 1998). Multimedia tools such as animations and simulations, which help students connect

between these levels, have been shown to promote conceptual understanding (Kozma et. al., 1997). However, in order for students to be able to learn in the absence of a teacher or facilitator, the process of self-regulated learning has been recommended. Formative assessment in the form of rich and timely feedback, along with the opportunity to revise responses, has been shown to support the development of learner self regulation (Nicol & Macfarlane-Dick, 2006) and research has shown that question prompts can facilitate explanation construction (Bereiter & Bird, 1985), monitoring and evaluation (Davis, 2000), and making justifications (Lin & Lehman, 1999).

## 2. Design of the Learning Environment for Modeling Education (LEMA)

The process of designing LEMA included identifying specific modeling abilities to target, identifying learning objectives, determining the features to be included and creating the instructional design. The modeling abilities were adapted from the scientific abilities rubrics (Etkina, et.al., 2006).

We define ‘Modeling ability’ as a measurable set of abilities in which students learn to make predictions, test predictions with respect to experimental results, and revise predictions if necessary. In the prediction phase, students should be able to devise an explanation for an observed pattern, make a reasonable prediction based on explanation. In the testing phase, students should be able to decide whether the prediction and the outcome agree/disagree. And in the revision phase, students should be able to revise the explanation when necessary.

LEMA was designed using features suggested for the development of students scientific abilities such as ‘learning material should allow students to explain reasoning, justify conclusions, analyze outcomes of an experiment, get immediate feedback, after sharing their explanations students design testing experiments to determine if their explanations work’ (Etkina, et.al., 2006). On the basis of all these features an Instructional Design Document was created and was given to two subject matter experts for content validity. Fig 1 given below shows a screen shot of the important features of LEMA. Left to Right- Simulation of the Microscopic Model, Prediction Questions, Justification Box, Experimental Results for comparison and judgement and Assertion and Reasoning based questions with customized feedback.



Figure.1—Screenshot of the features of LEMA

In the Simulation of the microscopic model, students are asked to interact with it with the help of variable manipulation, text entry and meter readings. This feature helps in developing all the abilities of modeling, namely the ability to make observations, predictions, testing predictions and revising them. This is done because it is said that features such as isolation and manipulation of parameters helps students to develop an understanding of the relationships between physical concepts, variables and phenomena (Lee, et.al., 2002). In the feature of prediction questions, students are given a macroscopic situation and are asked to use the microscopic model in order to predict what might be the outcome of this situation. This feature helps in developing the sub ability of making a reasonable prediction based on explanation in the prediction phase. This is important because any learning material should provide opportunity for predicting the outcome of a situation/experiment (Gilbert,2004). When students have predicted the outcome of any situation, they are asked to write explanation on which the prediction is based. This feature helps in developing the sub ability of devising an explanation for an observed pattern and making a reasonable prediction based on explanation. This is needed because students should be able to adapt a known model to the specifications of the given problem (Wells, et.al., 1995) During the test phase, students are provided with real world answers and hints and are asked to decide whether the prediction and the outcome agree/disagree in the testing phase. This is important because students should be able to analyze the outcomes of an experiment and be able to justify your conclusions (Wells, et.al., 1995). During the revise phase, students are shown their prediction and justification of the IV graph of the PN junction and they are asked to answer questions aligned with IV

graph chosen by them. If they are getting the answers incorrect, then they are given feedback which helps them identify what was missed by them in their observations are asked to note that particular aspect in the simulation. This is a very crucial feature because designing instruction using building blocks such as hint, if-confused and summarization is much more powerful than designing instruction at the level of show video. (Linn, et.al., 2000; Wielinga, et.al., 1992). In order to summarize LEMA, students are shown the working of the microscopic model of the PN junction, the experimental set up with meter reading and a graphical plot of the IV characteristics dynamically. This is done because employing a variety of representations (pictures, animation, graphs, vectors and numerical data displays) is helpful in understanding the underlying concepts, relations and processes (Robinson, 1987)

### 3. Evaluation & Discussion

#### 3.1 Research Method

The main study consisted of a two-group post-test only experimental research design, and was used to answer the following research questions:

RQ1: Did students who worked with LEMA develop modeling abilities?

RQ2: Which features in the LEMA did students perceive to be helpful in answering questions related to modeling abilities?

Before the main study, a pilot study was conducted to test the validity and usability of the learning materials in LEMA and the validity of the post-test. Students from the 1<sup>st</sup> year undergraduate Bachelor of Science (B.Sc.) program from various colleges under Mumbai University, India, were chosen as the sample. A quasi experimental research design was adopted. The students (N=73) who arrived at the experiment venue were assigned to two groups by randomized assignment. Group 1 (Experimental group) contained 37 students while Group 2 (control group) contained 36 students. Students in the control group were given a visualization which contained the same animation of the microscopic phenomenon, but did not contain the scaffolds and prompts present in LEMA. A total time period of 1 hour was allotted to the students for learning the topic. At the end of the hour, a new physical phenomenon was presented to the student by means of an simulation depicting its microscopic explanation. In order to answer RQ1 related to students' development of modeling abilities, we administered a post test which contained open ended questions that mapped to each modeling sub ability. To answer RQ2 on students' perceptions of useful features of LEMA, a reflection questionnaire was used as the instrument. Students were asked to rate each feature of LEMA on a scale of 0-2 where 0-Not Helpful, 1-SomeWhat Helpful, 2-Very Helpful. To grade the answers of the students to the post-test questions, scientific abilities rubrics (Etkina, et.al., 2006) were used.

#### 3.2 Results

The inter rater reliability for the raters was calculated and the value of Cohen's Kappa was found to be 0.839 with  $p < 0.001$ . Post analysis of the post test results using a Mann-Whitney U-test, we found that the experimental group (LEMA) showed a statistically significant difference at  $p = 0.05$  level in their improvement in their abilities of making observations, predictions, testing them and then revising them as compared to the control group.

Table 1: Mann-Whitney U-test Scores.

| Ability to describe observations | Ability of devising an explanation for an observed pattern | ability of making a prediction based on explanation | ability of testing a prediction | ability of revising a prediction |
|----------------------------------|--|---|---------------------------------|----------------------------------|
| p=0.195                          | p=0.000  | p=0.003   | p=0.014                         | p=0.008                          |

From the student perception data, we find the following percentage of students from the LEMA group who found each feature very-useful. (NA =Not Applicable)

*Table 2: Student perceptions of usefulness of a feature.*

| Ability | Simulation of Microscopic model | Prediction Questions | Justification on Box | Multiple Representations | Experimental Results for comparison and judgement | Assertion and Reasoning Questions |
|---------|---------------------------------|----------------------|----------------------|--------------------------|---|-----------------------------------|
| Predict | 70.27%                          | 64.86%               | 51.35%               | 70.27%                   | NA  | NA                                |
| Test    | 72.97%                          | NA                   | NA                   | 59.45%                   | 72.97%  | NA                                |
| Revise  | 64.86%                          | NA                   | NA                   | 56.75%                   | NA  | 56.75%                            |

We find that both groups did well in the ability of describing observations without explanations, but, the experimental group performed significantly better than the control group for all the other sub abilities, namely, the ability to devise explanation for an observed pattern, ability to make a reasonable prediction based on explanation, ability to decide whether the prediction and the outcome agree/disagree and the ability to revise the explanation when necessary. Since the only difference in treatment for the two groups was the learning material, we can argue that the features of LEMA lead to the improvement in students modeling skills. Factors such as proficiency in English, test with only one topic, data from one study as evidence could be limitations of this study. The main contribution of our work is the identification of design components of a ICT-based learning environment that explicitly targets students' modeling abilities. Future work involves creation of more number of LEMA modules in a variety of topics.

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# Evaluation of the Effectiveness of a Digital Microscope System with Tabletop Interface in a Science Class

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**Abstract:** This study examined the effects of utilizing a digital microscope system with tabletop interface in an elementary school science class. The findings show that the equipment was more effective than optical microscopes for microscopic observation tasks such as finding, focusing, and sketching.

**Keywords:** Tabletop, Multi-touch, Microscope observation

## 1. Introduction

In science class, elementary students observe water microorganisms by taking turns using an optical microscope. However, it is difficult for them to observe and sketch the same object. In order to facilitate students' discussion and cooperation, a new tool for the observation of microorganisms is needed.

Kitahara et al. (2006) showed that a tabletop interface was effective in collaborative learning. Moreover, there are studies of observations using digital microscopes instead of optical microscopes (Tessmer et al., 2011; Dickerson et al., 2007; Van Scoter, 2004). Morita et al. (2013) developed a digital microscope system with tabletop interface and showed that microscopic observations using this system were useful for understanding water microorganisms. Therefore, this study examines the effects of utilizing this equipment for microorganism observation education.

## 2. Procedure

### 2.1 *Digital Microscope System with Tabletop Interface*

Figure 1 illustrates the digital microscope system with tabletop interface (MT-SCOPE). MT-SCOPE consists of a multi-touch screen and digital microscope. The multi-touch screen has infrared LEDs, an acrylic sheet, a tracing paper, and an infrared camera. The system is capable of scaling, rotating, and moving microscope photos and videos through multi-touch operation.

### 2.2 *Subjective Assessment by Survey*

A total of 33 elementary school students participated in this study. After operating both types of equipment (optical microscope, MT-SCOPE), they responded to nine questions by selecting from the following four responses: Strongly Agree, Agree, Disagree, and Strongly Disagree. The positive (Strongly Agree and Agree) and negative (Disagree and Strongly Disagree) responses were totaled for each item and compared using Fisher's exact test.



(Sketching microorganisms)



(Observing microorganisms with multi-touch)

Students using MT-SCOPE

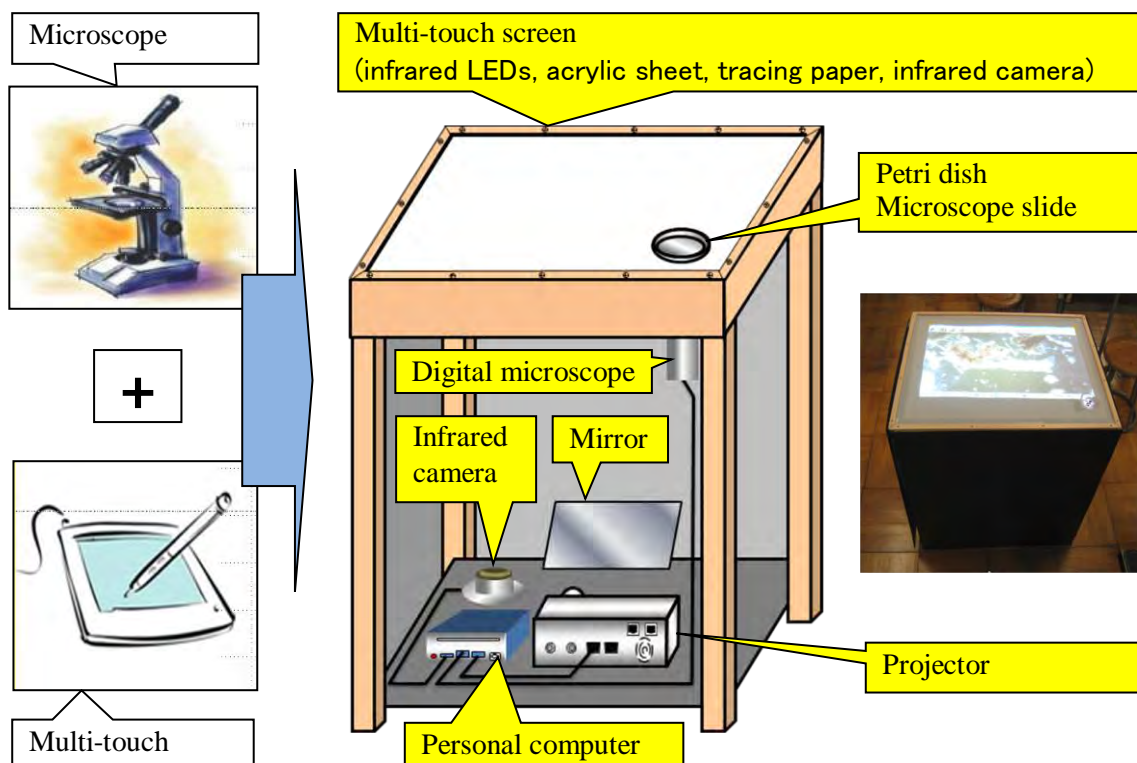


Figure 1. The Digital Microscope System with a Tabletop Interface for Microscope Observation.

### 3. Results and Discussion

Table 1 shows the results of Fisher's exact test. All the students responded in the affirmative to the statements "It was easy for me to find the water microorganisms" ( $p < .01$ ) and "It was easy for me to adjust the focus" ( $p < .01$ ). Moreover, there were many affirmative replies for "It was easy for me to sketch the water microorganisms" ( $p < .01$ ) and "I found the water microorganisms" ( $p < .05$ ). The results suggest that MT-SCOPE was more effective than optical microscopes for microscopic observation.

Conversely, there were a number of negative replies for "I discussed the water microorganisms with my group members" ( $n.s.$ ). This seems to indicate that the design of observation lessons needs to be improved in the future.



Table 1: Results of the subjective assessment.

| Question Categories   | Equipment | Positive       |       | Negative |                   | Fisher's Exact Test |
|---|-----------|----------------|-------|----------|-------------------|---------------------|
|   |           | Strongly Agree | Agree | Disagree | Strongly Disagree |                     |
| It was easy for me to find the water microorganisms.  | MS        | 15             | 12    | 4        | 2                 | **                  |
|   | MT        | 19             | 13    | 1        | 0                 |                     |
| It was easy for me to adjust the focus.   | MS        | 5              | 10    | 16       | 2                 | **                  |
|   | MT        | 16             | 14    | 3        | 0                 |                     |
| It was easy for me to sketch the water microorganisms.  | MS        | 10             | 11    | 10       | 2                 | **                  |
|   | MT        | 17             | 15    | 1        | 0                 |                     |
| I found the water microorganisms.   | MS        | 15             | 12    | 4        | 2                 | *                   |
|   | MT        | 31             | 2     | 0        | 0                 |                     |
| I observed the water microorganisms.  | MS        | 19             | 10    | 2        | 2                 | n.s.                |
|   | MT        | 31             | 1     | 1        | 0                 |                     |
| I discussed the water microorganisms with my group members.                                     | MS        | 9              | 15    | 5        | 4                 | n.s.                |
|   | MT        | 15             | 10    | 6        | 2                 |                     |
| After taking the practical class, I have become eager to learn more about water microorganisms. | MS        | 20             | 8     | 1        | 4                 | n.s.                |
|   | MT        | 22             | 7     | 2        | 2                 |                     |
| After taking the practical class, I have become eager to learn more about other microorganisms. | MS        | 23             | 5     | 2        | 3                 | n.s.                |
|   | MT        | 24             | 7     | 1        | 1                 |                     |
| I enjoyed this microscope observation lesson.   | MS        | 25             | 5     | 2        | 1                 | n.s.                |
|   | MT        | 30             | 2     | 1        | 0                 |                     |

MS: Optical microscope, MT: MT-SCOPE, \*\* $p < .01$ , \* $p < .05$ , n.s.: not significant.

#### 4. Conclusion

This study examined the effects of utilizing MT-SCOPE in an elementary school science class. The findings show that the equipment was more effective than optical microscopes for microscopic observation tasks such as finding, focusing, and sketching. Using the data from this study, future research should focus on improving MT-SCOPE and examining its effective practical uses in elementary schools.

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# Circuitously Collaborative Learning Environment to Enhance Metacognition in Solving Mathematical Word Problem

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**Abstract:** This article reveals the design of an ongoing research that investigates the effectiveness of an alternative learning environment Circuitously Collaborative Learning Environment (CirCLE), which is designed to enhance metacognitive awareness on the learning processes in algebraic mathematical word problem (MWP) solving environments. We perform the research based on the hypothesis that a student will be encouraged and can reflect his own thinking when he practicing a role of an inspector together with receiving appropriate feedback to revise his solutions.

**Keywords:** Metacognition, problem solving, peer assessment, collaborative learning

## 1. Introduction

In a usual collaborative learning environment, students have opportunities to share and are engaged in discussion to take responsibility for their own learning (Gokhale, 1995). However, research in Computer-Supported Collaborative Learning (CSCL) showed that it is difficult to clearly define the interaction between the initial conditions of collaboration and learning outcomes. Moreover, collaboration leads to positive outcomes only when students engage in knowledge-generative interactions such as giving explanations, and engaging in argumentation, negotiation, conflict resolution or mutual regulation (Dillenbourg & Jermann, 2007). To say that, it is not effective in noncompetitive groups or inactive students. To solve mathematical problems, it is necessary for students to think on their own cognitive strategy to deeply understand how the problems solved. Therefore, in this study, we propose an alternative learning environment, namely Circuitously Collaborative Learning Environment (CirCLE), which provides chances for participants to learn actively to solve algebraic mathematical word problems, in which students learn to solve MWP's by translating context problems into mathematical notations. Two key components, which are used to compose CirCLE, are a management strategy, named Peer Inspection (PI) strategy, and a communication media, named Inferential Diagram (ID). We intentionally design them to support students' metacognition by providing chances to reflect their cognition and rethink their learning strategy. The detail of PI and ID will be revealed in the rest sections.

## 2. Peer Inspection Strategy

PI is counted as a *formative peer assessment*; peer feedback is given while the learning is actually happening, helping students plan their own learning, identify their own strengths and weaknesses, target areas for remedial action, and develop metacognitive and other skills (Topping, 2009). The aim for designing PI is to be a learning management strategy for raising the learning of students both as *assessors* (reciprocal teaching (Palincsar & Brown, 1984)) and *assesseees* in meta-level through

modified peer assessment activities. The modified peer assessment activities in PI are composed of three main stages;

- i) *Problem providing*: Nakano, Hirashima, and Takeuchi (2002) mentioned that it is important to consider the differences of problems in understanding the problems deeply. In PI, to encourage students to focus on their own problem, a teacher, therefore, provides distinct problems for each student.
- ii) *Peer selection*: Each student will be assigned to inspect suitable works of peers by their learning performance; high performance (HP), average performance (AP), and low performance (LP), to simulate an environment that he/she can learn effectively. For example, for LP students who have no idea how to start, at least two correctly complete examples (If there is no correctly complete solution, a teacher will provide) should be assigned to them to let them follow or learn how to solve problems correctly and they also can use those examples as keys for inspecting assigned solutions of other peers.
- iii) *Peer feedback*: Challenging feedback corresponding to students' performance are also important (the teacher provides this), e.g., an HP student should receive feedback to against his idea, which will make him rethink on his own solutions. AP and LP students should receive properly correct feedback as guidance to revise their solution not to confuse them.

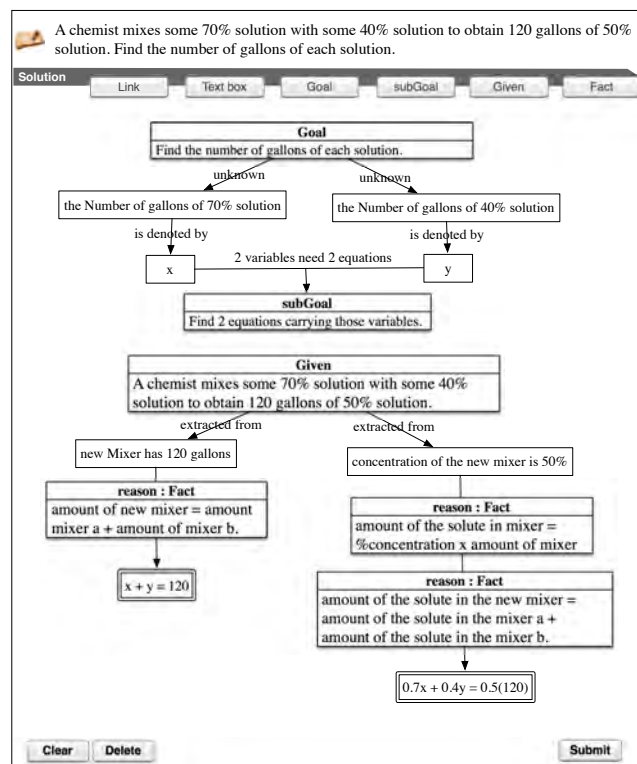
Furthermore, in this research, we also propose Initial Diagram (ID) as a solution method to be a communication media among participants to support and enhance potential of PI. The detail of ID is revealed in the following section.

### 3. Inferential Diagram

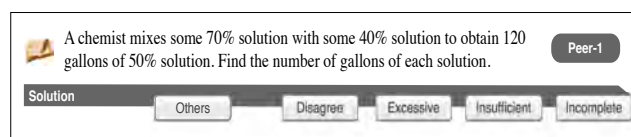
Perceptual inferences can be made more easily than symbolic inferences (Koedinger, 1991), therefore we design ID as a tool to externalize steps of inference when students solving MWP. It is used as a communication media among participants to reduce the complexity of commenting process and to foster students in reflecting their thinking process when solving MWP.

#### 3.1 Providing a solution of MWP using Inferential Diagram

To encourage a student to aware of solving MWP, we propose solution method, called Inferential Diagram (ID), in which a student has to explicitly state any information or statement by expressing its source or reason why he need it. In the user interface of the proposed system, see the figure 1(a), there are six necessary buttons; 1) 'Goal' button is used to state a problem goal, 2) 'subGoal' button is used to state sub-goal of a problem, 3) 'Given' button is used to illustrate information given, 4) 'Fact' button is used to refer common fact, theorems, common rules, or axioms, 5) 'Text' button is used to state reason or any other statements, and 6) 'Link' button is used to create a link between information nodes. To illustrate the relation between information nodes, a student can put



(a)



(b)

Figure 1. Providing solution using Inferential Diagram; (a) student interface and (b) peer interface

any text box on the link. See figure 1(a), the diagram could be interpreted as follows, ‘the Number of gallons of 70% solution is denoted by x’, ‘Since, there are 2 variables (x and y), then 2 equations carrying those 2 variables are required’, ‘The problem gave that the mixer has 120 gallons and because there is the fact that “*amount of new mixer = amount mixer a + amount of mixer b*” and from the assumption, then the equation could be formed as  $x + y = 120$ ’, etc.

### 3.2 Commenting peer’s solution via inferential diagram

It is not an easy task for some students to comment on peers’ works. Therefore, ID is designed to support students in this task. In CirCLE, by using ID, we provide five example comments as options; i) ‘*I do not agree with an Information in node A*’, ii) ‘*I do not agree with an Information in node A*’, iii) ‘*Does this reason make sense?*’, iv) ‘*Insufficient Information to infer A*’, and v) ‘*Incomplete solution*’. The difference between the student interface and the peer interface are the command buttons; see figure 1(b) comparing to the figure 1(a). To indicate that, for example, if one does not agree with information in a node-A, he can click on the node-A following by clicking on ‘Disagree’ button. In addition to provide an opened comment, a student can use the ‘Other’ button to add additional comments. To construct connections between previous and new knowledge, metacognitive questions, such as, ‘what are the similarities/differences between the problem you are assigned and the problems you have to inspect? and why?’ and questions, such as, ‘what are the strategies/tactics/principles appropriate for solving the problem and why?’, will be used to criticize students during their learning process.

## 4. Conclusion

Since, in CirCLE, students are not directly assigned to work in group, but in a class of specific topic in which all students have the same goal, the students share their solutions anonymously, they comment peers’ solutions, together with receiving feedbacks from peers’ inspection, then, revise their own solutions using those comments and experiences from inspecting peers’ works, therefore the term ‘Circuitously Collaborative Learning’ was used.

In this study, we aim to develop a computer-supported learning environment, which supports students’ self-learning regulation to motivate students’ metacognition. Therefore, CirCLE is designed to encourage a student’s metacognition by supporting a student’s self-regulated learning and reflecting his learning process. It is aimed that students can learn more effective and deeply understand MWP and they can be enhanced their metacognition via CirCLE.

## Acknowledgement

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# A Mathematical Model of Collaborative Learning using Differential Equations

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**Abstract:** This study presents a mathematical learning model for collaborative learning using differential equations. We first specify initial knowledge about a subject and each student's ability to understand the subject. Then, we analyze the evolution of students' knowledge over time. Our findings show that the effect of collaborative learning depends on how students are grouped together. These results can suggest ways of designing a class for effective collaborative learning.

**Keywords:** Collaborative learning, Mathematical modeling, Differential equation

## 1. Introduction

In recent years, numerous studies have shown the effectiveness of collaborative learning. However, most of these are inductive studies in which pedagogical findings are derived by observing students in the classroom. In contrast, a deductive approach leads to a conclusion from a general premise. Therefore, if we had a general framework as a premise for collaborative learning, we could design a class for effective collaborative learning. In this study, we construct a mathematical learning model to function as a general framework for collaborative learning.

Existing mathematical models of the teaching-learning process can be classified into three categories: differential equation modeling (Pritchard et al., 2008), Ising spin modeling (Bordogna et al., 2001, 2003; Yeung, 2006; Yasutake, 2011), and stochastic process modeling (Nitta, 2010). Note that the model of Pritchard et al. (2008) only applies to individual learning. In this study, we extend his model to use differential equations to describe collaborative learning.

## 2. Mathematical learning model by using different equation

### 2.1 Pritchard's model

Let us briefly review Pritchard's model. He introduces the following model to describe the evolution of a student's knowledge over time:  $dK(t)/dt = \alpha_1\beta(1-K(t))K(t) + \alpha_2(1-\beta)(1-K(t))$ . Here, the student's knowledge at time  $t$  is given by  $K(t)$  ( $0 \leq K(t) \leq 1$ ). The first term of the right-hand side of this model is motivated by the constructivist view in which students learn new knowledge by constructing an association between it and some prior knowledge. Here,  $\alpha_1$  is the probability that something taught to a student will be retained in his/her mind for potential learning. The second term is motivated by the tabula rasa theory of learning, and  $\alpha_2$  describes a learning rate similar to  $\alpha_1$ . The tabula rasa theory assumes that a student's memory is blank before learning begins. Finally,  $\beta$  is a parameter that determines the ratio of the learning effect of the two terms.

### 2.2 Our model

We describe the time evolution of the  $i$ -th student's knowledge during collaborative learning with another student as follows:

$$\frac{dK_i(t)}{dt} = c(\beta\alpha_i K_i(t)(1 - K(t)) + (1 - \beta)\alpha_i(1 - K_i(t))) + d \sum_{j \neq i} f_i(K_j(t) - K_i(t))(K_j(t) - K_i(t)) + e \sum_{i \neq j} g_i(K_i(t) - K_j(t))$$

where functions  $f_i(x), g_i(x)$  are defined as

$$f_i(x) = \begin{cases} \alpha_i & x > 0 \\ 1 - \alpha_i & \text{otherwise} \end{cases} \quad g_i(x) = \begin{cases} 1 - K_i(t) & x > 0 \\ 0 & \text{otherwise} \end{cases}$$

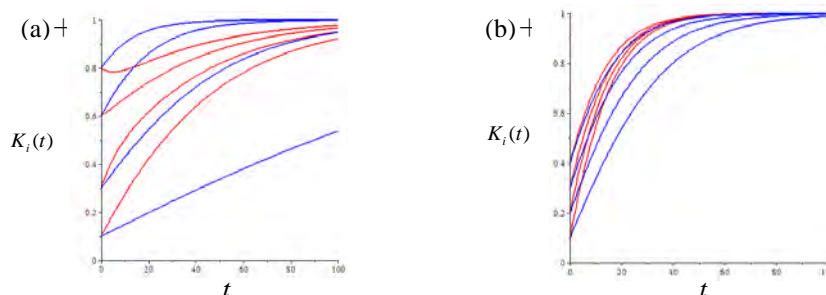
The first term of our model is similar to Pritchard's model. We introduce  $\alpha_i$ , which reveals the the  $i$ -th student's ability to understand, instead of  $\alpha_1, \alpha_2$  in Pritchard's model. The second term represents a learning effect in which students gain knowledge by being taught by other students. When the  $j$ -th student's knowledge is greater than that of the  $i$ -th student ( $K_j(t) - K_i(t) > 0$ ), the higher the value of  $\alpha_i$ , the more knowledge the  $i$ -th student gains. Conversely, when the  $j$ -th student's knowledge is lower than that of the  $i$ -th student ( $K_j(t) - K_i(t) < 0$ ), the higher the value of  $\alpha_i$ , the less the negative effect is on the  $i$ -th student. The third term of our model represents the gain in students' knowledge when they teach something to other students. This effect is revealed only if the  $i$ -th student's knowledge is greater than that of the  $j$ -th student. The lower the  $i$ -th student's knowledge, the greater the learning effect the  $i$ -th student gains. The ratio of three terms is determined by the values of  $c, d$ , and  $e$ .

### 3. Results and discussion

#### 3.1 Calculation results

We set the initial knowledge about a subject when a student starts studying and each student's ability to understand the subject as a control parameter. Under these conditions, we analyze the evolution over time of a student's knowledge in collaborative learning with three other students. Here, we show two characteristic results of our study. One result is obtained for case (a)  $K_1(0) = 0.1, \alpha_1 = 0.1, K_2(0) = 0.3, \alpha_2 = 0.3, K_3(0) = 0.6, \alpha_3 = 0.6$ , and  $K_4(0) = 0.8, \alpha_4 = 0.8$ , for student 1, 2, 3, and 4, respectively. The other result is obtained for case (b)  $K_1(0) = 0.1, \alpha_1 = 0.5, K_2(0) = 0.2, \alpha_2 = 0.6, K_3(0) = 0.3, \alpha_3 = 0.7$ , and  $K_4(0) = 0.4, \alpha_4 = 0.8$ , for student 1, 2, 3, and 4, respectively.

Those two results are shown in Figure 1 (a) and (b). The red lines denote collaborative learning and the blue lines denote individual learning. In case (a), collaborative learning is less effective for those students who have a high level of initial knowledge or a high ability to understand the subject. In case (b), collaborative learning is effective for all students.



**Figure 1.** The time evolution of students' knowledge during collaborative learning (red lines), with  $\beta = 0.5, c = d = e = 0.1$ , and individual learning (blue lines), with  $\beta = 0.5, c = 0.1, d = e = 0$ .

### 3.2 Comparison between inductive research and deductive research

Our model could apply to a variety of learning situations. Therefore, we compare the inductive research method, such as observing students in a classroom, to our deductive mathematical model. Nitta introduces stochastic process modeling (Nitta (2010)). He observed students in a classroom solving multiple-choice questions about introductory physics. The students solved a question, then solved the same question again soon after discussing it with other students. He calculated the percentage of students choosing the correct answer before and after collaborative learning took place. We investigated the initial knowledge and transitional knowledge at time  $t = 10$  for each student, which corresponded with the students' knowledge before and after discussing the problem with other students. Then, we compared our results to his. Figure 2 shows that the two results are qualitatively similar. Therefore, we can say our model is appropriate.

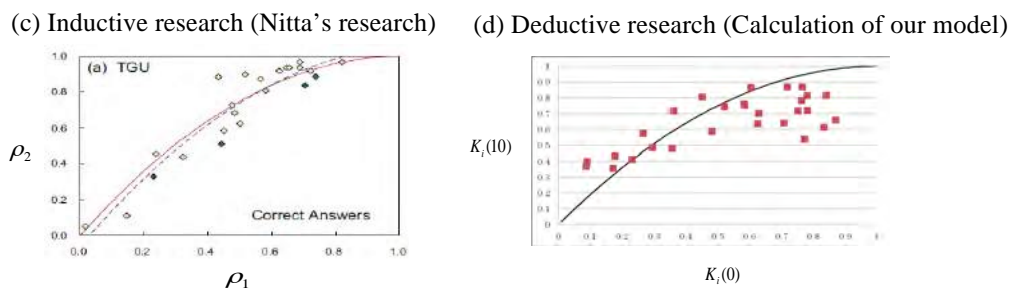


Figure 2. (c) Relationship of percentage of students choosing correct answer before ( $\rho_1$ ) and after ( $\rho_2$ ) collaborative learning [Reprint from Nitta (2010)]; (d) Relationship between initial knowledge and transitional knowledge at time  $t = 10$  in the case of collaborative learning.

## 4. Conclusion

Our findings show that the effect of collaborative learning depends on the way students are grouped. In case (b), collaborative learning is more effective than individual learning. Therefore, collaborative learning appears to be more effective when students who have a high ability to understand learn a new subject. However, according to our model, in some cases (e.g., case (a)), the learning effect of collaborative learning is limited when students who have a high amount of initial knowledge or ability to understand engage in collaborative learning. Mathematical learning models are important, because they enable us to discuss the effect of collaborative learning in a variety of learning situations. Finally, we compared our simulation result with actual classroom data. However, our mathematical model needs to reflect how learning takes place in a classroom in more detail.

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# Pre-service Teacher Existing Ideas of Using Computer-Supported for Scientific Inquiry

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**Abstract:** The study aimed to examine physics pre-service teacher existing ideas of computer-supported for inquiry physics learning and learning. Methodology is qualitative research. The research will interpret physics pre-service teacher existing ideas of computer-supported for inquiry physics learning and learning through framework of Chinn & Malhotra (2002) epistemology and cognitive processes of scientific inquiry. Participants included 15 physics pre-service teachers who enrolled for teaching practices in schools for one year, in Thailand. The questionnaire of Using Computer-Supported for Scientific Inquiry (QCSI) and interviewing were tools for interpreting physics pre-service teacher existing ideas of computer-supported for scientific inquiry. The findings revealed that the most of participants perceived few aspects of cognitive process of scientific inquiry when they gave the ideas of using computer-supported for physics teaching. Only three of six aspects of epistemology of scientific inquiry were found from physics pre-service teachers' ideas. These included responses to anomalous data, purpose of research, and theory-data coordination.

**Keywords:** Computer-supported, physics, scientific inquiry, pre-service teacher

## 1. Introduction

Although there are many potential benefits to using inquiry in a science classroom, many research found that teachers face challenges in implementing inquiry (Abd-El-Khalick et al. 2004). Teachers have a number of barriers to implementing inquiry in the classroom. In order to provide powerful chance of scientific inquiry, teachers should gain knowledge and skills of providing scientific inquiry activities. The computer-supported is another solution of generating inquiry experiment and situation (Chen et.al. 2013). In recent years, a number of computer-supported inquiry-based science learning environments have been created and studied with aiming to facilitate the development of cognitive and metacognitive strategies in pupils (Minocha & Thomas, 2007). However, it seemed that teachers had some difficulty to provide computer-supported for science teaching and learning (Maishra & Koehler, 2006). In order to enhance teachers to develop their knowledge of computer-supported science inquiry shift from simple to authentic inquiry, examining of their existing ideas about this should be addressed. This study attends to this issue by examining physics pre-service teacher existing ideas of computer-supported for inquiry physics learning and learning. To clarify the continuum of scientific inquiry, the scientific reasoning is the central issue of distinguishing. This study will adopt Chinn & Malhotra (2002) epistemology and reasoning processes of authentic science as framework of clarifying pre-service teachers' existing ideas of computer-supported for scientific inquiry.

## 2. Methodology

Methodology is qualitative research. The research will interpret physics pre-service teacher existing ideas of computer-supported for inquiry physics learning and learning through framework of Chinn & Malhotra (2002) epistemology and cognitive processes of scientific inquiry.

### 2.1 Participants



Participants included 15 physics pre-service teachers who enrolled for teaching practices in schools for one year, in Thailand. These pre-services have planned to provide computer-supported for physics teaching and learning when they are teaching in schools.

## 2.2 Data collection

The questionnaire of Using Computer-Supported for Scientific Inquiry (QCSI) and interviewing were tools for interpreting physics pre-service teacher existing ideas of computer-supported for scientific inquiry. The QCSI provided three open-ended questions about computer-supported for scientific inquiry in order to probe their ideas of inquiry in aspects of epistemology and cognitive processes. Then, the interviewing was carried out in order to further probe what pre-service exactly mean or respond to the QCSI.

## 2.3 Data Analysis

Participants' responding was categorized into different existing ideas of computer-supported for scientific inquiry. Chinn & Malhotra (2002) epistemology and cognitive processes of scientific inquiry was referenced as expected ideas of providing computer-supported for scientific inquiry.

## 3. Findings and Discussion

Pre-service teachers' ideas seemed to lack of providing computer-supported for inquiry. However, some parts of their ideas could be counted into some aspects of cognitive processes and epistemology of scientific inquiry as follow:

### 3.1 Existing ideas about aspects of cognitive processes in using computer-supported for scientific inquiry

Table 1: Existing ideas about aspects of cognitive processes in using computer-supported for scientific inquiry

| Aspects of cognitive processes | Frequency (N = 15) | Percents |
|--------------------------------|--------------------|----------|
| Generating research questions  | 5                  | 33.33    |
| Designing studies              | 4                  | 26.67    |
| Making observations            | 9                  | 60.00    |
| Explaining results             | 2                  | 13.33    |
| Developing theories            | 0                  | 0.00     |
| Studying research reports      | 2                  | 13.33    |

It found that the most of participants perceived few aspects of cognitive process of scientific inquiry as showed in Table 1. They aware of computer-supported could be organized for physics inquiry in some aspects. It is only simple scientific inquiry. Number of them perceived that computer-supported could help making observation. However, their making observation would be only counted for transforming observations. Cognitive processes of inquiry on aspects of making observations, explaining results, studying research reports and designing studies were mentioned in their explanation. Even though, their ideas could be interpreted into some aspects of cognitive process of scientific inquiry, they also misunderstood in some issues of scientific inquiry e.g. making observations, and explaining results.

For example, Prin pre-service teachers' ideas of computer-supported for physics learning could be interpreted his cognitive processes of inquiry in three aspects including making observations, explaining results, studying research reports. His idea about explaining results was provided only aspect of transforming observations which refer to one or more rounds of data transformation. However, some of them seemed to he have no ideas to use computer-supported for scientific inquiry. Bell pre-service teacher thought that cognitive process of inquiry could be read from sentences or pictures provided in the websites rather than constructing from human endeavors during inquiry tasks.

### 3.2 Existing ideas about aspects of epistemology in using computer-supported for scientific inquiry

The findings indicated that participants have some perceived about epistemology of scientific inquiry when they showed the ideas of providing computer-supported for physics teaching and learning. Only three of six aspects of epistemology of scientific inquiry were found from physics pre-service teachers' ideas. These included responses to anomalous data, purpose of research, and theory-data coordination as showed in Table 2.

Table 2: Existing ideas about aspects of epistemology in using computer-supported for scientific inquiry

| Aspects of cognitive processes   | Frequency (N = 15) | Percents |
|----------------------------------|--------------------|----------|
| Purpose of research              | 7                  | 46.67    |
| Theory-data coordination         | 6                  | 40.00    |
| Theory-ladenness of methods      | 0                  | 00.00    |
| Responses to anomalous data      | 3                  | 20.00    |
| Nature of reasoning              | 0                  | 0.00     |
| Social construction of knowledge | 0                  | 0.00     |

For example, Lompad pre-service teacher's ideas reflected that he held idea of theory-data coordination. His explanation could be interpreted that he aware of giving students chance to generate scientific knowledge from data to theories. It showed existing idea about relationship of theories and data. Interestingly, epistemology of scientific inquiry in aspects of theory-ladenness of methods, nature of reasoning, social construction of knowledge seemed to has difficulty of organizing in Thai physics classroom. These three aspects related to argumentation in scientific classroom. This finding consistency to previous studies of Thai classroom (Ketsing& Roadrangka, 2010) that discussed that Thai science classroom needs to support argumentation in classroom.

## 4. Conclusion

It showed that most of physics pre-service teachers' existing ideas about computer-supported were provided for motivation of physics learning, scientific model, remote learning, simulation for abstract concepts or dangerous experiments, database, instructional media, and flipped learning. However, most of them lack of how to provide computer-supported in physics teaching as authentic inquiry. Few aspects of cognitive process of scientific inquiry had showed when they gave the ideas of using computer-supported for physics teaching. Only three of six aspects of epistemology of scientific inquiry were found from physics pre-service teachers' ideas. This suggests that epistemology and cognitive process of scientific inquiry should be concerned when teachers develop computer-supported for science learning.

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# Remote Laboratory System for Technology-Enhanced Science Learning: The Design and Pilot Implementation in Undergraduate Courses

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**Abstract:** In this study, a new remote laboratory (RL) system is developed through some innovative ideas and methods for practicing technology-enhanced learning of science in schools. The Internet-based RL system will enable students to control the server-side laboratory equipment and to carry out real-time scientific investigation activities at distance places. As a pilot study, a set of newly developed remote-controlled experiments were first tried out by a total of 64 undergraduate students who studied some science education and teacher training courses. The evaluation used mixed research method which included questionnaire survey and interviews as specifically developed by us to collect data on students' perceptions, views and implementation issues related to the use of the RL system. The survey findings showed that the participants agreed with the appropriateness of various educational merits of the RL system but negative comments and suggestions for improvement were also received. Through iteration of Design-Based Research (DBR), we have refined our RL system.

**Keywords:** remote laboratory, technology-enhanced learning, science education

## 1. Introduction

With the rapid advancement of technology and the prevalent use of Internet in education, science practical work in form of web-based laboratory or remote laboratory (RL) has recently been adopted in cloud computing. As a simple definition of the RL system, "the basic idea is for a user to connect via the Internet with a computer from place A to a real experiment carried out in place B" (Grober, Vetter, Eckert, & Jodl, 2007, p. 127). Recent education reforms have identified the importance of technology-enhanced science learning, which can be achieved in science education through RL system (Kong, Yeung, & Wu, 2009; Lowe, Newcombe, & Stumpers, 2013). Using this RL system, students can view and control apparatus/equipment in science experiments, and downloads real-time data in classroom, computer laboratory or even at their homes. Therefore, the RL can be considered as a kind of new development in technology-enhanced learning (TEL) in which appropriate technology and pedagogies are innovatively applied in science education.

The first part of this study is to design and develop of an innovative RL system through technology-enhanced inquiry for Hong Kong science education. Of course, we are aware that it is hard to evaluate this innovative system just based on the design or development itself. As a result, a pilot evaluation in two undergraduate classes was conducted as the second part of the study.

## 2. Research Methodology

### 2.1 The RL System Design

In developing and designing the RL packages, this study adopts the Design-Based Research (DBR) framework (Design-Based Research Collective, 2003; Reeves, 2006; Wang, & Hannafin, 2005) and it involves four important iteration phases of design, testing, analysis, and refinement.

For design, the development of the RL system includes identifying the needs of the RL system for science practical work and searching feasible experiments, calibration of sensors, software development, and designing a complete remote-controlled experimental setup for an inquiry science experiment. Hence, several feasible experiments (Table 1) that can be incorporated into the RL system were identified with reference to the local school science curricula. The system includes the Laboratory Virtual Instrument Engineering Workbench (LabVIEW) software which is a graphical programming language that uses icon-based rather than lines of text form to generate programs. It equips with the data acquisition hardware and remote control application through the web publishing tool.

**Table 1: The design and content of remote-controlled experiments.**

| Experiment                  | Changing Parameter   |
|-----------------------------|--|
| E1: Sound as vibration      | Wave type, sound frequency & volume.                         |
| E2: Electrical circuit      | Number of bulbs in series & parallel.                        |
| E3: Phototropism experiment | Three position of light source & plants horizontal position. |
| E4: Gravitropism experiment | Plants vertical position at 30° or continuously.             |

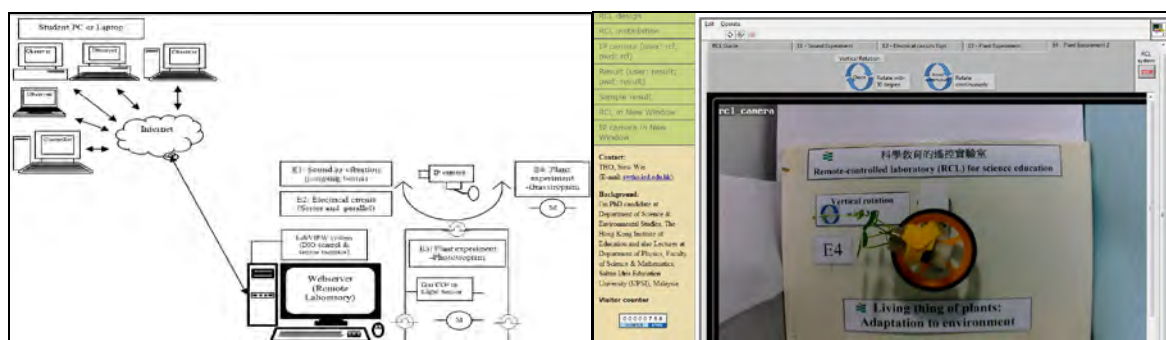
### 2.2 Evaluation: Testing and analysis

For evaluation, 64 valid undergraduate students in two different courses namely Course 1 (major in a science and web technology programme) and Course 2 (major in a teacher training programme) voluntarily participated in this mixed method research. During their laboratory session, a set of newly developed RL technology-enhanced inquiry activities was conducted by the participants. Based on their learning experiences, self-developed survey questionnaire with four Likert scale and open-ended questions as well as interview were used to collect participants' views, perception and difficulties of using the RL system.

## 3. Findings, Analysis and Discussion

### 3.1 RL system

For the RL system, four remote-controlled experiments were successfully developed. Figure 1a presents the design of the RL system for performing remote experiments and Figure 1b shows the webpage for the E4 plant experiment of Gravitropism to be conducted by students. The RL guide and movies for those experiments could be found online at <http://rcl.ied.edu.hk:8000/sample/index.htm> and the webpage also demonstrates how this remote technology is being employed.



**Figure 1.** Remote laboratory system: (a) the structure of RL system for performing science experiments; (b) webpage display of the RL system for gravitropism experiment.

### 3.2 Survey

For this first implementation, we focused our analysis on the undergraduate students' views and suggestions to the RL system refinement before its formal implementation and evaluation in secondary schools. It is because their valuable views and suggestions are very important for us as they learned

science education and teacher training courses. For this reason, no conceptual test was used in this DBR study. Table 2 reports the evaluation data as obtained from the student survey. Overall, the survey findings from all participants showed that they agreed with the educational merits underlying the RL system in the present study. However, Course 2 participants constantly rated higher in the survey items compared to Course 1 participants. Based on open-ended questions and interview data, the comments and suggestions for improvement of the RL system were received.

Table 2: Participants' response on survey items (N=64).

| Category                         | Course 1: mean (SD) (N=30) | Course 2: mean (SD) (N=34) | Overall: mean (SD) (N=64) |
|----------------------------------|----------------------------|----------------------------|---------------------------|
| Insight of Science & ICT         | 2.91 (.55)                 | 2.98 (.64)                 | 2.95 (.60)                |
| Operating the RL system          | 2.90 (.50)                 | 3.06 (.42)                 | 2.98 (.46)                |
| Enriching the learning           | 2.82 (.89)                 | 3.03 (.59)                 | 2.93 (.75)                |
| Developing application           | 2.78 (.66)                 | 2.99 (.52)                 | 2.89 (.59)                |
| Stimulating motivation           | 2.80 (.78)                 | 3.14 (.54)                 | 2.98 (.68)                |
| Improving teaching skills        | 2.87 (.65)                 | 3.06 (.45)                 | 2.97 (.56)                |
| Promoting group work             | 2.73 (.73)                 | 2.97 (.57)                 | 2.86 (.66)                |
| Enhancing teaching self-efficacy | 2.81 (.67)                 | 2.99 (.45)                 | 2.90 (.56)                |

### 3.3 Refinement

Based on analysis, we refined the RL system by using high resolution of IP camera, modifying existing remote experiments and adding new feasible remote experiments (plants respiration, battery bank, and solar energy experiments) as well as providing clearer RL operating guideline.

## 4. Conclusion

This pilot study has achieved several important outcomes. Initially, the students' perceptions, comments and suggestions of their learning experience with RL system were obtained. Then, the refinement RL system was successfully developed with some innovative application in a few science experiments that can be used inside or outside the school environment to enhance the science learning and complementary to the regular classroom teaching processes.

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# The Model Construction and Platform Development of Students' Originality Incubator System

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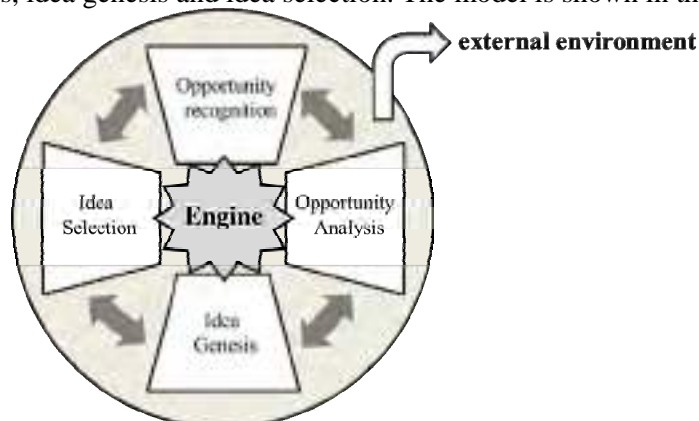
## 1. Introduction

The cultivation of technological innovative talents has always been the top priority of countries all over the world. Prior researches have focus on foster students' innovation education by changing governmental strategies or teaching methods (Van Vught, 1989; Shavinina, 2013). Gunnarsdottir (2013) suggested that in innovation education, ideation process is been described as Need-Solution-Products to access their creative. Children gather, analysis and share their needs, solutions and present their products in a learning community environment. With the development of network and information technology, it provides students an easy way to learn and communicate their own ideas in school or outside.

Therefore, this paper is concerned that the originality incubation inner process of undergraduates in a social networking environment, constructed a model of originality incubation system for college students and develop an 'Idea Pool' platform which support the college students' originality generation, development process and formation of learning community. The purpose of 'Idea Pool' is to enhance students' innovative capability by promoting the constant iteration of originality groups in the originality height and knowledge depth, as well as the maturity of originality.

## 2. Model Construction of Students' Creative Incubator System

This study constructs a model of originality incubation system for college students on the basis of the new concept development theory (NCD theory) which proposed by Koen (2001). The originality incubation system model describes the process of forming feasible originality from the original originality, and it mainly consists of four elements, including the opportunity recognition, opportunity analysis, idea genesis and idea selection. The model is shown in the figure1.



**Figure 1.** Undergraduate originality incubation model.

The system model mainly consists of the elements, relations, engine and influence of environment on elements.

External environment. During the originality incubation process, environmental factors influencing the creative process mainly consist of the creative atmosphere in campus, strength of the

sponsor of creative activities, strength of the competition group involving in the creative activities, research trend of the creative projects, as well as the technological development.

Engine. Engine is the power that drives the cyclic motion. During the originality incubation process, the communications with peers and teachers, as well as the study of domain knowledge are the main strength of promoting the element cycle in the originality incubation process. In addition, the leadership of group leaders, capacity of group members, collaborative atmosphere of the group, and teacher’s guidance are also of great significance for driving the creative process.

Four internal factors. Until the final feasible creative prototype is formed, these four factors of creative process reflect an iterative loop, rather than the linear relationship. In other words, the creative process has no specific starting point and terminal point. The originality may start at any element or finish at any element. Furthermore, the originality may iterate for several times in one element and then transfer to another element, and it may also iterate among the elements.

### 3. The framework and function design of ‘Idea Pool’

According to the originality incubation model for undergraduates proposed previously, it can be discovered that the creative process is a random and iterative process, and such a process may be characterized by many chances. During such a process, it may require an open environment for the generation of opportunities, as well as an open environment for promoting the effective communication and the constant maturity of originality, especially in the idea genesis and opportunity recognition two links. ‘Idea Pool’ polish the immature originality into feasible originality by focusing on the accumulation of partners, resources, discussion and relevance. The process of feasible originality generation in ‘Idea Pool’ is shown in the figure2.

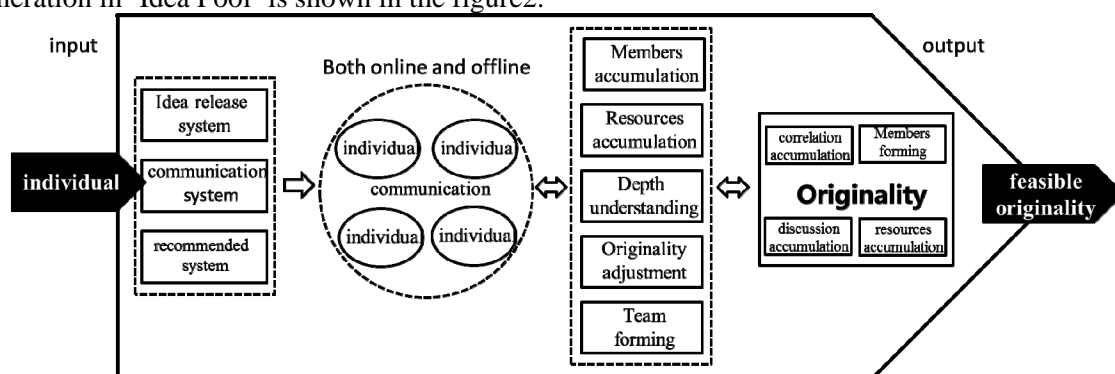


Figure2. The framework of feasible originality generation in ‘Idea Pool’

This platform mainly consists of the following three systems, including the idea release system, communication system and recommended system, and the overall frame diagram is shown in Figure 3.

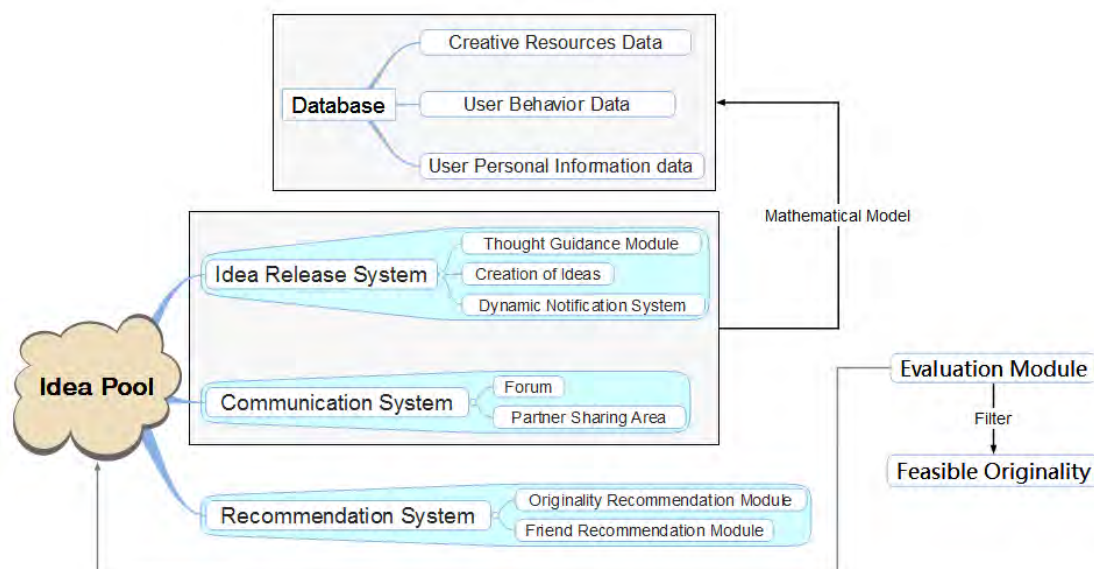


Figure 3. Overall framework of ‘Idea Pool’ educational platform.

In 'Idea Pool', Idea release system sets the template for guiding the thoughts, and provides three problems for clearing the thoughts, namely targeted group, problems that shall be settled, and possible solutions; Communication system consists of the forum and partner sharing area. The design of the forum mainly adopts the classification guide, and users can set up different themes for seminar discussion, including on-line and off-line; Resource recommendation system can extract the key words for the user according to the concern domain they selected and the favorite ideas they labelled before, in order to save time for students, reduces the blindness of searching and improves the efficiency. One of the core interfaces of 'Idea Pool' is shown in Figure 3.



Figure 3. Front page of 'Idea Pool'.

#### 4. Summary

'Idea Pool' mainly takes advantage of the on-line and off-line combined study method to help college students' generating and grinding originality by creating a favorable learning community. At present, the 'Idea Pool' is mainly promoted on campus, forming the network resource links with the originality as the center, so as to connect similar ideas and people with common ideas, and to promote the undergraduates for forming the originality circle.

So far, the 2.0 edition of this platform (Cooperating the action plan of Sun Yat-Sen University) has already been on trial in Sun Yat-Sen University. Till February 2014, the platform has already achieved 10 originalities, and the average originality reliance degree is 28.15%. The data we have collected was not very sufficient, next step we will take more evaluate data into consideration to investigate the usability and usefulness of the system.

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# A Flexible System and Data Model for the Representation and Management of PBL Scripts

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**Abstract:** As problem-based learning (PBL) is becoming more and more popular, there is also a growing interest in developing and using technologies in the implementation of PBL. However, teachers may have difficulties to design a pedagogically high-quality and technically executable, online or blended PBL process on their own, because they lack appropriate expertise in learning theories and design methods as well as a deeper understanding of the potential affordances of technologies. From this premise, we are committed to developing and testing methods and tools to support the design and delivery of online or hybrid PBL processes with high flexibility and a low threshold of usage requirements. As a first milestone towards this goal we have developed a web-based PBL authoring tool for facilitating teachers to design, represent, understand, communicate, customize and reuse online or blended PBL processes. This paper presents a technical approach to the PBL authoring tool and focuses on supporting the representation and management of PBL scripts, computational descriptions of PBL process. In comparison with other tools and technical approaches, it is concluded that a combined use of semi-structured data management and a unified data format appears to be a promising approach to effectively and efficiently support the representation and management of PBL scripts.

**Keywords:** PBL, learning design, PBL authoring tool, PBL script, semi-structured data, data management, graphical representation, web-based application

## 1. Introduction

Problem Based Learning (PBL) is a learning method to structure the curriculum in such a way as to involve confronting students with problems from practice as a stimulus for learning (Boud & Feletti, 1998). It engages learners in an active, collaborative, student-centered learning process that develops critical thinking, problem-solving, team-work, and self-directed learning abilities needed to meet the challenges of life and career in our increasingly complex environment (Hmelo-Silver & Eberbach, 2012). PBL has been successfully used in various different domains and its benefits have been largely demonstrated (Savery, 2006). The application of new technologies such as Web 2.0 and virtual collaboration environments can enrich and improve implementations of PBL (Kaldoudi et al., 2008). Nevertheless, to achieve its full power, an online or blended PBL process needs to be well designed, and a sound online or blended PBL process may be a collaborative product of years of research, application, assessment and redesign. Usually, designing such a PBL process is an intensively mental work and an implicit process. Traditionally, the teacher individually constructs a PBL design based on personal experience and represents it in natural language as a course plan or lesson plan on paper. Teachers may have neither appropriate expertise in learning theories and design methods nor a deep understanding of the potential affordances of technologies. They lack guidance to design a high-quality and technology-supported PBL plan in a specific context in order to benefit from PBL and new technologies.

Our general goal is to study and develop methods and tools to support the design and delivery of online or hybrid PBL processes in an effective, efficient and flexible manner. As a milestone to achieve this goal we developed a web-based PBL authoring tool that aims at facilitating teachers in design, representation, understanding, communication, customization and reuse of online or blended PBL processes. We try to help teachers to make the implicit design process explicit in order to improve design quality and to represent a traditionally informal description as a formal model for scaffolding

and orchestrating a PBL process by the computer. This paper presents our technical approach to develop a web-based PBL authoring tool. We claim that semi-structured data management and a unified semi-structured data form can make up an effective combination to technically support the representation and management of PBL design.

The rest of the paper is organized as follows: Section 2 describes a typical PBL process script represented in natural language and characterizes a PBL design. Section 3 presents the implementation and the functionalities of the PBL authoring tool to give an impression of our tool. Section 4 identifies technical requirements that how to represent and manage PBL scripts in order to implement the tool. Section 5 compares our tool with related work on the aspects of user interface and data management. The final section summarizes our work and indicates the future work.

## 2. Requirements to Represent and Manage PBL Scripts

PBL can be conducted in a number of ways. There are different PBL models such as McMasters PBL model (Woods, 1996), the Maastricht “seven jump” model (Barrows, 1996), the Aalborg “Problem Oriented Project Pedagogy (POPP)” model (Dirckinck-Holmfeld, 2002), Mills “five-stage” model (Mills, 2006), and SALFORD model (McLoughlin & Davrill, 2007). According to concrete situations such as the learners’ prior domain knowledge and PBL skills, the topics to be learned and the problem used to drive learning, and the availability of learning technologies, a PBL process can be designed to fit the specific learning context. In order to illustrate how a PBL process is usually described informally in natural language, we take a segment of “seven-jump” model as an example through this paper from (Maurer and Neuhold, 2012):

“To get students started on a certain topic, they are confronted with an assignment that ... outlining the problem or asking for a specific task to complete. ... Students are supposed to have read and looked at this assignment already before their tutorial (or during the break), so that they can start with **clarifying terms and concepts**. This first step guides students mentally into the topic, and by discussing unknown words or concepts it is ensured that all students understand the text as it stands and that the group shares ideas about illustrations that might be part of the assignment. This first step provides a common starting point and leads the group into the topic. In the next step, the whole group agrees on the **formulation of the problem statement** that frames the whole assignment, provides a title for the session, and makes the group agree on what the general impetus of the assignment is about. Problem statements can take the form of more traditional titles, but are sometimes also formulated as broader research questions or provoking statements. The problem statement should trigger the next step of the **brainstorm**. ... Everything is allowed during this step, and ideas are collected unquestioned at the whiteboard (i.e. there are no wrong ideas; everyone should be allowed to follow her/his own ideas). ... The outcome of the brainstorm is noted on the whiteboard by the secretary that during the next (fourth) step should be **categorized and structured** by the students. ... but by structuring the brainstorm students categorize keywords that fit together and in this way they find common patterns that in the next step will allow for the formulation of specific questions. As last step of the pre-discussion, students agree on the **formulation of common learning objectives**, by referring to the brainstorm and the now structured collection of ideas that they have noted on the whiteboard. ...”

This PBL model consists of several steps (marked in bold, here only shows five steps for the reason of space) which includes *clarifying terms and concepts*, *formulation of the problem statement*, *idea brainstorming*, *categorizing and structuring ideas*, and *formulation of learning objectives*, etc. In each step one or several activities are performed by the facilitator, group, individual learner or stakeholders, e.g. scientific staff. For instance, according to the quoted text, after a problem statement was formulated in step 2, the third step *idea brainstorming* will be triggered. Assume that this learning model will be performed by a class which is divided into 3 groups and instructed by one facilitator, then in this step, a specific activity sequence could be 1) based on the problem statement formulated in the previous step, each group creates a basic hypothesis; 2) from this basic hypothesis each group proposes their tentative solution; 3) the facilitator views these solutions and give his or her feedback. Each group will improve their tentative solutions based on the feedback. In this step, there are some artifacts will be produced: three groups of basic hypotheses, three groups of tentative solutions and the facilitator’s

feedback. All this work could be carried out by using an (online) whiteboard. Figure 1 illustrates the process above.

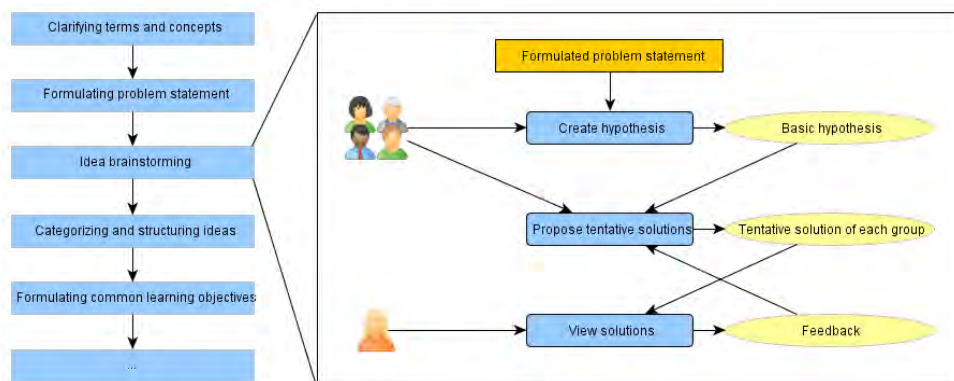


Figure 1. Structure demonstration of a PBL process.

As it is shown in the figure 1, there are several top level steps in the left, which is also called phases. The phases have a process sequence from top to bottom. Then in each phase, *idea brainstorming* for instance, there is a second level of description, or phase internal definition. Teacher needs to organize actors first and then assign actors to different activities. Some activities will produce artifacts or need learning resources. The activities are also under a process sequence.

Existing ICT applications for PBL still lack flexibility and usability/understandability by teachers who are not PBL experts. Either some applications are easy to use because they have well-designed PBL process pattern inside, e.g. STELLAR (Hmelo-Silver et al., 2009) and ePBL (Ali & Samaka, 2013), but too rigid to apply different PBL models; or some applications are flexible enough, but difficult for teachers who lack a deep understanding of PBL processes. For example, teachers need to figure out which activities are appropriate for a certain phase; what kinds of artifacts should be there as temporary outcome or final outcome for certain phase and so on. Since process scripts are usually just embedded in teacher's practice and they tend to be implicit. Thus in educational practice, PBL processes mostly are executed only based on a social protocol and a manual configuration and management of various application tools and digital or non-digital artifacts. As a consequence, there is a need to support teachers in representing PBL processes more explicitly and formally.

In order to overcome these barriers and to enable computerized support of different models of online PBL, one possible way is to adopt the concept of CSCL script. As we know, this concept has been used to structure computer supported collaboration (Dillenbourg, 2002). It has been considered an effective means of facilitating specific interaction patterns in CSCL situations (Fischer et al., 2007). Numerous approaches to representing CSCL scripts and CSCL scripting languages have been reported in the literature (e.g. Dillenbourg, 2002; Miao et al., 2005; Miao et al., 2007; Dillenbourg & Tchounikine, 2007; Harrer et. al. 2007). Our approach is particularly inspired by Miao et. al. (2000), and we proposed our PBL specific scripting language, namely PBL scripting language. Rather than using generic vocabularies, our scripting language only relies concepts that teachers use daily to describe PBL processes such as *problem engagement*, *identify learning issue*, *generate solutions*, *evaluate acquired knowledge*, etc. Also, as a kind of Domain Specific Modeling Language (DSML), these vocabularies and rules are specified by PBL domain experts taking into account different PBL models. In this way, teachers can be enabled to make use of different PBL models to create different but correct and computer understandable PBL scripts. As a result, teachers' mental scripts become representable, manageable and runnable online or as blended PBL course plans.

Therefore, there is a requirement to find a way of providing a web-based application which is aimed at empowering teachers to represent, improve, understand, share, reuse and manage online or blended PBL scripts in a design-time basing on the applying of our PBL scripting language.

### 3. A Web-based PBL Authoring Tool

In order to fulfill the requirement mentioned above, we have developed a web-based PBL authoring tool whose basic concept has already been introduced and evaluated. Miao et al. (2013) provide evidence that this tool is understandable and usable by teachers to develop online PBL course plans. Taking up the example in section 2, figure 2 shows the three major User Interface elements of this tool. They separately represent the organization design UI, the script level design UI and the phase level design UI. The most important functional area is the middle area which contains, from left to right, 1) script file management panel (for scripts management, sharing, reusing, etc.), 2) meta-type pool (which provides corresponding meta-types for different types of edit-spaces according to the PBL scripting language meta-model), 3) graphical script edit-space and 4) property panel.

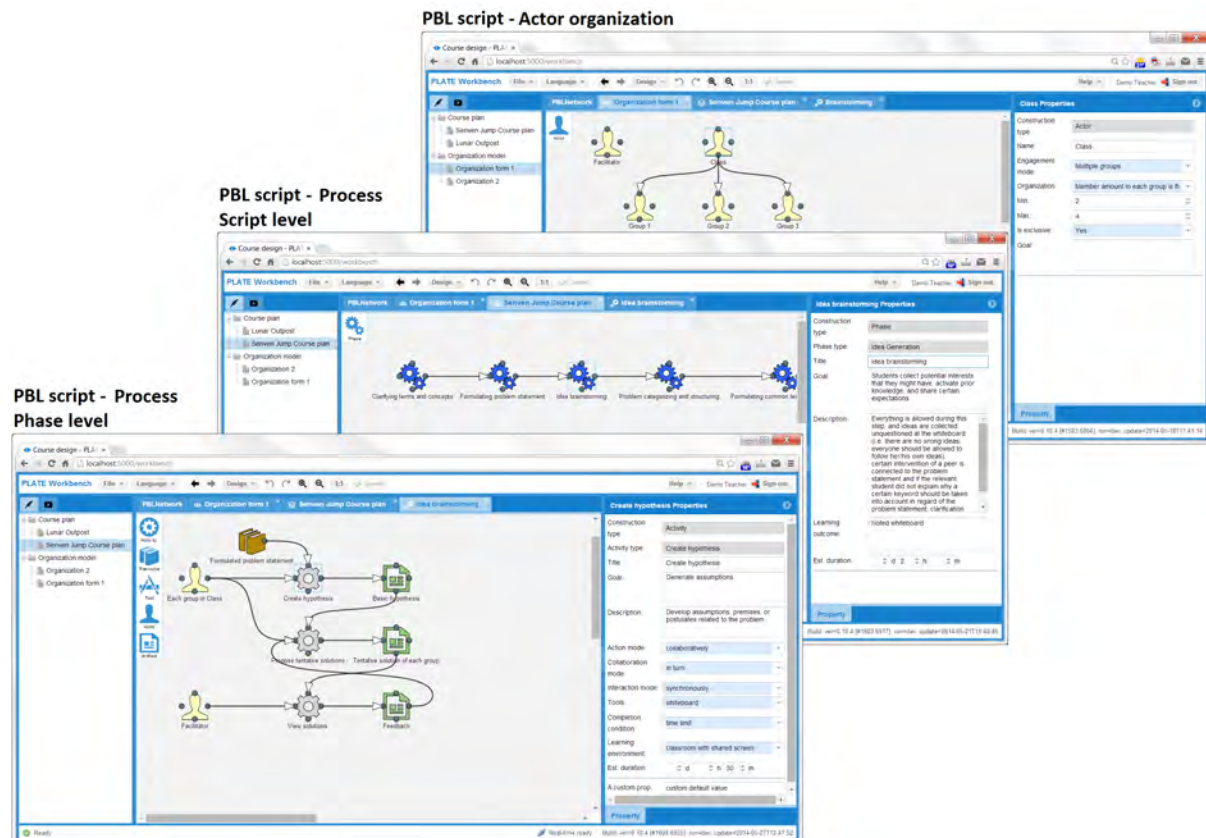


Figure 2. User interfaces of actor organization design, script level design and phase level design of PBL script in the PBL authoring tool.

Specifically, in the organization design, teacher can drag the *actor* meta-type icon from the meta-type pool and then drop it into the edit-space to create an actor node. Then the teacher will be asked to determine its type. This ensures that the node is appropriate for correct PBL process as well as can be understood by computer. According to the definition of PBL scripting language the type of actor could and only could be an *individual*, a *single group* or *multiple groups*. Teacher just needs to choose one to define it. For example in the organization design UI, an *individual* node is created and named as *Facilitator*, a *multiple groups* node is created and named as *Class* (in the property panel we can see the minimum participants of each group is 2, maximum is 4, and so further). Teacher can also create connections between them to define their relations. The organization can be shared by multiple PBL processes.

After an organization is defined, teacher can begin to define the core part of a PBL process: script level process and phase level process. Almost the same to the way of designing organization, teacher can also simply by dragging, dropping, choosing, editing properties, connecting, etc. to design these two levels of process. But compared to the organization design, there are 3 other important points need to be emphasized. 1) There are more meta-types which include *phase*, *activity*, *resource*, *tool* and *artifact* generated according to our language meta-model to the meta-type pool while in the organization design there is only *actor*. Actually, the process of creating these types (including *actor*) of nodes on the edit-space is the process of instantiating node types defined in the language meta-model to

node instances. In other words, teacher just needs to instantiate the meta-types instead of designing from scratch by themselves. This mechanism ensures that the design of script is both flexible and responsible (Wang et al., 2014). As it is shown in the script level UI of figure 2, the node *Idea brainstorming* is based on the type *Idea Generation*. *Idea Generation* is not defined by teacher but by expert. So that when teacher designs the internal structure of the *Idea brainstorming* node (phase level design), all available node types and nodes' properties under this phase are only the appropriate types and properties for this phase according to the meta-model's specification. For example, when teacher wants to create an activity, the only options are *Offer conjecture*, *Create hypothesis*, *Propose tentative solutions*, etc. Or when teacher wants to create an artifact, only *Hypothesis*, *Solution*, etc. can be chosen. Inappropriate node definition will be avoided. 2) The types of actor node are the nodes defined in actor organization, but with corresponding extension. For example, since there is a *multiple groups* type node *Class* created, when teacher drags an actor into the edit-space, a list which contains *All members in Class*, *Each member in Class*, *All groups in Class* and *Each group in Class* will be generated for choosing. So in the phase level design UI, an *Each group in Class* actor node is there as an example. Connected this node, there is a *Create hypothesis* node. In property panel of this node, for example, teacher can choose *collaboratively* as the *Class' Action mode*, and let each group *in turn* perform the activity. Each group will *synchronously* use *whiteboard* to generate their *Basic hypothesis* within *30 minutes*. 3) Except there are fixed properties for each node in the script and phase design level, it is possible to add new custom properties into the property panel, because the property requirement in real world is always uncertain. As you can see there is an *A custom prop.* at the bottom line in the property panel in the PBL phase level design UI. It is achieved through extending our scripting language meta-model by experts, rendered in the script design UI, which is used to save, retrieve more information to get higher expression ability.

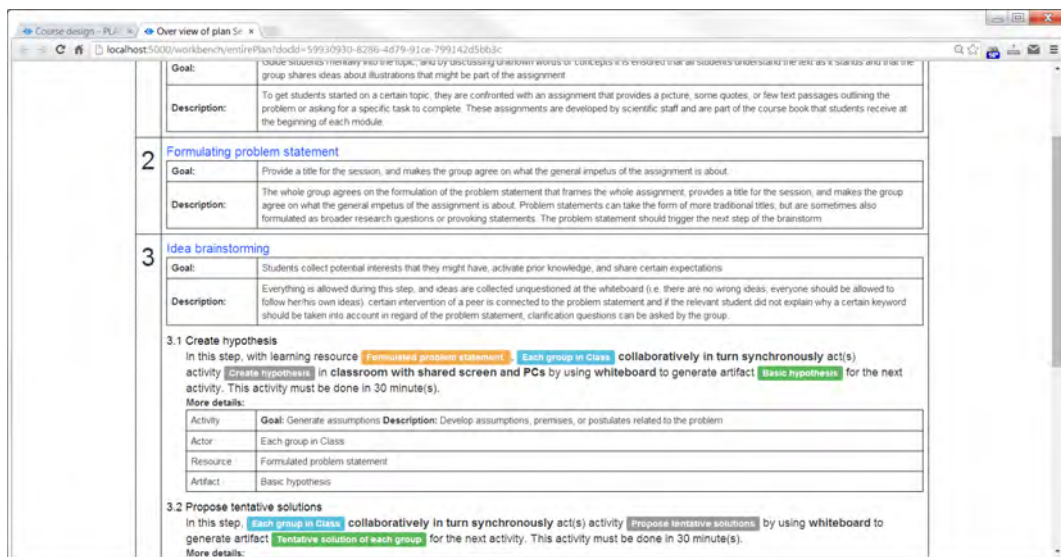


Figure 3. The textual output of the graphical designed PBL script.

When teacher finishes his or her design, a graphical PBL script can be exported as a complete textual script. Figure 3 shows the textual output of the example used in figure 2. Notice that if the teacher did not specify the *Goal* or *Description*, etc. the tool will automatically generate a default general definition based on the language meta-model and the node type chosen by the teacher at design-time. In this output, the top level contains the phases; then each phase contains activities (for saving space and as an example, there is no internal definition in phase 1 and 2). In phase 3, *Idea brainstorming*, we can see the activities inside. A summary generated by the tool for each activity according to which *actor*, *resource*, *artifact*, etc. it connects and what property values are set. For example the generated summary of activity 3.1 *Create hypothesis* is: "In this step, with learning resource *Formulated problem statement*, *Each group in Class* collaboratively in turn synchronously act(s) activity *Create hypothesis* in classroom with shared screen and PCs by using whiteboard to generate artifact *Basic hypothesis* for the next activity. This activity must be done in 30 minute(s). "

This proves that the tool has already understood what the teacher’s script means. So interoperating the graphical script for other run-time learning systems, e.g. IMS-LD players, becomes possible.

#### 4. An Approach of Supporting the Representation and Management of PBL Scripts

The previous section has given an initial impression of our approach. But to actually implement it, several technical problems need to be overcome: 1) How to support this kind of unified manner to represent actor organizations and the processes? Because the heights of the script document tree could be greater than 1 or 2 as the example. The degrees of the sub-trees could also be greater than 5, 7 or 9 as the example. 2) How to effectively manage (save, retrieve and compute) the graphical scripts? The saving/retrieval includes saving/retrieving all the nodes, saving/retrieving (custom) properties of every node, saving/retrieving all the relations between the nodes, saving/retrieving the multi-levels structure; the computing includes transforming graphical scripts to complete textual documents. This section will present a flexible system and data model approach to overcome these problems.

##### 4.1 The Implementation Concept

Although the multi-levels structure of a PBL script is semi-structured, which has uncertain height and degree, it has a special hierarchical characteristic. That is, different level is for definition, same level is for relation. For example, the script level is the general process definition of a script divided by phases; the phase level is the detailed definition of each phase. In contrast, the script level defines the relations between phases; the phase level defines the relations among activities, actors, etc. Similar, if one wants to give more fine-grained definition for the *Class*, one can also define a lower level for it. Therefore, the edit-space can be designed to support the design of a whole PBL process iteratively. Each edit-space represents the definition of only one upper layer node. Each definition is a directed graph that consists of nodes and connections. Figure 4 illustrates this kind of iterative representation from two aspects. The edit-space 1 is for designing the phase’s sequence for example. After a phase was defined it can be opened into a new edit-space. Similar to the first, in the edit-space 2, activities, resources, tools, actors, artifacts and their relations can be defined. If required, a third level of edit-space can be opened. Therefore a process script even if with infinite height and degree can be defined. Since manipulation requirement of each level is similar, the functionalities required for each edit-space are similar too.

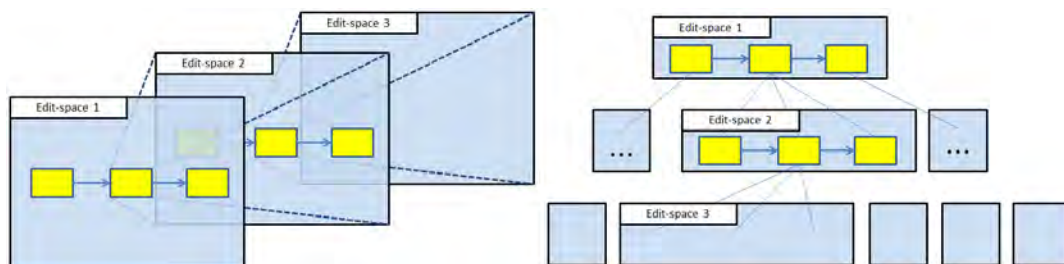


Figure 4. Iterative representation concept of a PBL process in multi-level edit-spaces

Actually, database can be also designed to save the definitions in each edit-space iteratively in order to save infinite height and degree of PBL scripts. Because there are only finite meta-types of nodes in the PBL scripting language, which only includes *phase*, *activity*, *resource*, *tool*, *actor* and *artifact*, and nodes in edit-space are just the instances of those meta-types, all nodes can be iteratively saved in their own meta-types of collections. Relation connections among nodes are seen as connection type instances which can be saved in a connection collection. Figure 5 illustrates this kind of storage approach. Each node has a *definition id* field as a pointer points to another edit-space; each edit-space has a *segment id* to let the nodes or connections know where they locate. Nodes and connections of different edit-spaces from different scripts are scattered stored in their own meta-types of collections.

The retrieval of a definition is just to find all the nodes and connections where their *segment ids* equal to the edit-space’s *segment id*. Then the data can be directly sent to client side without any logical calculation. Basing on their graphic coordinate values all nodes and connects will be correctly rendered

on edit-space. Because the nodes and connections as minimum units are stored separately, it shows several benefits: 1) It is very effective to add, remove, update and find node whenever where it is in one or many PBL scripts. When teacher edits a node or connection, any change can be saved without involving any other nodes or connections. So high computation cost in updating script is avoided. 2) It is very easy to handle the change of process structure. Because the node definitions are not really connected to each other, the change of structure only needs to change the pointer value. This benefit make it is possible to effectively reuse and share any levels of sub-trees of any script. When teacher wants to view the complete script, all nodes and connections can be easily retrieved because all of them whom belongs one complete script have a same *script id*. The only additional thing is that before a complete script is sent back to client, a semantic engine will organize them into a correct order.

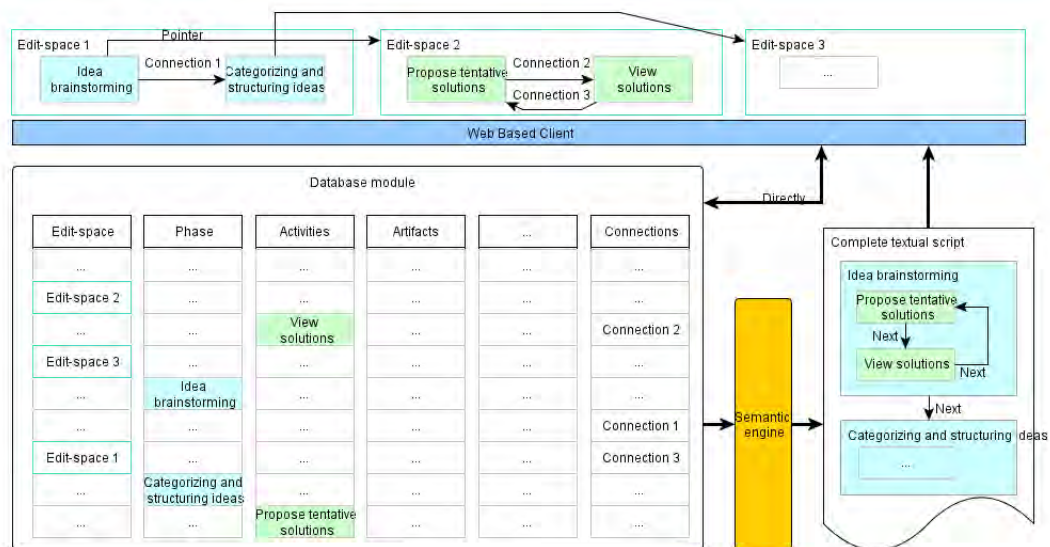


Figure 5. The storage concept of the PBL script

#### 4.2 Combined Use of Semi-structured Data and Unified Data Format

The previous section has elaborated the implementation concept of representing and managing the semi-structured script data, but to technically implement it is another challenge. The following facts must be considered: 1) Not only the structure itself of PBL script is semi-structured, but also the node data itself is semi-structured. For example, as mentioned before, node can have custom fields. The data type of a field could be string, array or others. Figure 6 shows this characteristic. In comparison to activity *Propose tentative solutions*, the custom fields of activity *View solutions* may be more complicated, if it needs an array to store the values for a drop-down list of a combo box. 2) As a web-based application, to maximally avoid browser compatibility issues, we need to use pure JavaScript to develop the rich graphical client.

Because the Node.js can be chosen as our web server, we can use JavaScript to program both client side and server side. Figure 7 shows the system architecture from the perspective of data handling. Since the client side and sever side of the system are both built by using JavaScript and JSON is the object notation of JavaScript; also because we can use MongoDB as our system database and the data persistence format in MongoDB is JSON (or BSON<sup>1</sup>), the data interchange format inside the whole system can be unified as JSON object. As we know, JSON is an ideal data-interchange language for representing semi-structured data. Therefore the node/connection objects in the system could be simply as JSON objects. Consequently, on the one hand, client side and server side can communicate each other directly through JSON object (after serialization). In client side, nodes and connections can be directly rendered to edit-space or sent back to server side without any format transformation. Also without any transformation, server side can directly process the nodes or connections from client side. On the other hand, data from client side can be stored inside the database directly. Even if there are new

<sup>1</sup> Short for Binary JSON, is a binary-encoded serialization of JSON-like documents.

custom attributes, such as string or array fields, which are customized added, client and server side JavaScript interpreter and MongoDB can still handle and store them natively.

Together with using pure JavaScript for the client UI, Node.js as the web server and MongoDB for the data persistence, JSON becomes a natural choice as a unified data format in our whole system. Combined with the implementation concept for handling the semi-structured process descriptions, all the requirements for the representation and management of PBL scripts are met.

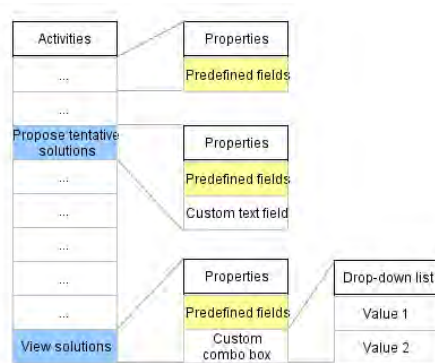


Figure 6. Custom property in node

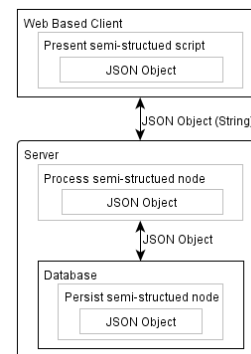


Figure 7. System architecture from the perspective of data handling

## 5. Related Work

Generally speaking, currently there are two kinds of implementation that can flexibly support PBL design: IMS-LD authoring tools and the LAMS (Dalziel, 2003). For IMS-LD authoring tools, there are Reload (Reload 2005), MOT+ (Paquette, et. al, 2006), ASK-LDT (Karampiperis & Sampson, 2005) CopperAuthor (CopperAuthor 2005) and CoSMoS (Miao, 2005). These tools are very flexible to represent and support the design of different learning process models and output the models as Unit of Learning (UoL) packages. The packages can be interpreted by IMS-LD run-time applications, such as CopperCore player (Martens & Vogten, 2005) and SLED (McAndrew, Nadolski & Little 2005). All these tools are general learning design tools; they have the capability of supporting PBL design. For the LAMS, a study has shown that it also can be used for PBL design (Richards & Cameron, 2008).

However, all of them have some shortcomings in term of supporting PBL design. From the perspective of supporting visual learning design, IMS-LD authoring tools and LAMS misses the capability of facilitating teachers in developing sound PBL process since they are too general and not PBL domain specific. From the perspective of utilizing Web technologies, these tools came about by adopting traditional software development concept, most of them are desktop applications. As we know, desktop applications have high maintenance cost, are not anywhere available without pre-installation, are not cross-platform (if they are not on the top of Java) and so further. From the perspective of data management approach, existing applications store learning design artifacts either by using traditional relational database or directly as XML files. Relational databases are good at data storage and querying, but they cannot manage this kind of semi-structured data well since they are relational and not schema free. XML file is a kind of ideal media for storing this kind of semi-structured data; one drawback is that it is not ideal for data manipulation, such as partial update, search, etc. which will lead to considerable computational overhead in server side. Although there are some combination solutions to manage XML documents through relational database, XML queries are still inefficient (Shanmugasundaram, et. al. 2008).

## 6. Summary and Future Work

PBL is a kind of high collaborative learning process with a distinctive pedagogy, therefore there are difficulties in designing the process script, which include designing actor organization and designing learning process. Thus an extended CSCL scripting language, the PBL scripting language, is developed.



To ease the applying of the language in Web 2.0 era, we developed a web-based PBL authoring tool to provide a rich and intuitive representation for helping design any kind of PBL scripts of any kind of models. Our former pilot study (Miao et al., 2013) has shown that the difficulties to design and delivery pedagogically high-quality, human readable, reusable, sharable and computer-executable, online or blended PBL process are reduced as intended. Our tool has been implemented based on the premise that there are two common dimensions of semi-structured characteristics inside PBL scripts. One is from the point of view of the scripts; the other is from the point of view of a single node/connection inside scripts. From the first dimension, if we see a script document tree from root to leaf, the sibling nodes and relations are the definitions of its upper level parent node. That is, nodes (connections) are used to define node; if we only focus on one sibling level, horizontally it is just about the definition of the relations among the sibling nodes. The sibling nodes do not define each other. So by iteratively doing these two things, any PBL script can be defined, regardless how complicated an organization or a learning process is. From the second dimension, we use JSON as a unified data process and storage format. Since JSON format is designed to represent semi-structured data, the uncertainty of node's or connection's structure can be processed. In order to effectively implement these two dimensions of design as a web-based application, we use JavaScript to program both client side and server side. In case of storing and retrieving the JSON data, we use MongoDB as database, so that all the semi-structured characteristics of the two dimensions can be effectively handled. At last we also discussed some other related work. In term of user interface and data management, other work more or less has their drawbacks. Therefore we conclude that a combined use of semi-structured data management and a unified data format appears to be a promising approach to effectively and efficiently support the representation and management of PBL scripts.

This paper illustrates an approach to design and implement a web based authoring tool to help teachers represent and manage their PBL mental scripts as graphical scripts. And then the graphical scripts can be transformed into textual scripts or learning systems executable scripts. Our future work includes two directions: one is to make these transformation steps automatically. That is, extract process directly from existing semi-structured textual scripts, and then store them in system, represent them by our graphical user interface and transform them to other learning systems; the other is to develop our own specific PBL run-time learning environment, so that we can provide an integrated way to test and run the PBL scripts for both teachers and learners.

## Acknowledgement

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# Algorithmic Thinking Learning Support System in Block Programming Paradigm

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**Abstract:** The goal of this study is to develop a learning support system for algorithmic thinking for novices. This paper describes some educational functions of this system. The main features of this system are 1) the teacher can control the usage of control elements for developing algorithms based on his educational philosophy, 2) a simple task-answer management system is included and 3) eAssessment functions based on the Student-Problem table method are implemented.

**Keywords:** Algorithmic thinking, education for beginners, student-problem score table analysis, problem reviewing.

## 1. Introduction

An algorithm is defined as “... a set of rules that precisely defines a sequence of operations such that each rule is effective and definite and such that the sequence terminates in a finite time”[Stone 1972, Knuth 1980]. As such, until recently, algorithms have been taught in programming courses. However, since about five years ago, algorithms have been taught before programming. There have been many papers on this kind of algorithm and/or algorithmic thinking education, e.g., Sarawagi 2010, Hubalovsky 2010, Futschek 2011.

We have proposed an educational method for algorithmic thinking in fundamental education for computer science course students in 2008[Fuwa 2009] and examined the effectiveness of our algorithmic thinking learning support system. We designed our system based on discovery learning[Bruner 1960] and guided discovery[Cook 1991]. This system uses only three flow structure elements: calculation, selection and repetition. Students describe the algorithm using these three elements.

“What kinds of problems are suitable for assessing the students’ ability and evaluating achievement level?” This is our research question. To review some typical exercise questions, we introduce the Student-Problem (SP) Score Table Analysis method. This paper describes educational functions in our algorithmic thinking system and our eAssessment function.

## 2. Brief Description of Our Learning System

### 2.1 Educational Features

We have developed a web based learning system for basic algorithmic thinking education[Kayama 2014a]. This system has the following pedagogical features:

1. The algorithm is represented not by a flow chart, but by columns of blocks such as stacks that grow downward.
2. Input errors can be reduced.
3. The rules to describe the algorithm can be increased in pedagogical stages.

Feature 1 makes learners concentrate on block combinations without thinking about notation. Each block corresponds to all the elements for constructing the algorithm. Learners can insert, move or delete the blocks with their mouse.

To realize feature 2, the variables only need to be typed once. After that, they can be selected from a list. Only operations that are allowed can be selected from a list.

Feature 3 allows control of the blocks visible in proportion to the learner's learning progress. This makes learners think about the algorithm in a situation with limited available blocks. On the other hand the blocks that have not been learned are invisible, which helps learners think about the algorithm without stress.

## 2.2 Learning Support Functions

### 2.2.1 Overview

The system with the features explained in the previous subsection was developed using the Web2pf framework. The combination of some elements represents the structure of the algorithm. Each process is described with a combination of comment statements and a selection of items.

Fig.1 shows an example screen shot of our algorithm editor for learners. In this system, a user chooses an element for use in the algorithm by double clicking on the editor area. A learner constructs an algorithm with blocks which were chosen. Executable parts are connected to the “start” block (upper left area in Fig.1). The sets of blocks that are not used can also be put in this editor area. They are shown in gray. A learner can watch the change in the variable values that he/she uses in his/her algorithm. Moreover, some output data can also be watched in this editor.

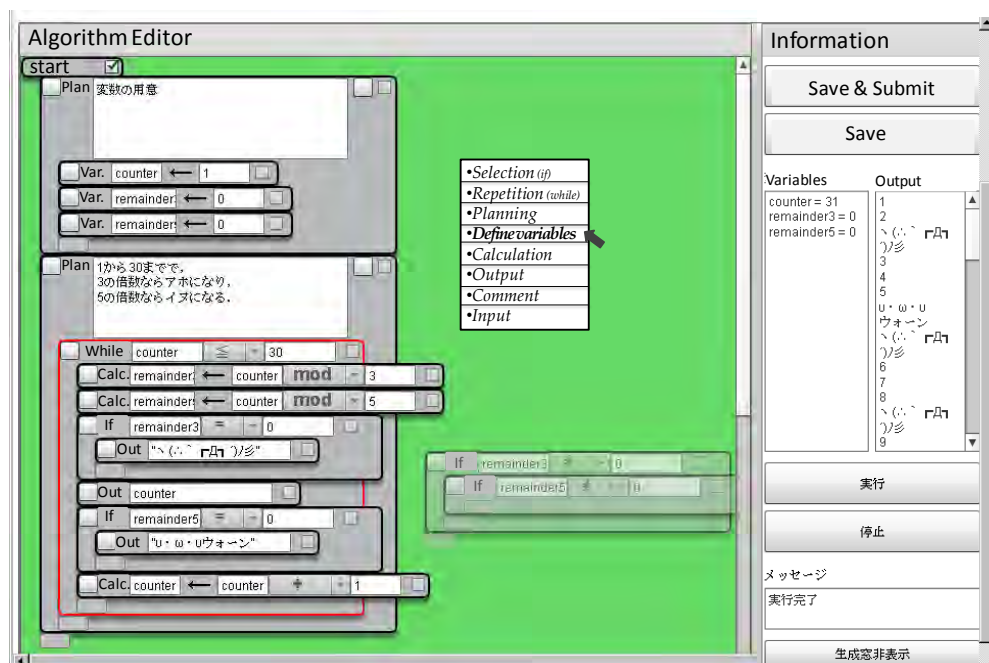


Figure 1. The algorithm editor of our tool.

There are two kinds of blocks, structural blocks and commentary blocks. The structural blocks are calculation, variable declaration, selection, repetition and break. The selection block and repetition block can be nested in other blocks. The commentary blocks are planning and comment. The planning block can be nested in other blocks including structural blocks.

Fig.2 shows the window where rules can be defined for describing the algorithm and the selectable items for the learners. A teacher can define the description rules for each algorithm question. He/she only needs to click the check boxes shown in Fig.2, and then saves this rule with a name. When he/she submits a question, one description rule can be attached.

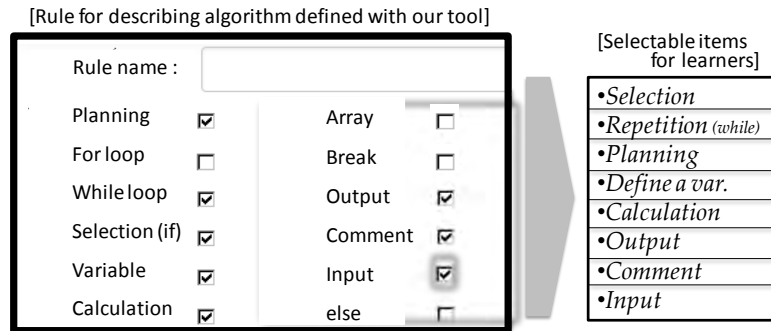


Figure 2. Definition of the rule for describing the algorithm.

The teacher usually plans the learning steps for his students. As an example, suppose that the first step is a calculation by assignment and/or arithmetic operations with abstract numbers and/or variables, the second step is a conditional test with relational operations and the third step is an iteration with termination conditions. Corresponding to these steps, the algorithm description rules can be defined. Fig.3 shows this set of learning steps and the description rules.

### 2.2.2 Element Usage of Control

Each teacher has his/ her own policy to teach algorithmic thinking. Each policy has to be appreciated because a teacher has a responsibility for his/her course. Therefore, by using our system, teachers can control which elements are visible according to the class rules. Different algorithm building elements are attached to the three steps in Fig.3. The rule set can be independently managed for each step. A teacher can set this rule before his/her lesson. This rule can be changed during the lesson.

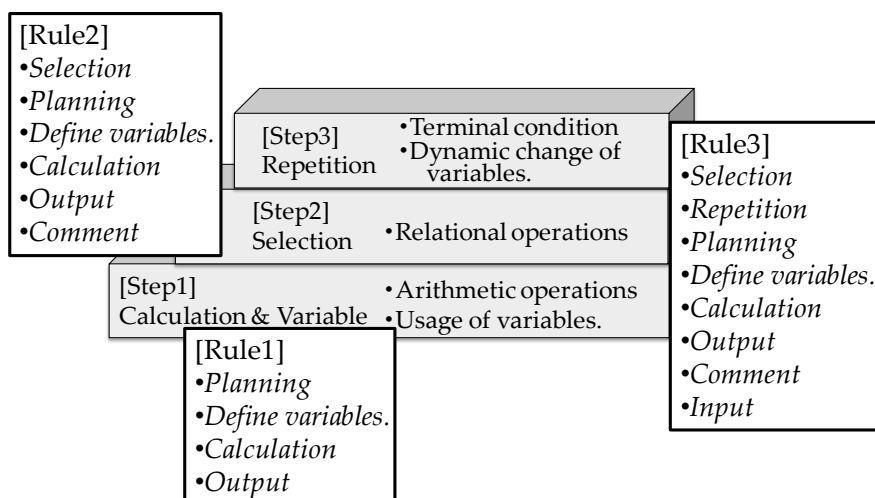


Figure 3. The learning steps and the algorithm description rules.

Moreover, a teacher can define which activities are permitted for constructing algorithms, i.e., permit to submit, save, execute, edit, syntax check, show program code, log operation history or not. In our system, these things are defined as controllable elements. By using this function, the teacher can define an algorithm reading task (not permit learners to edit and run), an algorithm reading and running task (not permit learners to run) and a scaffolding task (give a template algorithm using planning blocks with teacher's comments).

Teachers can also decide whether the trace function is available and its interval. Teachers can make the trace function available to debug the algorithm or to make it unavailable to make learners think about tasks and learning progress. If a teacher gives permission to use this function, learners can trace the execution of the algorithm and specify a variable when tracing. The right area in Fig.1 shows a variable trace area and the result of algorithm tracing (output area).

### 2.2.3 *Template for each Task*

This allows learners to see a part of the algorithm or the whole algorithm on their monitor. Therefore, combining this function with the learning activity control function, learners use this system to dissect the algorithm, finish incomplete parts of the algorithm, select a suitable algorithm from some choices, and describe the algorithm from scratch.

### 2.2.4 *Simple Task-Answer Management System*

#### *a) State management of learners' reports*

This system helps teachers and learners manage the report status for each learner and each task. For instance, saved but not submitted, submitted, rejected, accepted, unevaluated or evaluated. Students' answers are divided into two columns: unevaluated and evaluated. In the evaluated answers, a grade for each answer is shown.

#### *b) Semi auto test for the submitted answers*

If a teacher defines the test rules for a problem, our system tests students' answers automatically. There are three types of test results: 1) normal exit and the algorithm outputs the expected results (OK), 2) normal exit but the algorithm does not output the expected results (NG), 3) grammatical error or abnormal exit or time out (??).

### 2.2.5 *eAssessment functions based on Student-Problem Score Table Analysis*

The student-problem (SP) score table analysis is an educational analysis method based on students' responses, i.e. test score patterns [Sato 1974, Harnisch 1981]. The SP score table is a two-dimensional table where rows are student numbers and columns are problem (i.e., test question) numbers. In the table, if a particular student answers a particular problem correctly, the cell is filled with a 1. Otherwise, the cell is filled with a 0. This table is sorted by column and by row in decreasing order of occurrence of 1s. The students are sorted by their total score. If some students have the same score, they are ordered based on the sum of the number of correct answers to the problem which they answered correctly.

As a consequence, the upper-left triangular region is filled with nearly all 1s. Ideally, students with higher scores should solve those problems which are answered correctly by most students. Similarly, if a problem is solved by most of the students, a good student is able to solve the problem.

## **3. eAssessment with Our Tool**

### *3.1 S Line and P Line*

In an SP score table, there are two types of lines named the S line and the P line.

The S line is defined based on the scores of all students. Starting from the top student of the table, for each student, a short vertical line is drawn on the right of the score for the problem column which is the same as the student's score. The S line shows the frequency distribution of the students' scores. Ideally, there should only be 1s on the left side on this line and 0s on the right side. Teachers can capture the status of the achievement of each student.

The P line is defined based on the score of all problems. From the highest score problem, for each problem, a horizontal line is drawn below the score for the student row which is the same as the number of correct answers for the problem. This line shows the frequency distribution of the problems' score. Ideally, only 1s should be above this line and 0s below it. Teachers can capture the suitability of each problem or the effect of his/her instruction.

These two lines are ideally located close together in the table. The difference between the S line and the P line shows some pedagogical agenda to be solved.

1. The suitability of problems for this learner group.
2. The effectiveness of the teacher's instruction for this learner group.
3. The achievement level of each student.
4. The variation in learning abilities of the learners.

### 3.2 Caution Indices

This method includes two index types: a caution index for students ( $C_s$ ) and a caution index for problems ( $C_p$ ).

#### 3.2.1 Caution Index for Student

By using the  $C_s$  index, we can easily detect the students who need attention. Theoretically, the threshold value is 0.5. If there are students whose values are under 0.5, they show abnormal response patterns for the problems, i.e., careless mistakes by high achieving learners and lucky guesses by low achieving learners. Moreover, teachers can diagnose students who cannot use the learning environment, especially the description method.

The combination of the  $C_s$  index and the percentage of questions answered correctly expresses the achievement level of students. We call this graph the Student Score Graph. Fig.4(a) shows our interpretation of the Student Score Graph. The vertical axis is the number of problems answered correctly (Num. for short) and the horizontal axis is the  $C_s$  index. This graph is separated into 4 sections by the vertical axis (Num.) threshold value of 50% of total problems and the horizontal axis ( $C_s$ ) threshold value of 0.5. The left part of this graph is when the  $C_s$  index is less than 0.5. The students in this area seem to have normal reactions to the problems. If a student is in the upper left section (Num. $\geq$ 50%), he/she is a “good” student. The lower left section (Num. $<$ 50%) is a “developing” student who needs more practice.

The right part is when the  $C_s$  index is more than 0.5. The students in this area seem to have abnormal reactions to the problems. Students in the upper right section, where Num. is high, tend to make careless mistakes for fundamental problems or to not fully acquire the related knowledge. When Num. is low and the  $C_s$  index is high, the comprehension of the students is quite uncertain. Students in the lower right section tend to have unstable answers. Therefore, they require special attention from the teacher. In our research, the  $C_s$  index has been used to identify students who need attention in each lesson.

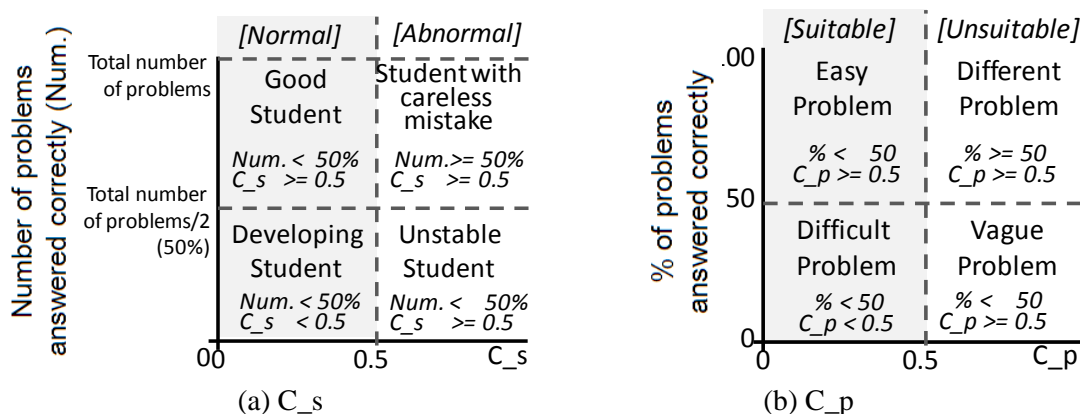


Figure 4. The relation of the Caution Indices and the number/percentage of the problems answered correctly

The right graph in Fig.5 is an example of the Student Score Graph. The radius of each circle represents the number of students located at that position. The center position of each circle shows the score combination. The five students mentioned above are located in the lower right section. The teacher may give these students particular attention.

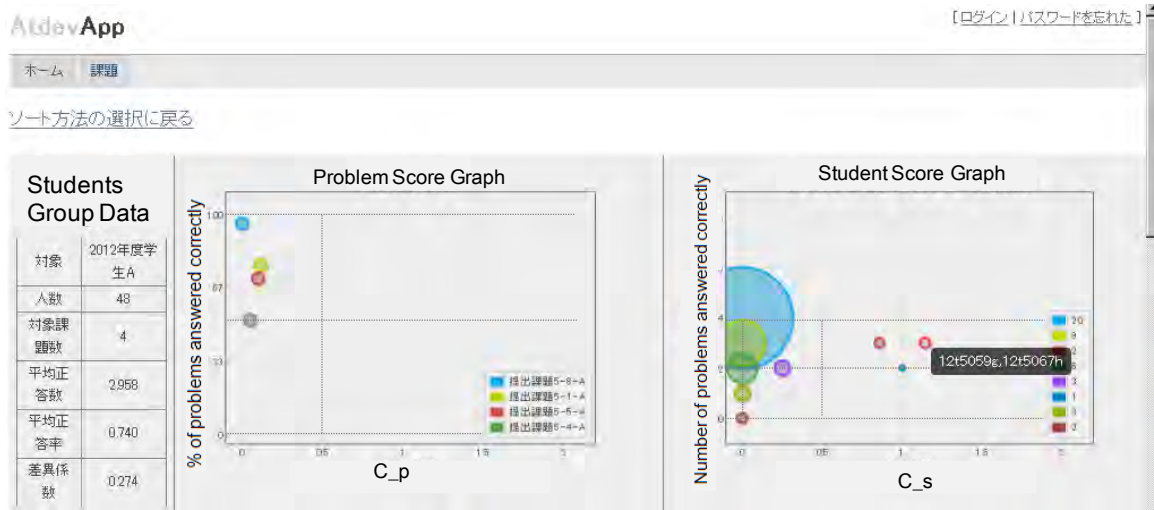


Figure 5. Problem score graph and Student score graph generated by proposed our tool.

### 3.2.2 Caution Index for problem

By using the  $C_p$  index, teachers can analyze the quality of a problem. We can detect inadequate questions which may include vague instructions or ill-structured tasks. Theoretically, the threshold value is 0.5. If  $C_p < 0.5$ , teachers can modify or delete defective problems, and fit good ones into an item bank for future use. In Fig.5, there are no problems that need to be improved because their  $C_p$  indices are all under 0.5.

The combination of the  $C_p$  index and the percentage of problems answered correctly expresses the appropriateness of the problem to evaluate the students' abilities. We call this graph the Problem Score Graph. Fig.4(b) shows our interpretation of the problem score graph. The vertical axis is the percentage of problems answered correctly (% in short) and the horizontal axis is the  $C_p$  index. This graph is separated into 4 sections by a % threshold value of 50% and a  $C_p$  threshold value of 0.5.

The left part of this graph is when the  $C_p$  index is less than 0.5. This means the problems in this area are "suitable" to evaluate students' abilities. If a problem is in the upper left section ( $\% \geq 50$ ), it is an "easy" problem. A problem in the lower left section ( $\% < 50$ ) is a "difficult" problem which good students tend to answer incorrectly. The right part is when the  $C_p$  index is more than 0.5. This means the problems in this area are "unsuitable" problems to evaluate students' abilities. If a problem is in the upper right section, however, the % is high, so this problem includes some "different" factor to evaluate target abilities. A problem in the lower right section is a "vague" problem. The % is low and the  $C_p$  index is high. This means the problem includes ambiguity factors in its description. For example, the problem statement is difficult to read, or the way of answering the problem is not suitable for the learning environment. The  $C_p$  index has been used for evaluating the quality of each problem for each school year. The left graph in Fig.5 is a Problem Score Graph..

### 3.3 Practical Usage

We have been using this method to assess the problems in our course [Kayama 2014b]. In 2011, we made six groups of problems.

(A) Algorithm creation with guidance. A learner is given some variables with their initial values which can be used to create the algorithm, and guidance for creating the algorithm. He has to add appropriate blocks based on the given guidance.

(B) Algorithm creation from scratch. A learner has to add appropriate blocks without guidance. He is only given some variables with their initial values. If he does not want to use the given variables, he can define other variables.

(C) Algorithm creation by filling in blanks and adding explanations. A learner is given an incomplete algorithm with some blanks. He has to try to read the intention of the algorithm with the given blocks. After that, he adds some appropriate blocks to create the complete algorithm (C1). Then he is asked to explain the procedure by adding blocks (C2).

(D) Addition of the explanation for the procedures in the algorithm. A learner is given a complete algorithm with some "Plan" blocks. He is asked to explain each procedure in the blocks.

(E) Addition of the explanation for whole algorithm and the block sets in the algorithm. A learner is given a complete algorithm with some "Plan" blocks as in (D). He is asked to explain the whole algorithm (E1) and each procedure in the blocks (E2).



(F) Addition of the estimated value for the output and explanations of the block sets in the algorithm. A learner is given a complete algorithm with some “Plan” blocks as in (D) and (E). He is asked to explain the estimated value for the output (F1), and each procedure in the blocks (F2).

(A) and (B) are algorithm creation problems. On the other hand, (D), (E) and (F) are algorithm reading problems. Only (C) is categorized as both.

In each problem group, there is one calculation problem, two selection problems, two repetition problems and one combination problem, for a total of six problem types.

Therefore, we prepared 36 problems to analyze the appropriateness of the problems to evaluate the learners' abilities in algorithm creation and reading.

The subjects were 96 freshmen, who had finished our “algorithmic thinking” course. These students were divided into 6 groups. Each group was assigned six problems, one from each problem group and problem type. They had to answer all the problems in 90 minutes.

Table 1 shows the analysis result using our tool. In this table, each cell is marked in one of three categories: blank, difficult and different. Blank indicates that the problem is in the “Easy Problem” area in Fig.5(b). Difficult indicates that the problem is in the “Difficult Problem” area. Different indicates that the problem is in the “Different Problem” area. There are no “Vague Problems” in this test.

As for the algorithm reading problems, the “Different Problems” tend to be “explain the procedure” group problems (especially D, E2 and F2). As for the algorithm creation problems, (C1) asks students to fill in blanks in a given algorithm. This problem is the most difficult of the 6 problem groups. The percentage of students who answered this problem correctly shows a statistically significant difference between (B), which asks students to create an algorithm from scratch and (F), which asks students to estimate the output value from a given algorithm.

Table 1: The problem assessment with the SP score table analysis in 2011.

|                             |  | Calculation | Selection1 | Selection2 | Repetition1 | Repetition2 | Combination |
|-----------------------------|--|-------------|------------|------------|-------------|-------------|-------------|
| Algorithm Creation Problems | (A) Creation with guidance                         |             |            |            | Different   |             |             |
|                             | (B) Creation from scratch                          |             | Difficult  |            |             |             |             |
|                             | (C1) Creation by filling in blanks                 |             | Difficult  |            | Difficult   |             | Difficult   |
| Algorithm Reading Problems  | (C2) Addition of the explanations                  |             |            |            |             | Difficult   | Difficult   |
|                             | (D) Explaining the procedure in blocks             |             |            | Different  |             |             |             |
|                             | (E1) Explaining the whole algorithm                |             |            |            |             |             |             |
|                             | (E2) Explaining the procedure in blocks            | Different   |            |            | Different   |             |             |
|                             | (F1) Explaining the estimated value for the output |             |            |            | Different   |             | Difficult   |
|                             | (F2) Explaining the procedure in blocks            |             | Different  |            |             | Difficult   | Difficult   |

Based on these facts, we chose two groups of questions: (B), which is algorithm creation from scratch, and (F1), which is the estimated value of the output, to evaluate the students' abilities.

About the problem types, this table shows that the Selection1 problem type is more difficult than the Repetition1 type. Moreover, we found that students who can solve Selection1 can get a higher score in the repetition problems. Repetition1 has “Different” marked in 3 problem groups. This result shows that Repetition1 in this test is not a suitable problem type to evaluate students' abilities.

In 2012, we introduced two of the groups of problems mentioned above. For each problem group, we prepared eight types of problems. The subjects were 95 freshmen who had finished our “algorithmic thinking” course. These students were divided into two groups. Each group was assigned eight problems (four algorithm reading problems, and four algorithm creation problems), one from each problem type. They had to answer all problems in 90 minutes.

The relationship between the C\_p index and the percentage of problems answered correctly is shown in Fig.6(a) (algorithm creation problems) and Fig.6(b) (algorithm reading problems). The suitability of the problems was confirmed for all problems. They are located in the “Suitable” area. Though some problems are “Difficult Problems” for this group, overall these problems are suitable to evaluate our students' abilities.

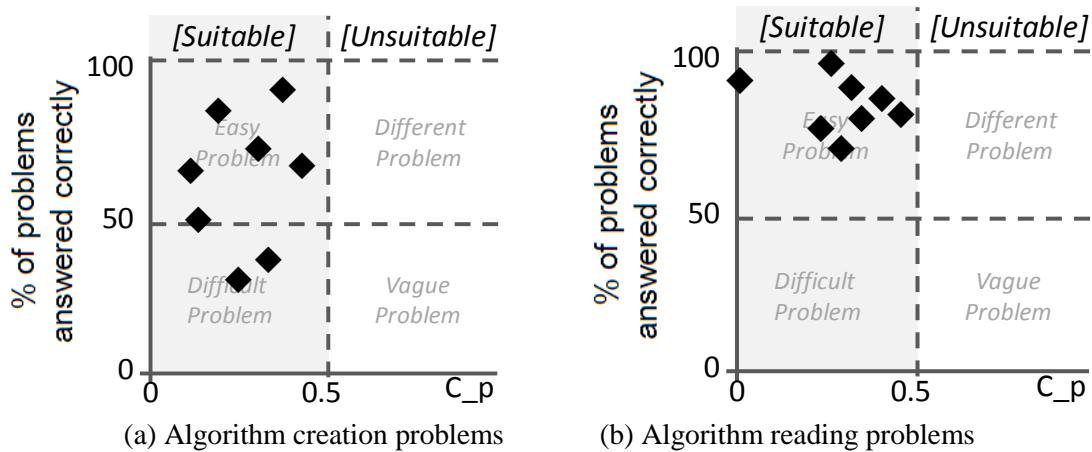


Figure 6. The relation of the C\_p index and the percentage of problems answered correctly for 2012 problems.

#### 4. Conclusion

In this paper, we described the pedagogical features and main functions of a learning support system for algorithmic thinking education. We have used this system since 2008 in our computer science course. The ability to control the usage of algorithmic elements such as input, output, selection or repetition is a unique function that no other system has had before. Teachers can define the element usage rule depending on the learning progress of their learners and their educational philosophy.

Moreover we show our eAssessment function based on the SP score table analysis. By using this function, we have reviewed the problems used in our course. As a result, the pedagogical quality of the problems has improved. In the future, we will pedagogically analyze and design learning scenarios with this supporting system.

#### Acknowledgements

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# Learning by Posing Problems Using Illustrations Instead of Words

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**Abstract:** Learning by posing arithmetic word problems is well-recognized as an effective means to mastering the use of solution methods; however, several learners cannot pose problems using words. In problem-solving exercises, if a learner cannot understand what is expressed in a problem statement, an illustration of the scene expressed in the statement can help the learner understand. Therefore, in this paper, we propose learning by posing problems with illustrations instead of words. One of the purposes of learning mathematics is to acquire the ability to derive a numerical relation from a scene and to associate a calculation expression with various scenes. We expect that posing problems via illustration and without words is an effective way for beginners to learn. In the problem-posing exercises, learners construct various types of problems. Teachers have to evaluate each posed problem and advise learners on the basis of the evaluations. This task places a heavy burden on teachers. Therefore, we developed a computer-based environment for posing problems using illustrations. The environment provides a learner with a calculation expression and illustrations. The illustrations can be disassembled into several figures. A learner assembles an illustration that describes a story of arithmetic problem that correspond to the calculation expression by combining the figures. The learner uses no sentences in this problem-posing exercise. The environment diagnoses the illustration problem and produces advice to the learner. We conducted a preliminary evaluation of the environment to confirm that a learner who cannot pose problems via words was able to pose problems using illustrations. Our results were promising, indicating that our environment provides a means for learners who cannot pose problems via words.

**Keywords:** Problem-posing, interactive learning environment, visualization, arithmetic problem

## 1. Introduction

In this paper, we describe a computer-based environment for learning by posing problems expressed using illustrations for learners who cannot describe problems using words.

Learning by posing arithmetic word problems is well-recognized as an effective way to master the use of solution methods (Polya, G., 1945) (Ellerton, N. F., 1986) (Yu, F., Liu, Y. H., and Chan, T. W., 2003); however, it can be difficult to provide problem-posing exercises wherein learners construct various types of word problems. Because it is difficult to prepare adequate feedback for every problem that learners construct, teachers are required to evaluate each posed problem and advise learners on the basis of the evaluations, which places a heavy burden on teachers.

Given these circumstances, a computer-based learning environment called MONSAKUN was developed for interactive problem posing using arithmetic word problems (Hirashima, Yokoyama, Okamoto, and Takeuchi, 2007) (Hirashima and Kurayama, 2011). MONSAKUN provides learners with disassembled sentences and calculation expressions. The learner is required to pose a problem that is solvable by the calculation expression by selecting some of the sentences and sorting them into their proper order. MONSAKUN diagnoses the combination of the sentences and presents advice to the learner; however, there are several learners who cannot pose problems from the disassembled sentences in MONSAKUN.

In problem-solving exercises, if a learner cannot understand what is expressed in a problem statement, an illustration of the scene expressed in the statement can help the learner understand.

Therefore, in this paper, we propose learning by posing a problem expressed by illustrations instead of words. First, a calculation expression is presented to a learner. Next, the learner poses a problem by creating an illustration that describes a story of increasing, decreasing, or combining illustrated elements that match the calculation expression. The learner uses no sentences in this problem-posing exercise.

One of the purposes of learning mathematics is to acquire the ability to derive a numerical relation from a scene and to associate a calculation expression with various scenes. We expect that posing problems via illustration and without words is an effective way for beginners to learn.

We developed a computer-based environment for posing such illustration problems. This environment provides learners with components of the illustration and a calculation expression. As noted above, the learner assembles a scene that describes a story of increasing, decreasing, or combining elements that correspond to the calculation expression. The illustration is assembled by combining its components. The environment diagnoses the illustration problem and produces advice to the learner. In this paper, we introduce our learning environment and present results of a preliminary evaluation of the environment.

## **2. Related Work**

Arithmetic textbooks in elementary school are replete with illustrations to help learners understand. The visualization approach has generated new enthusiasm for mathematics and has improved problem-solving performance (Moses, 1982). Learning by posing problems using illustrations is based on this viewpoint. We expect posing illustration problem as being a more effective means for learners who cannot describe problems by words.

Joya's "fraction block" (Joya, Maeda, and Hirashima, 2013) is similar to our research wherein a learner creates an illustration that describes a numerical relationship. The fraction block reifies characteristics of "ratio fraction" as a pair of numerator and denominator blocks. The block length can be varied by maintaining the same ratio of numerator blocks to denominator blocks. Joya developed a learning environment wherein learners can directly operate these fraction blocks to derive one quantity from another.

Although both Joya's and our environment use illustrations, there is a difference in purpose. The fraction block is a kind of graph. Hanagata (1990) stated that graphs and diagrams help learners understand quantitative relations and solution methods for a variety of problems; however, Hanagata also noted that graphs and diagrams rarely help to understand what is expressed in problem statements in the early stages of mathematical development. A beginner cannot associate abstract figures on the basis of the solution method such as the fraction block with a problem sentence if the beginner is unaccustomed to the abstract figures.

Hanagata suggested that an illustration of the scene expressed in the statement helps learners understand what is expressed more than graphs and diagrams in the early stages of learning, because the learners can directly associate the illustration with a scene in their life. The purpose of our research is to support learners who cannot pose problems in the form of sentences, therefore we do not use graphs and diagrams, but rather than illustrations of the given scenes.

## **3. Learning by Posing Illustration Problems**

In this section, we describe learning by posing problems using illustrations instead of words. First, we describe a structure of problems in our learning environment. Next, we describe how to pose a problem using illustrations in our system.

### 3.1 Structure of Problem

Our research focuses on problems that are solved by either one addition or subtraction operation. Addition and subtraction operations can be classified into increase-change, decrease-change, combine, and compare (Riley, Greeno, and Heller, 1983). Our learning environment can diagnose increase-change, decrease-change, and combine operations. Increase-change and combine problems are solved via addition formula  $A + B = C$ . Decrease-change problems are solved via subtraction formula  $A - B = C$ .

The structure of problems in our learning environment is based on MONSAKUN, which is a learning environment for problem posing by words. Yamamoto, Kanabe, Yoshida, Maeda, and Hirashima (2012) explained the structure of problems in MONSAKUN. In MONSAKUN, a problem comprises three sentences. Two of the three sentences are “existence sentences,” which express a number of objects. The third sentence is a “relation sentence,” which expresses a numerical relation between the objects in the two existence sentences. For example, the following sentence is an increase-change problem: “Tom has three pencils. Tom buys two pencils. Then, Tom has five pencils.” The first and third sentences are existence sentences, whereas the second sentence is a relation sentence. The numerical relation in the problem is  $3 + 2 = 5$ .

Much like MONSAKUN, a problem in our system comprises three illustrations. Two of the three illustrations express a number of objects, and the third expresses a numerical relation between the objects.

Our learning environment provides three kinds of objects for existence illustrations, namely: food, money, and people. A person can have food and money. The environment also provides several places wherein people exist. For example, a learner can assemble existence illustrations corresponding to the following sentences: “Taro has three apples”; “Taro has five dollars”; and “Three people are in the sandbox.” Figure 1 shows an example of an existence illustration.



Figure 1. Example of an existence illustration

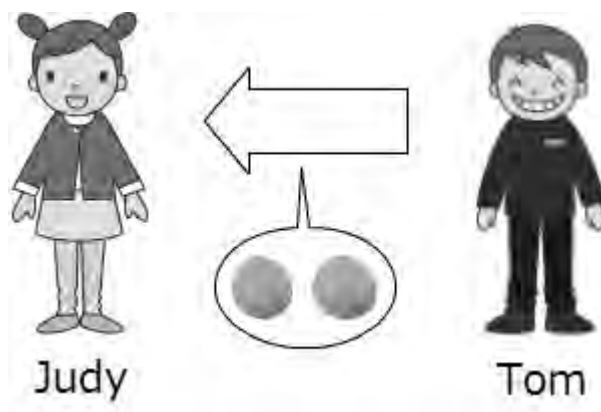


Figure 2. Example of a relation illustration

In our environment, a learner can express “give/get,” “buy/sell,” “move” and “combine” via relation illustrations. The actions “give,” “get,” “buy,” “sell,” and “move” are illustrated using an

arrow, as shown in Figure 2. “Give” and “get” are expressed by the same figure, depending only on the different subjects at each arrow endpoint, as are “buy” and “sell.” More specifically, “give/get” is a movement of food and is illustrated by an arrow annotated with food between two people. “Buy/sell” is illustrated by an arrow with money and food between a person and a store. “Move” is a movement of people and is illustrated by an arrow with people between places. We do not provide an illustration for “combine”; however, a learner can assemble a “combine” illustration by combining two existence illustrations. Figure 2 shows an example of a relation illustration in which Tom gives Judy two oranges.

If a problem includes a relation of “give/get,” “buy/sell,” or “move”, there is a temporal ordering between the three illustrations. One illustration is anterior to the increase or decrease. The other is posterior to the increase or decrease. In the case of word problems, existence sentences are arranged in a temporal order. For example, in the following word problem, Taro had three pencils before buying and therefore has five pencils after the buying: “Taro has three pencils. Taro buys two pencils. Taro has five pencils.”

In posing illustrations, we provide morning, noon, and evening illustrations to express temporal order. If a learner wants to pose an increase/decrease problem, the problem is composed of an existence illustration in the morning, a relation illustration at noon, and an existence illustration in the evening.

### 3.2 Interface for Posing Illustration Problems

In this subsection, we describe how to pose a problem using illustrations in our system. Figure 3 shows an interface of our learning environment. First, the environment provides a learner with a calculation expression (upper left portion of Figure 3) and illustrations (right portion of Figure 3). The illustrations can be disassembled into several figures. A learner assembles an illustration problem that corresponds to the calculation expression by combining the figures. The lower left portion of Figure 3 shows the illustration problem in the process of assembly.

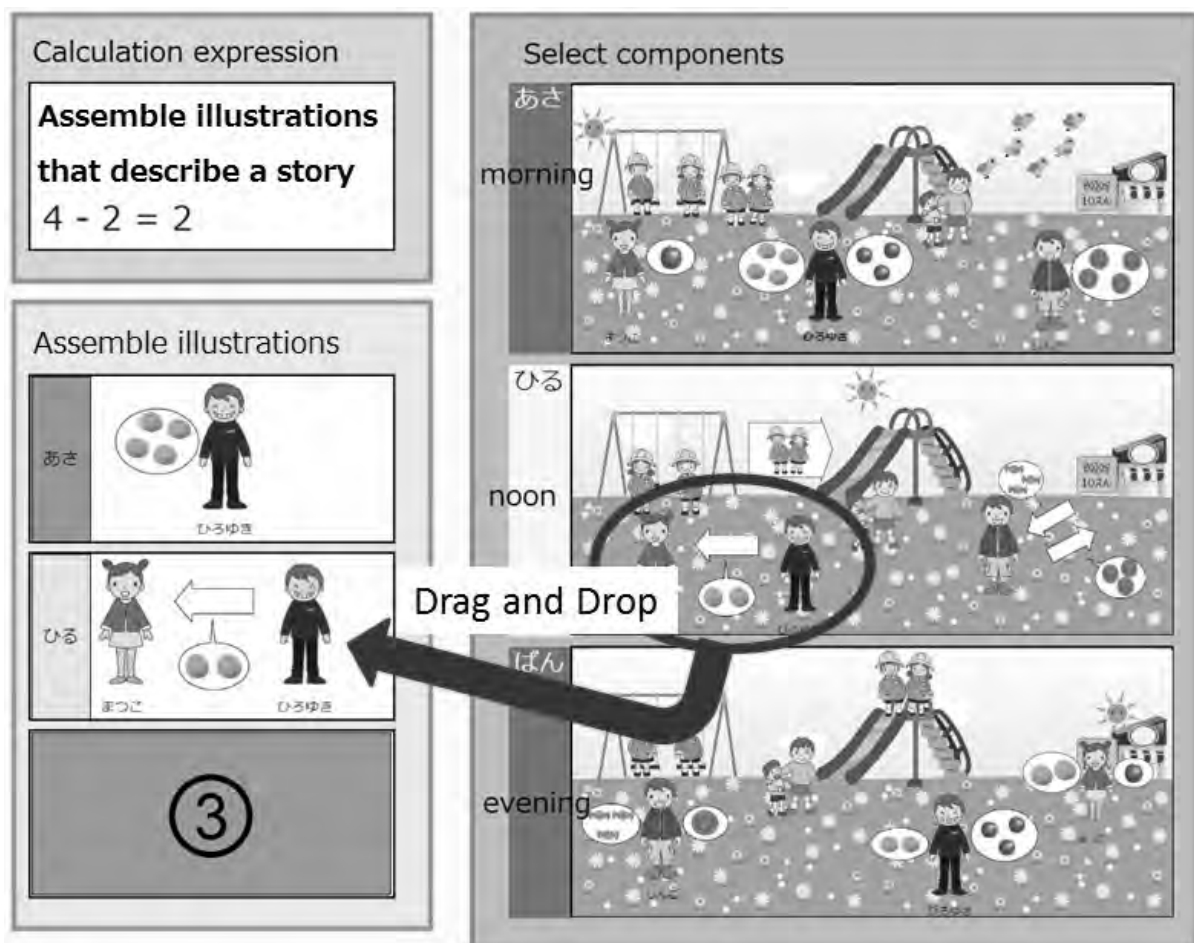


Figure 3. Interface for posing illustration problems

The illustrations provided comprise all types of illustration problems: “give/get,” “buy/sell,” “move,” and various combine problems. A learner selects one illustration problem that corresponds to the calculation expression from the provided illustrations. The system provides the illustrations by combining various existence illustrations and “give/get,” “buy/sell,” and “move” relation illustrations so as not to logically contradict. If a problem includes an increase or decrease relation, there is a temporal order as noted above. Therefore, the provided illustrations are composed of morning, noon, and evening illustrations. The system combines various existence and relation illustration based on the temporal order.

In the illustrations provided in the right portion of Figure 3, there are 20 illustration problems: three increase-change problems, three decrease-change problems, 14 combine problems. Two of the 20 illustration problems corresponds to “ $4 - 2$ .” The illustration in the morning in the upper portion of Figure 3 comprises six existence illustrations: “Four people are by the swing”; “Two people are by the slide”; “Matsuko has an apple”; “Hiroyuki has four oranges”; “Hiroyuki has three apples”; and “Shingo has 40 yen.” The illustration at noon in the middle portion of Figure 3 comprises four relation illustrations: “Two people move from the swing to the slider”; “Matsuko gets two oranges from Hiroyuki (Hiroyuki gives two oranges to Matsuko)”; “Shingo buys three candies from the shop (The shop sells three candies to Shingo)”; and “Shingo buys the candies for 30 yen from the shop (The shop sells the candies for 30 yen to Shingo).” The illustration in the evening in the lower portion of Figure 3 comprises eight existence illustrations: “Two people are by the swing”; “Four people are by the slider”; “Shingo has three candies”; “Shingo has 10 yen”; “Hiroyuki has two oranges”; “Hiroyuki has three apples”; “Matsuko has two oranges”; and “Matsuko has an apple.” As noted above, there is no “combine” relation illustration in Figure 3, because a learner can assemble a “combine” illustration by combining two existence illustrations.

Each existence and relation illustration can be moved by drag-and-drop freely in the interface. A learner selects two existence illustrations and one relation illustration and then moves them into the blanks in the lower left portion of the interface (see Figure 3) to pose a problem. Time information is also moved into the blanks using the drag-and-drop. Note that there are three blanks because a problem comprises two existence illustrations and one relation illustration. If a learner wants to express a combine relation, the learner moves two existence illustrations into the same blank, means calculating a total number of objects in the two existence illustrations.

Next, our environment diagnoses the illustration problem and outputs whether it is correct. If incorrect, the reason or reasons why is displayed. The problem sentence represented by the illustration problem is also displayed. This problem sentence helps a learner understand the meaning of the assembled illustrations and see how to describe a problem.

If an illustration problem includes a figure consisting of an arrow with food, the system outputs two problem sentences. Because the arrow with food is translated into “give” and “get,” the system describes the problem in two ways (i.e., the “give” relation and the “get” relation). Similarly when a figure consists of an arrow with money and food, the system outputs both “buy” and “sell” sentences. In short, the illustration problem can be transformed into two problem sentences, and the two problem sentences correspond to the same calculation expression.

## 4. Implementation

In this section, we describe how our system diagnoses an illustration problem. First, we describe information comprising illustrations for the diagnosis. Next, we describe how to diagnose a problem with the information in our system.

### 4.1 Illustration Information

An existence illustration contains the following information: the type of illustration, the corresponding verb, the object name, the number of objects, the owner or place, and the temporal order. The type of illustration is used to distinguish between existence and relation. The verb is used to translate the illustration into a problem sentence. Figure 4 shows an example of this set of information.



Type of illustration: existence  
Verb: has  
Object name: apple  
Number of objects: 2  
Owner: Tom  
Temporal order: morning

Figure 4. The Example of information comprising an existence illustration

An increase/decrease relation illustration contains the following information: the type of illustration, the corresponding verb, the increased/decreased object name, the increase/decrease number, the owner whose objects are increased, the owner whose objects are decreased, and the temporal order. Figure 5 shows an example of this set of information. There is no information for the combine relation, because we do not provide illustrations for combining.

Type of illustration: relation  
Verb: give/get  
Increased/decreased object: apple  
Increase/decrease number: 2  
Owner whose objects are increased: Taro  
Owner whose objects are decreased: Judy  
Temporal order: noon

Figure 5. The Example of information comprising a relation illustration

#### 4.2 *Diagnosis of a Posed Illustration*

Our environment first checks whether the illustration problem is composed of two existence illustrations and one relation illustration. Otherwise, the system displays “It is not an arithmetic problem. A calculation expression is not formed. The first (or second/third) illustration is incorrect.”

If the relation illustration is an increase/decrease relation, the environment checks that the object names in the three illustrations are the same. Otherwise, the system displays “There is no relation between <object name A> and <object name B>.” Furthermore, the environment checks that the temporal order in one existence illustration is morning, the other existence illustration has a temporal order of evening, and the temporal order in the relation illustration is noon. Otherwise, the system displays “An illustration before (or after) the giving (or buying/moving) is required. Select an illustration in the morning (or evening).” Next, the environment checks that the owner of objects in one existence illustration is the same as the owner whose objects are increased, and the owner of objects in the other existence illustration is the same as the owner whose objects are decreased. Otherwise, the system displays “There is no relation between <owner A> and <owner B>.”

Finally, the environment derives a calculation expression from the illustrations and ensures the derived calculation expression matches the provided calculation expression. If the owner of objects in the morning illustration is the same as the owner whose objects are increased, the calculation expression is “number of objects in the morning illustration” + “increase number in the relation illustration” = “number of objects in the evening illustration.” Conversely, if the owner of objects in the morning illustration is the same as the owner whose objects are decreased, the calculation expression is “number of objects in the morning illustration” – “increase number in the relation illustration” = “number of objects in the evening illustration.” If the derived calculation expression is different from the provided calculation expression, the system displays “These illustrations do not correspond to the calculation expression. The calculation expression of these illustrations is <derived calculation expression>”

If the relation illustration is a combine relation, the environment checks that the temporal order of all illustrations is the same. Otherwise, the system displays “There is no relation between a number of

<object name> in the <temporal order A> and a number of <object name> in the <temporal order B>.” Next, the environment checks that the relation illustration comprises the other illustrations. Otherwise, the system displays “There is no relation between first (or third) illustration and second illustration.” Furthermore, the environment checks that the object types in the three illustrations are the same. For example, it is meaningless operation that a number of food plus an amount of money. If one illustration includes food, the others must include food. If the object types are different, the system displays “It is meaningless operation that a number of <object name A> plus a number of <object name B>.”

Finally, the environment derives a calculation expression from the illustrations and ensures the derived calculation expression matches the provided calculation expression. The calculation expression is “number of objects in one existing illustration” + “number of objects in the other existing illustration” = “total number of objects in the two existence illustrations.” If the derived calculation expression is different from the provided calculation expression, the system displays “These illustrations do not correspond to the calculation expression. The calculation expression of these illustrations is <derived calculation expression>”

## 5. Evaluation

We conducted a preliminary evaluation of our environment to confirm that a learner who cannot pose problems via words was able to pose problems using illustrations. The participants of our study were four seven-year-old children. They were divided into two groups. Two of the four participants were first posed problems using words via MONSAKUN and then posed problems using illustrations via our environment. The other two participants first used our environment and then used MONSAKUN.

We started by first explaining problem posing to all four participants. Next, we explained how to use MONSAKUN to the two participants. These two participants used MONSAKUN for 15 minutes. After using MONSAKUN, we explained how to use our environment. These two participants then used our environment for 15 minutes. For the other two, we first explained how to use our environment, and they used our environment for 15 minutes. After using our environment, we explained how to use MONSAKUN, and they used MONSAKUN for 15 minutes.

MONSAKUN can provide various types of problem-posing exercises. In this evaluation, the participants posed the easiest type. MONSAKUN provided the participants with a calculation expression without the result of the calculation. The participants were required to pose a word problem that is solvable by the calculation expression by selecting two positive sentences and one interrogative sentence and sorting them into their proper order. For example, MONSAKUN provided the participants with “ $3 + 2$ ” and the participants posed the following word problem: “Tom has three pencils. Tom buys two pencils. Then, how many pencils does Tom have?” Conversely, our environment provided a calculation expression with the result of the calculation as noted above. One existence illustration expressed the result of the calculation, instead of the interrogative sentence.

Table 1: Results of experimental use.

|                               | Participant | MONSAKUN         |                    | Our environment  |                    |
|-------------------------------|-------------|------------------|--------------------|------------------|--------------------|
|                               |             | Correct problems | Incorrect problems | Correct problems | Incorrect problems |
| MONSAKUN →<br>our environment | A           | 2                | 9                  | 5                | 1                  |
|                               | B           | 6                | 1                  | 6                | 0                  |
| Our environment →<br>MONSAKUN | C           | 0                | 2                  | 1                | 3                  |
|                               | D           | 2                | 2                  | 4                | 1                  |

Table 1 shows the results of our study. The four participants are indicated by letters A B, C, and D. Participants A and B posed problems via words before posing problems via illustrations; conversely, participants C and D posed problems via illustrations before words. In the table, the number of correct problems is the number of problems correctly posed by the participant. The number of incorrect problems is the number of problems incorrectly posed by the participant.

Participants A, C, and D were not good at posing problems via words. Although participant C was also not good at posing problems via illustrations, participants A and D could pose problems via

illustrations more effectively than via words. Our initial results here suggest that learners who cannot pose problems by words can pose problems by illustrations. Participant B could pose problems by both words and by illustrations. We expect that a learner who understands problem-posing via words can also pose problems via illustrations in the same way.

## 6. Conclusion

Learning by posing arithmetic word problems is well-recognized as an effective way to master the use of solution methods; however, there are several learners who cannot pose problems via words. Therefore, in this paper, we proposed learning by posing problems using illustrations instead of words and developed a computer-based learning environment for such a task. The environment provides a learner with a calculation expression and illustrations. The illustrations can be disassembled into several figures. A learner assembles an illustration that describes a story of arithmetic problem that correspond to the calculation expression by combining the figures. The learner uses no sentences in this problem-posing exercise. The environment diagnoses the illustration problem and produces advice to the learner. One of the purposes of learning mathematics is to acquire the ability to derive a numerical relation from a scene and to associate a calculation expression with various scenes. We expect that posing problems via illustration and without words is an effective way for beginners to learn.

We also presented results of our preliminary evaluation using four seven-year-old participants. Our results were promising, indicating that our environment provides a means for learners who cannot pose problems via words. In future work, we hope to conduct more evaluations; we require more participants to confirm the effectiveness of our environment. Furthermore, we also plan to implement the “compare” relation, as well as multiplication and division.

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# Structural and trend analysis of tagging as a mechanism for organizing learning resources

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**Abstract:** The tagging mechanism has enabled students to organize plenty of online posts, pictures, and academic articles. Previous research has reported that the design of user interfaces for information organization may affect the way of future problem-solving and recall. Over the years, there have been considerable studies on the design of user interfaces for tagging. However, these studies put more emphasis on efficiency of tagging and future recall, but seldom on the structure of tagging outcomes and the tagging process. Therefore, the study designed and compared three types of user interfaces, that is, tag list, tag cloud, and tag network, and then employed network analysis and trend analysis to discover the structural and temporal patterns of tagging. Results of the study showed that, based on the proposed structural indicators and the trend analysis method, the three user interfaces designed for tagging have different degree of effects on tag reusing behaviors. Compared with tag list and tag network, tag cloud can lead more participants to make use of pre-used tags. By visualizing the tagging results as networks for representing the structure of information organization, we further categorized the tagging results into centralized, clustered and separated networks, which can be predicted by the weighted reused times of tags proposed in the study. Besides, participants using tag cloud interface created more clustered networks than those using the other two interfaces. The clustered network structure is corresponding to the selection strategy of the learning resources in the study.

**Keywords:** Tag, information organization, user interface design, memory, network analysis

## 1. Introduction

In the current learning environment, information technologies have been widely applied in the information problem solving process, including searching, navigating, reading, retrieving, understanding and organizing steps (Walraven, Brand-Gruwel, & Boshuizen, 2008). These information technologies, such as search engines, annotation software, bookmarks of browsers or social bookmarking services like *Diigo*, may not only alter students' habit of searching information and constructing knowledge (Brand-Gruwel, Wopereis, & Vermetten, 2005), but also affect their metacognitive learning strategies (Brown, 1987).

Before the network became popular, Wyman and Randel (1998) had indicated that information organization may affect the problem solving and recall efficiency. In the current learning environment, many information organization tools have been used in classrooms and students' daily life. For instance, Liu and Chang (2008) applied bookmarking as students' learning portfolio, described how their participants collected, shared and formed discussion groups with tagging mechanism. Maggio et al. (2009) made use of tags to assist the patrons to learn the complicated concept of medical controlled vocabulary. *Diigo*, a popular social bookmarking service on the Internet, promoted a "*Diigo in Education*" service for K12 educators, which allows teachers to collect essential and extended readings for their students. Moreover, Estellés, González, and del Moral (2010) introduced how to integrate *Diigo* into online courses, and provided several successful cases of academic situations such as sharing and keeping track of teaching resources. Im and Dennen (2013) shared their experiences of how their students contributed links and commented on others' collections via *Diigo*.

While tagging mechanism has been widely applied in current Web 2.0 services, most of the above studies put their focus on the social function of tagging such as sharing or collaborative filter.

However, this study, similar to several research (Civan, Jones, Klasnja, & Bruce, 2008; Bergman, Gradovitch, Bar-Ilan, & Beyth-Marom, 2013a, 2013b; Hsieh, Chen, Lin, & Sun, 2008; and Hsieh & Chiu, 2011), centered on the personal information organization function of tagging. The information organization refers to the process that users utilize tools to categorize or label their received information in an ordered way to enhance the efficiency of future problem solving and memory retrieving (Bergman, Beyth-Marom, & Nachmias, 2008; Wyman & Randel, 1998).

However, Wyman and Randel (1998) pointed out that different ways of information presentation may affect the structure, organization, and representation of human physical memory. For example, Marshall (1990) has found that node count and degree of connectivity, two network-based structural indexes, can predict the knowledge of learners. Gitomer (as cited in Wyman and Randel, 1998) compared two groups of repairmen with equal electronics knowledge, and found that the high skilled group can describe components of electronic circuits at a high abstract level. Regarding the user interface for tagging, Gao (2011) and Sen et al. (2006) have shown that the ways of visualizing tags, such as tag list or tag cloud, will affect the future tag selection and application.

Similar to Civan et al. (2008) and Bergman et al. (2013a, 2013b), the author has published a paper (Hsieh et al., 2008) to compare the information organization efficiency between archiving by folder and labeling by tagging. The current study put the focus on the comparison among three user interfaces for tagging, that is, tag list, tag cloud, and tag network. Furthermore, based on the relation between information organization and personal knowledge structure (Wyman & Randel, 1998; Marshall, 1990), the study applied network visualization to each participants' tagging results as an externalization of their knowledge and memory structures as well as Sen et al.'s (2006) trend analytic method to discover the temporal features of a user's tagging tendency for applying pre-used or new tags.

## 2. Literature Review

### 2.1 User interface effects on tag selection

User interface can provide visual clues (e.g., size, color, and link) to assist users in discovering hidden information patterns and relations among concepts, retrieving information accurately and efficiently, as well as alleviate their demand on cognitive load (Gao, 2011). Regarding tagging mechanism, most of the user interfaces put the pre-used tags in order or visualize them in certain ways for future use. Therefore, in the future tagging process, a user can create a new tag for a new resource, or select (apply) a pre-used tag from the user interface.

The study implemented three kinds of user interfaces for tagging, including tag list, tag cloud, and tag network. The tag list method places tags in alphabetical order, or permutes them by their frequency (i.e., reused times, Halvey & Keane, 2007). The tag cloud method highlights tags in larger font size on a two-dimensional plane according to the reused times of tags. Lohmann, Ziegler, and Tetzlaff (2009) applied the eye-tracking method to investigate how their participants looked at the different tag cloud layouts. The eye tracking data showed that the participants not only had more eye fixations on large font size tags on the middle of the plane, but also tended to have fixations on upper left quadrant of all user interfaces. Gao (2011) classified methods of generating tag cloud into two types: according to the tag reused frequency or the tag semantic relation. We adopted reused times of tags to construct tag cloud in this study.

Based on the viewpoint that network structure can represent information organization structure (Marshall, 1990; Wyman & Randel, 1998), when a pair of tags is applied to a digital resource, it can be said that the pair of tags has a co-occurring relation between them, which can be represented by two nodes (Shen & Wu, 2005; Gao, 2011). Tags can also be viewed as concepts in human physical memory, and relations among them can be regarded as links among concepts for future retrieval. Therefore, the tags and their co-occurring relations can be visualized as tag networks, which help users to discover new concepts through connected links. For example, by network representation, social bookmarking services such as *citeulike*, *Diigo*, or *del.icio.us* recommend related articles with shared tags to users (Wu, Gordon, & Demaagd, 2004; Shen & Wu, 2005; Hsieh & Chiu,

2011). Stefaner has designed a network-based navigator allowing users to traverse the URLs on the social bookmarking service del.icio.us<sup>1</sup>.

With regard to the evaluation of user interface usability, most of the previous studies put their emphasis on evaluating the usability of tag cloud. While evaluating the tag cloud usability on social networking, Sen et al. (2006) calculated the changes of new tag proportion to discuss how the pre-used tags affect future tag selection for movies. Gao's (2011) study resized the tag font size according to its pre-used frequency to assist future tag selection. It showed that the use of tag cloud interface can increase the wording consistency and therefore "*alleviate the physical demand perceived by users*" (Gao, 2011, p. 821).

## 2.2 Tag structural indicator

Since Marshall (1990) indicated that network indicator such as centrality and connectivity can be used to evaluate a user's knowledge structure and recall strategy, there has been several research works applying network analysis method to the investigation of tagging results. For example, while Cattuto, Barrat, Baldassarri, Schehr and Loreto (2009) focused on tag network dynamics, Shen and Wu (2005) employed network analysis indicators to show the structural properties of tag networks. The network indicators included degree distributions, clustering coefficients, and average path length. Hsieh and Chiu (2011) commented that the proportion of adding new tags or applying pre-used tags may affect the future network structure, which is corresponding to Sen et al.'s (2006) analytic method. Viewing tag results as networks, Kipp and Campbell (2006) investigated 64 popular URLs' tags and found that the usage of tags follows the long-tail phenomenon, which means that several tags will be reused heavily. Heymann and Garcia-Molina (2006) found that most of the users labeled resources in intuitive ways, not in logical or systematical ways, which increased the difficulty of future retrievals. Therefore, they applied the concepts of agreement, density and overlapping to generate hierarchical tag networks, and pointed out that the centrality, a network indicator, played an important role in re-constructing the hierarchical tag network.

Cattuto et al. (2009) and Schmitz et al. (2007) investigated how the change of tag network size affects that of the average path length, cliqueness, and connectedness. They believed that the social bookmarking shows collective dynamics, not a forehand and planned behaviors. Both of the studies discovered small world properties of tag networks. While the above studies used network analysis to show tag dynamics and tag results, evaluations for quantifying the tag networks are needed to predict future information organization efficacy (Pak, Pautz, & Iden, 2007). Pak et al. (2007) also commented that tagging mechanism often generated many item-specific terms, which may increase the working load of memory. The hierarchical categorization based on folder archiving has been evaluated by breadth and depth for more than one decade (Jacko & Salvendy, 1996; Zaphiris, 2000). Gao (2011) also proposed that consistent wordings will increase the usability of the whole system. In other words, a good user interface for tagging should lead users to reuse pre-used tags, rather than adding new tags endlessly.

## 3. Methods

### 3.1 System Design

To explore the effects of user interface on tagging mechanism, the researchers designed a tagging system to which instructors can upload three kinds of learning resources, including URLs, figures and PDFs, change the order of learning resources, and control the user interface displayed to students. Once an experiment is finished, instructors can download the log and take a quick view on the tagging results in the forms of both tag cloud and tag network provided by the system. Participant id, article id, tag, and timestamp were recorded in the log for future analysis.

Figure 1 illustrates the user interface for students to read a URL and tag it by adding new tags or applying pre-used tags on "Tag UIs". Three user interfaces (see Figure 2) were designed to assist tagging activities. Students were assigned different user interfaces according to their classes. Tag list

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<sup>1</sup> [http://well-formed-data.net/experiments/tag\\_maps/](http://well-formed-data.net/experiments/tag_maps/)

in Figure 2 lists the tags in alphabetical order and attaches a number to each tag to indicate its reused frequency. Tag cloud visualizes the reused times of tags with different font sizes. High frequency tags are displayed in large font size. A link in a tag network further visualizes co-occurring times of a pair of tags. Whenever a student adds a new tag or reuses an old one, the user interface will be updated immediately. Furthermore, students can click a tag on tag cloud or tag network interfaces to apply it to the target URL. We utilized Force-Direct algorithm developed by Kamada and Kawai (1989) and Fruchterman and Reingold (1991) to visualize the tagging network.



Figure 1. The tagging user interface including the reading material, tagging area, and user interface (Tag UIs) for tagging activities.

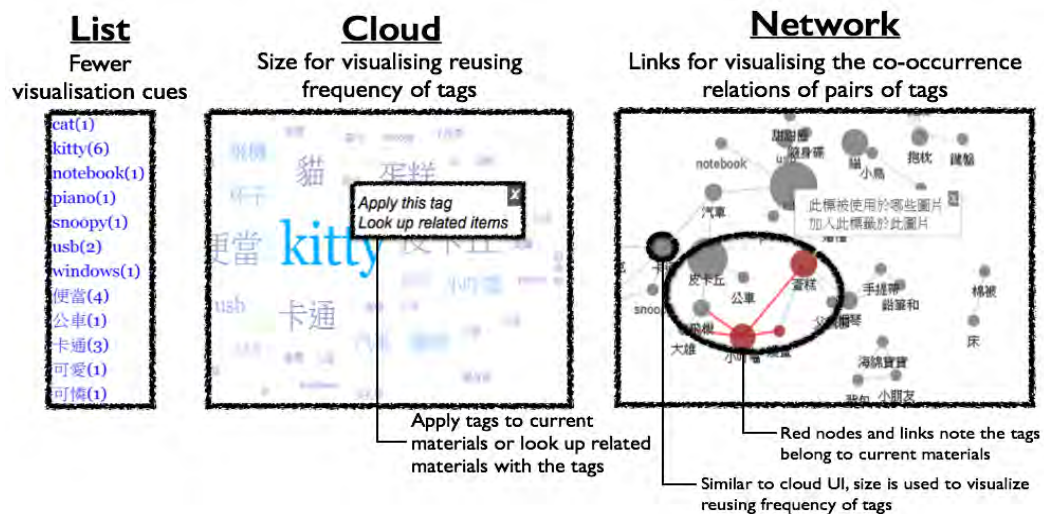


Figure 2. Examples of tag list, cloud, and network for tagging activities.

### 3.2 Experiment Designs

To investigate the effects of user interfaces on information organization, three classes from a vocational school in northern Taiwan were selected purposefully. Participants of the three classes belong to three different branches irrelevant to information science. The experiments were conducted in the course “Introduction to Computer Science,” where the three classes were assigned to use tag list ( $n = 40$ ), tag cloud ( $n = 31$ ) and tag network ( $n = 34$ ) as experimental groups.

The materials used were 30 computer science related online articles selected by researchers and course teachers from three Taiwanese websites (i.e., *techorange.com*, *inside.com.tw*, and *wired.tw*). The topics of these articles cover the issues including social networking sites, mobile phones and apps, as well as network marketing, tools, and online startup.

For each class, the authors first introduced the concept of information organization and demonstrated the tagging system for 40 minutes. After that, the participants played a labeling game designed by the authors for 20 minutes and were encouraged to use several terms to describe the

characteristics of their classmates. Finally, the participants were requested to read and tag the 30 articles in 90 minutes. The authors taught these courses by ourselves and the original course instructor remained in the classroom for assistance.

The system recorded (article, tags, timestamp) entries for each tag adding operation. Besides, with the consent of the course instructor and students, the authors used digital video recorder to record the teaching process and student responses. After the experiments, several participants' logs were filtered out due to meaningless tags in their logs (e.g., "aaaaa", "123", "44444"). The final effective samples are 36, 28, and 29 participants for tag list, tag cloud and tag network respectively.

Each participant's tagging result was visualized as tag network for further comparison. In addition to descriptive analysis, on the basis of Marshall's (1990) viewpoint on information organization and Sen et al.'s (2006) analytic method, we recognized "reused times of tags" as an important factor that can be analyzed with three indicators. The first one is the number of distinct tags used by a participant. The tendency of adding new tags to label learning resources will lead to a higher number of distinct tags. The second indicator calculates the reused times of the highest frequency tag. For example, a participant was found to label all 30 articles with the tag "technology". His/her reused times of the highest frequency tag would be 30, which means that the participant considered the tag "technology" the core concept during the experiment. It should be noted that labeling all learning resources with the same tag hardly makes significant differences between them, and leads to a less effective information organization.

In addition to the indicator quantifying the use of highest frequency tag, we employed Hirsch's (2005) *h*-index as the third indicator to quantify middle frequency tags. The use of middle frequency tags can be viewed as a means to show the general characteristics of learning resources, while the use of low frequency tags to show the specific characteristics. The *h*-index, known for its avoidance of extreme value, was originally created to analyze the productivity and impact of a scholar (Hirsch, 2005). The original definition of *h*-index is that a scholar has index *h* if *h* of his/her papers have been cited at least *h* times. The application of *h*-index in our study for evaluating a user's behavior of reusing tags can be that if *h* of the tags has been reused at least *h* times, the user receives an *h* value as the quantifying value of his/her use of middle frequency tags.

Since tagging mechanism is an information organization method, there may not be a clear correlation between information organization and learning efficacy. Therefore, rather than evaluating the results of learning performance, we conducted a recall test with 15 items to assess the influence of tagging on recall efficacy. One sample item is "Please indicate that which option is the 2011 restaurant recommendation service based on atmosphere."

## 4. Results

### 4.1 Descriptive analysis

Table 1 shows the descriptive results of the three experimental groups (i.e., tag network, tag cloud, and tag list). On average, participants of the tag cloud group used the fewest tags to label the learning resources with a low standard deviation. Comparing the total number of tags and that of distinct tags, we found that the experimental groups using tag interfaces of list and cloud tend to reuse pre-used tags. Also, participants of the tag cloud group have a higher average of reused times of the highest frequency tags and *h*-index than the other two groups, which means that tag cloud can lead users to generate more high and middle frequency tags. According to the concept of information organization, high and middle frequency tags, compared with low frequency tags, can better reflect the main topics of the learning resources.

Correlations of the three indicators for evaluating different levels of reusing tag frequency are shown in Table 2. Both *h*-index and reused time of the highest frequency tags have a significantly negative correlation with the number of distinct tags in all three experimental groups, which means that the behavior of reusing tags may decrease that of creating new tags. The experimental group using tag cloud had the highest significantly negative correlation between the number of distinct tags and the other two indicators. (-0.87\*\*\* and -0.72\*\*\*).



Table 1. Descriptive results of the tags used in the three different user interfaces (total number of articles is 30).

|   |         | Mean   | Median | Max. | Min. | Std.  |
|---|---------|--------|--------|------|------|-------|
| Total number of tags                      | Network | 170.37 | 157    | 286  | 145  | 33.25 |
|   | Cloud   | 155.07 | 151.5  | 185  | 139  | 10.19 |
|   | List    | 165.77 | 158    | 298  | 101  | 30.92 |
| Number of distinct tags                   | Network | 142    | 143    | 286  | 85   | 39.99 |
|   | Cloud   | 108.1  | 109.5  | 156  | 24   | 31.48 |
|   | List    | 124.8  | 132    | 258  | 12   | 50.32 |
| Reused time of the highest frequency tags | Network | 10.00  | 6      | 30   | 1    | 8.45  |
|   | Cloud   | 11.43  | 10     | 29   | 2    | 6.85  |
|   | List    | 11.18  | 12     | 30   | 1    | 6.92  |
| <i>h</i> -index of middle frequency tags  | Network | 4.12   | 3      | 7    | 1    | 1.54  |
|   | Cloud   | 4.97   | 4      | 8    | 2    | 1.52  |
|   | List    | 4.41   | 3      | 9    | 1    | 1.93  |

Table 2. Correlation among reused time of the highest frequency tags, *h*-index, and number of distinct tags in three user interface experiment groups.

|  | Network                        | Cloud                          | List                            |
|--|--------------------------------|--------------------------------|---------------------------------|
| Number of distinct tags vs. <i>h</i> -index                            | -0.71<br>( <i>t</i> =-5.30***) | -0.87<br>( <i>t</i> =-9.16***) | -0.63<br>( <i>t</i> =-4.95***)  |
| <i>h</i> -index vs. reused times of the highest frequency tags         | 0.71<br>( <i>t</i> =3.06***)   | 0.56<br>( <i>t</i> =3.45**)    | 0.672<br>( <i>t</i> =5.44***)   |
| Number of distinct tags vs. reused times of the highest frequency tags | -0.50<br>( <i>t</i> =5.30***)  | -0.72<br>( <i>t</i> =-5.30***) | -0.561<br>( <i>t</i> =-4.07***) |

#### 4.2 Visualization and Structural Analysis

By visualizing the tagging results as network structures, we named Hsieh et al.'s (2008) two types of tag networks as centralized and separated networks, and further added the third type in the current study as clustered network, as shown in Figure 3. The three networks are defined as follows: 1) a tag network is categorized as a “separated network” when it has more than 10 disconnected subcomponents; 2) a tag network is categorized as a “centralized network” when one or two of its tags has been applied for more than 20 learning resources; 3) if a tag network belongs to neither of the previous cases, it will be categorized as a “clustered network.” Centralized networks should have high reused times of the highest frequency tags but low *h*-index, while clustered networks have relatively high *h*-index. On the contrary, both indicators in separated networks should be low. With a focus on 3 to 4 main topics, the knowledge structure of learning resources in the study are believed to be better represented by clustered networks, as shown in Figure 3. The proportions of final tag network structures of the three experimental groups are shown in Table 3. The result indicates that participants using tag cloud interface created more clustered networks, while those using tag network interface created more separated networks.

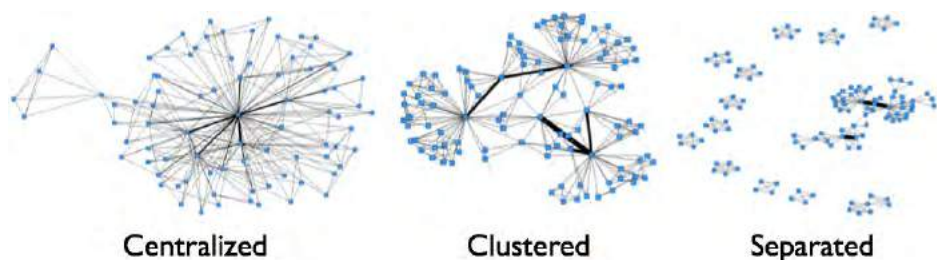


Figure 3. Three typical structures of tag networks: centralized, clustered, and separated.

Table 3. Network visualization results of each user interface.

|                    | Network    | Cloud      | List       |
|--------------------|------------|------------|------------|
| <b>Centralized</b> | 4 (13.8%)  | 2 (7.1%)   | 3 (8.3%)   |
| <b>Clustered</b>   | 7 (24.1%)  | 16 (57.1%) | 18 (50.0%) |
| <b>Separated</b>   | 18 (62.1%) | 10 (35.7%) | 15 (41.7%) |

### 4.3 Sequential Analysis

By recording timestamps of the tagging activities, we can conduct a trend analysis on the tagging process. We defined the “new tag proportion” for each article as the number of new tags divided by the total number of tags. An example (3, 0.8) denotes that a participant added four new tags and applied one pre-used tag for the 3rd article. According to the results shown in Figure 4, line charts of the three experimental groups show valleys at 12th, 16th, and 19th, and peaks at 11th, 13th, and 18th learning resources. Those valleys indicate that most of the participants happen to apply pre-used tags on these articles. Since the articles appeared in the same order, the consistency of tag usage among participants shows that they have followed the instruction and taken the tagging task seriously. Besides, the average number of new tags decreases in the process of the tagging experiment, especially in the experimental group using tag cloud interface, which means that tag cloud interface has relatively effective influences on leading users to use more pre-used tags.

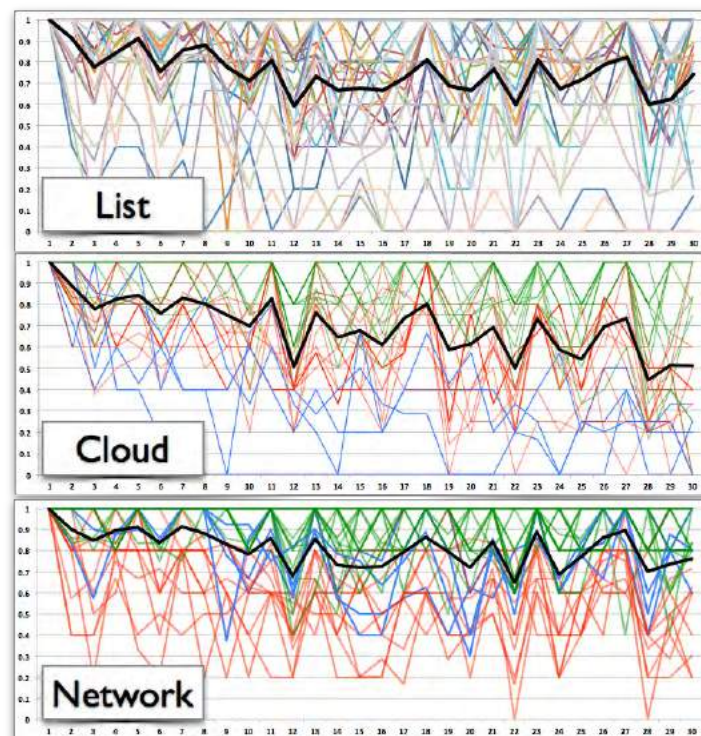


Figure 4. Line charts of the new tag proportion in the three user interfaces. Each line represents a participant’s tagging behavior.

While the above line charts displayed the difference of new tags used in the tagging process, they could not show that of the use frequency of pre-used tags. Therefore, the equation shown in Figure 5 is used to weight the score by tags’ reused times ( $t$  stands for each tag in an article  $p$ ).  $k$ -mean algorithm was applied to cluster the lines into three groups colored by blue, red, and green. An interesting observation is that, in all the three experimental groups, the clustered weighted reused times seem to be a good factor to predict the final tag network structure (i.e., centralized, clustered, and separated network structures as shown in Figure 5).

It means that, if we recognized that the clustered network structure is a better information organization, we can predict the final structure of users' tagging behaviors according to their early tagging activities, and provide them useful suggestions to help them organize their materials more effectively and efficiently.

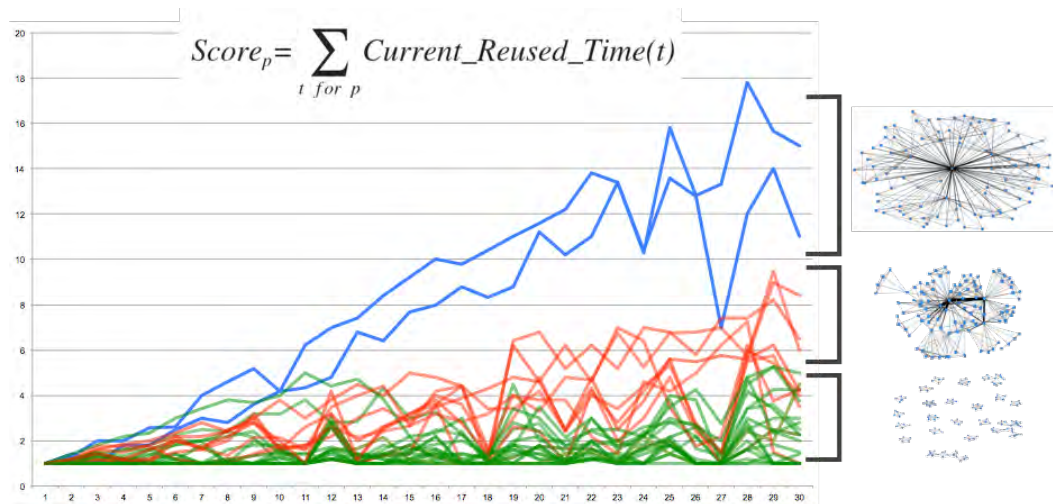


Figure 5. The results of weighted pre-used tags by reused times. Blue, red and green stand for the result of  $k$ -mean clustering algorithm ( $k = 3$ ). The three clusters match the network representation of final tagging results on the right side.

## 5. Conclusion and Discussion

The study designed different user interfaces to assist our participants in the tagging activities, and investigated their effects on the tagging behaviors. Significant effects were found in the descriptive results and trend analysis of the reused frequency of tags. Furthermore, in terms of information organization, tag cloud interface serves as a better guide for the participants to reuse pre-used tags. Although the tag network interface provides more visual clues, too much information on it failed to help the participants to reuse pre-used tags or improve the wording consistency of tags.

Based on the concept of network-based indicators for evaluating information organization by Marshall (1990), we adopted Shen and Wu's (2005) idea to turn final outcomes of tagging activities into network structures for further observation. Three types of networks, centralized, clustered, and separated, were used for categorization of the tagging results. We found that the tag cloud group had more clustered networks than the other two groups. The clustered type of network means that participants found multiple topics from the learning resources, which are corresponding to those selected by the researchers and the course teacher. Unlike the tag cloud group, participants using the tag network interface tended to create many disconnected subcomponents, suggesting that the tag network interface designed in the study cannot help participants to organize their information well. Combining the observation on network structures and the trend analysis, we found that weighting the reused times of tags can predict the network structures of final tagging outcomes. A possible future work is, based on the reused times of tags, we can design a tag recommendation mechanism to guide users to construct a better information organization structure for future navigation.

Nevertheless, the limitation of the study was due to the experiment method. The tagging activities on a bookmarking system in real life should be a long-term behavior. Since the participants were requested to finish the task in 90 minutes on our designed system, the results could be bias due to the system design and time limits. For example, the tag network interface has richer information clues than the other interfaces, and therefore takes more time

to understand and become familiar with it. With a time limit, rich information clues may demand additional cognitive load.

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# Study on Pass-Fail Prediction for the National Radiological Technologist Examination by Discriminant Analysis Using Mock Examinations

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**Abstract:** The objective of this study was to establish a technique for pass-fail prediction for a national examination from the results of intramural mock examinations, for practical use within a school. At the initial stage, we performed pass-fail prediction by discriminant analysis using intramural mock examination and national examination results for the national radiological technologist examination over a period of one year at a certain school. Specifically, we carried out experiments to investigate the optimal attributes and techniques for prediction by discriminant analysis using the Mahalanobis distance. It was found that the correct identification rate was higher when using the scores obtained in 14 subjects than when using the total of the scores of a mock examination as an attribute. Moreover, the method of dividing the national examination results into two or more groups, conducting discriminant analysis, and performing pass-fail prediction based on those results was determined to be effective. The predictive accuracy of discriminant analysis performed directly on two pass-or-fail groups was 84.3%. On the other hand, the accuracy of pass-fail prediction based on the results of discriminant analysis of five groups was 89.3%, providing a higher predictive accuracy than the former method.

**Keywords:** Pass-fail prediction, discriminant analysis, national examination, radiological technologist

## 1. Introduction

National qualifications are required in order for health professionals to perform their work in Japan. It is important for medical schools to have all students pass a national certification examination. In reality, however, not every student passes the examination. There are various reasons for this. To improve this situation, the schools need to provide effective education while assisting individual students to design an appropriate learning program and maintaining their motivation. We focused on educational guidance based on pass-fail predictions for a national examination. This guidance approach allows students, based on pass-fail predictions, to increase awareness of their goals and design an appropriate learning program at the early stages of preparation for the examination. It also allows them to make preparations for the examination while modifying the learning program based on pass-fail predictions conducted on a regular basis. Currently, pass-fail predictions for national examinations are often carried out intuitively based on the experience of faculty members. Data-based objective predictions are considered to be useful in these circumstances.

In the United States, there is a large-scale examination called HESI Exit Exam (E<sup>2</sup>) which has been administered by over 600 schools in 50 states (Langford & Willson 2012; Langford & Young, 2013). The study indicated that the accuracy of E<sup>2</sup> in predicting National Council Licensure Examination for Registered Nurses (NCLEX-REN) success is very high (96.36%-99.16%) and the E<sup>2</sup> scores are useful as a benchmark. Unfortunately, there is not such examination for most medical technologist qualification in Japan.

The objective of this research is to develop a method for making pass-fail predictions for a national examination from the results of intramural mock examinations, with utilization by a single school in mind. The national radiological technologist examination was used as an example in this study. As the first step in the development of the method, we evaluated pass-fail predictions by discriminant analysis using intramural mock examination and national examination data collected over a period of one year. Specifically, we studied the attributes to be used and the optimal method of making predictions.

In a study related to pass-fail predictions for national examinations for health care professionals, Richard et al (2004) analyzed the background and scholastic data of undergraduate nursing student who had graduated from a nursing school. They found that gender, age, Scholastic Aptitude Test (SAT) verbal, SAT quantitative and Cumulative Nursing GPA were significantly different between students who had passed NCLEX-REN and students who had not. They created a discriminant function to predict success on NCLEX-REN and the overall hit rate for this function was 70.1%. Truman (2012) compared graduates of a specific rural associate degree nursing program who had been successful on the initial attempt at NCLEX-REN to graduates who had not. As results, it was revealed that Scholastic Aptitude Test (SAT) verbal and nursing GPA significantly predicted NCLEX-RN success.

Miyashita et al (2004) compared average scores in examinations for enrolment in a higher year of study, average grades for 24 subjects in a course-specific graduation examination (course graduation examination), scores in mock examinations for a national examination (prep-school examinations), and scores in a comprehensive final-year examination for final sixth-year students (comprehensive examination) with scores for the national medical practitioners examination, and showed that there is a strong correlation between scores in the prep-school and comprehensive examinations and those in the national examination, indicating that the mock examinations and comprehensive examinations are suitable for predicting scores in the national examination. The previous studies suggest that pass-fail predictions for a national examination can be made more accurately from scores in mock examinations than from those in subject examinations.

Miyamoto et al. (2008) made pass-fail predictions for a national examination from scores in graduation examinations conducted by schools of medicine. The correct pass-fail identification rate for each year ranged from 82.7 to 97.2%. The correct pass-fail identification rate based on the overall average was 91.2%. The rate predicted for the following year using the discriminant for the year of interest ranged from 82.7 to 92.0%, and the overall average was 88.1%. While Miyamoto et al. made predictions from scores in the graduation examination; we evaluated pass-fail predictions, which are used for guidance provided about six months prior to graduation. In addition, we improved the accuracy of the pass-fail prediction by dividing scores in national examination into several groups.

## **2. Target National Examination and Data Used, and Outline of the Experiments**

### *2.1 Target National Examination*

The national examination used in this study was the national radiological technologist examination, described below.

- Held once a year, in February
- Number of questions: 200
- Pass criteria: 60% (120 points) or more and not more than one subject with a score of zero
- Question type: Marked sheet examination in which students select one correct answer from five choices
- 14 examination subjects: General basic medicine, radiation biology (including radiation hygiene), radiological physics, radiochemistry, medical engineering, diagnostic imaging equipment, X-ray photography, diagnostic imaging examination, image engineering, medical imaging informatics, radiation measurement, nuclear medicine examination techniques, radiation therapy techniques, and radiation safety management

## 2.2 Data Used

The data used in this study were the results of seven intramural mock examinations (including the graduation examination) and the national examination taken by the students graduating from a school in 2011. The data were processed in such a manner as to prevent information from being identified with a particular school and students. We obtained permission for the use of the data for research purposes under the following conditions:

- The data must be modified (student names to be removed and student numbers converted to IDs that cannot be identified with a particular student).
- Information on the source of the data (school name, information provider, number and percentage of students who passed the national examination) must not be disclosed in the results of the study.

An intramural mock examination is prepared by the faculty members. The question type and the number of questions in each subject are the same as those in the national examination. The maximum score is 200 points for both examinations.

A score in each subject is recorded for the mock examination. The total score obtained by post-examination self-assessment is recorded for the national examination. For the national examination, pass and fail information is released by the Ministry of Health, Labor and Welfare, but scores are not released. Therefore, the self-assessed total scores were used for analysis.

## 2.3 Outline of the Experiments

Pass-fail predictions for the national examination were made by Mahalanobis distance-based discriminant analysis. In a future study, we will obtain information on the probability of individual students passing the national examination and information that can be used to instruct students on which subjects they need to focus on. We will also make pass-fail predictions from the most current results every time a mock examination is conducted. To achieve this, we will make it possible to conduct predictions for each mock examination, instead of making predictions after the results of seven mock examinations become available. The experiments and their objectives are described below.

- Experiment 1: Discriminant analysis of the results of each mock examination. In this experiment, the attributes to be used were determined by comparing two methods for the analysis of mock examination results: a method using a score for each of the 14 subjects and a method using the total score. Moreover, trends in pass-fail predictions from the results of seven mock examinations were identified.
- Experiment 2: Discriminant analysis of the results of all seven mock examinations. The aim of this experiment was to determine the usefulness of pass-fail predictions from the results of all mock examinations as a means of pass-fail prediction for each mock examination.
- Experiment 3: Pass-fail predictions made by dividing national examination results into several groups. In this experiment, it was determined whether national examination results can be predicted at a detailed level. It was also determined whether the accuracy of pass-fail prediction can be improved by making pass-fail predictions from detailed predictions of examination results.
- Experiment 4: Pass-fail predictions without the use of mock examination data in the same session. Mock examination data in the same session as for the prediction sample cannot be used to make pass-fail predictions. Therefore, a similar experiment to Experiment 3 was performed without the use of mock examination data in the same session.

The free statistics software “R” (version R3.0.0) was used for statistical processing. In the discriminant analysis, the equality of the variance-covariance matrix between the pass and fail groups was tested at a significance level of 5%. In the case of equal variance, the Mahalanobis distance was calculated by pooling the variance.

The methods and results of Experiments 1 to 4 are described and discussed in the following sections.



### 3. Experiment 1: Discriminant Analysis of the Results of Each Mock Examination

First, we focused on the score for each of the 14 subjects and the total score (the sum of the scores for the 14 subjects) to determine the attributes of the intramural mock examination results to be used to effectively determine a pass or fail in the national examination. We performed discriminant analysis with different combinations of these attributes and determined the combination of attributes that gave a high correct identification rate.

#### 3.1 Method

##### 3.1.1 Data Preparation

Data on the results of each examination were prepared as shown in Table 1. The pass-fail attribute is A for a score of 120 or higher (pass) and B for a score of 119 or lower (fail).

Table 1: Example of a data set for Experiment 1

| Sample No. | Subject 1 | ... | Subject 14 | Total score in mock exam | Total score in national exam | Pass-fail (group) |
|------------|-----------|-----|------------|--------------------------|------------------------------|-------------------|
| 1          | 6         | ... | 11         | 116                      | 135                          | A                 |
| 2          | 3         | ... | 7          | 95                       | 119                          | B                 |
| 3          | 5         | ... | 8          | 125                      | 120                          | A                 |
| 4          | 5         | ... | 10         | 119                      | 95                           | B                 |
| ⋮          | ⋮         | ⋮   | ⋮          | ⋮                        | ⋮                            | ⋮                 |
| n          | 8         | ... | 10         | 138                      | 141                          | A                 |

##### 3.1.2 Testing of Equal Variance

A method for testing the equality of the variance-covariance matrix with the statistics software “R” was applied to obtain the p value. The p values for the seven mock examinations ranged from 0.107 to 0.947. The variance-covariance matrix was determined to be equal between Groups A and B. The variance was pooled to calculate the Mahalanobis distance.

##### 3.1.3 Procedure

The following steps were performed on the data for the first to seventh mock examinations using the score for each of the 14 subjects (14 attributes) and the total score (one attribute).

The Mahalanobis distance from the average for Group A and from the average for Group B was calculated for each sample in Table 1. Predictions were made using the data for the group with a shorter distance as the data set. The results of the predictions were compared with the actual data set for the group, and the number of correct predictions was counted. The correct identification rate was obtained by dividing the number of correct predictions by the total number of data sets.

Table 2: Results of discriminant analysis for each mock examination

| Mock Exam \ Attribute | 1 <sup>st</sup> exam | 2 <sup>nd</sup> exam | 3 <sup>rd</sup> exam | 4 <sup>th</sup> exam | 5 <sup>th</sup> exam | 6 <sup>th</sup> exam | 7 <sup>th</sup> exam |
|-----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| 14 Subjects           | 88.9                 | 84.1                 | 83.6                 | 86.3                 | 88.0                 | 94.7                 | 87.7                 |
| Total Score           | 63.9                 | 71.0                 | 64.2                 | 67.1                 | 57.3                 | 69.3                 | 66.2                 |

#### 3.2 Results

Table 2 shows the correct identification rate for each mock examination obtained using the score for each of the 14 subjects and the total score. As shown in this table, for all mock examinations, the

correct identification rate was higher when the score for each of the 14 subjects was used than when the total score was used.

The correct identification rate obtained using the 14 subjects as attributes gradually decreased for the first to third mock examinations, increased to a maximum of 94.7% for the sixth mock examination, and decreased for the seventh mock examination. In other words, the results show that the accuracy of the prediction is not higher for mock examinations closer to the date of the national examination.

### 3.3 Discussion

The results of Experiment 1 show that the score for each of the 14 subjects should be used as an attribute for discriminant analysis instead of the total score in a mock examination. The use of the score for each of the 14 subjects may make it possible to analyze which subjects each student should focus on.

From the results of Experiment 1, it is not clear whether the timing of the mock examinations affects the accuracy of the pass-fail prediction. We hypothesized that the accuracy of the pass-fail prediction would be higher for mock examinations closer to the date of the national examination because we considered that the competence of the students would be at a level where they were ready for the national examination. From Table 2, however, it can be seen that the accuracy of the prediction is not necessarily higher for mock examinations closer to the date of the national examination than for earlier mock examinations. This indicates that the accuracy may be more strongly affected by differences in the level of difficulty of the questions and similarity of the content of questions in the national and mock examinations than by proximity to the date of the national examination. There is a weak correlation between the number of examinations and the accuracy of predictions made using the score for each of the 14 subjects (correlation coefficient = 0.46). The accuracy of the prediction may also be affected by information on the date of the national examination.

## 4. Experiment 2: Discriminant Analysis of the Results of All Seven Mock Examinations

Based on the results of Experiment 1, the score for each of the 14 subjects, which resulted in a high correct identification rate, was used as an attribute. In Experiment 2, the results of all seven mock examinations were used for discriminant analysis. Two cases were analyzed: a case where the scores for each of the 14 subjects were used as attributes and a case where the number of days from the date of the mock examination to the date of the national examination, which comprises information indicating the timing of the mock examination, was added as an attribute (15 attributes in total).

Table 3: Example of a Data Set for Experiment 2

| Mock exam            | Sample No. | Subject 1 | ... | Subject 14 | No. of days to national exam | Total score in national exam | Pass-fail (group) |
|----------------------|------------|-----------|-----|------------|------------------------------|------------------------------|-------------------|
| 1 <sup>st</sup> exam | 1          | 6         | ... | 11         | 210                          | 135                          | A                 |
|                      | 2          | 3         | ... | 7          | 210                          | 119                          | B                 |
|                      | ⋮          | ⋮         | ⋮   | ⋮          | ⋮                            | ⋮                            | ⋮                 |
|                      | $n_1$      | 7         | ... | 12         | 210                          | 141                          | A                 |
| ⋮                    | ⋮          | ⋮         | ⋮   | ⋮          | ⋮                            | ⋮                            | ⋮                 |
| 7 <sup>th</sup> exam | $n_6+1$    | 5         | ... | 10         | 30                           | 135                          | A                 |
|                      | $n_6+2$    | 4         | ... | 8          | 30                           | 119                          | B                 |
|                      | ⋮          | ⋮         | ⋮   | ⋮          | ⋮                            | ⋮                            | ⋮                 |
|                      | $n_7$      | 8         | ... | 10         | 30                           | 141                          | A                 |

The number of the last sample before the  $m^{\text{th}}$  mock examination is represented by  $n_m$ .

### 4.1 Method

#### 4.1.1 Data Preparation

Data on the results of all seven examinations were prepared as shown in Table 3. The number of days to the date of the national examination was added as an attribute. The number of days to the date of the national examination indicates how many days before the national examination the mock examination was conducted. The pass-fail attribute is A for a total score of 120 or higher (pass) and B for a total score of 119 or lower (fail) in the national examination.

#### *4.1.2 Testing of Equal Variance*

The method for testing the equality of the variance-covariance matrix with the statistics software “R” was applied to obtain the p value. As a result, the p value was 0.0129 for the score for each of the 14 subjects (14 attributes without the number of days to the national examination) and 0.0196 for those with the number of days included (15 attributes). The variance-covariance matrix was determined to be not equal between Groups A and B. Therefore, the variance was not pooled to calculate the Mahalanobis distance.

#### *4.1.3 Procedure*

As with Experiment 1, the correct identification rate was obtained using the data on all seven mock examinations in two cases: a case where the score for each of the 14 subjects was used (case without the use of the number of days) and a case where the score for each of the 14 subjects and the number of days to the date of the national examination were used (case with the use of the number of days).

### *4.2 Results*

The correct identification rate was 88.1% in the case without the use of the number of days and 89.3% in the case with the use of the number of days. The accuracy of the prediction was slightly higher in the latter case.

### *4.3 Discussion*

It was found that if the data for the results of all mock examinations were processed in a batch, the variance-covariance matrix of the mock examination results was not equal between the pass and fail groups. Therefore, the variance was not pooled to calculate the Mahalanobis distance.

The accuracy of the prediction was slightly higher in the case with the use of the number of days to the date of the national examination, which comprises information indicating the timing of a mock examination. However, it is not clear whether this information contributes to the accuracy of the pass-fail prediction due to the proximity to the date of the national examination. In this experiment, to make pass-fail predictions for a sample, mock examination data in the same session as for the sample were included in the data set. As a result, the effect of the mock examination data in the same session on the accuracy of the prediction increased due to the use of the number of days, and the possibility of correct predictions increased.

## **5. Experiment 3: Pass-fail Predictions Made by Dividing National Examination Results into Several Groups**

In Experiments 1 and 2, discriminant analysis was performed on the pass and fail groups to determine the accuracy of the prediction. In Experiment 3, the number of national examination score groups was increased to make more detailed predictions of national examination results, and discrimination analysis (multiple discriminant analysis) was performed. The accuracy of pass-fail (two groups) predictions from the results of the analysis was evaluated.

### *5.1 Method*

### 5.1.1 Grouping

Table 4 shows the grouping. The scores in the national examination were divided according to the number of groups, as shown in the table. That is, students were grouped by the range of their scores in the national examination shown in Table 4. For example, in the case of four groups, a score from 140 to 200 inclusive falls within Group A and a score of 130 to 139 inclusive falls within Group B.

In the case of two groups, students were divided into only two groups: passing students and failing students. In the case of three and four groups, passing students were divided into several groups. In the case of five groups, failing students were divided. The students were divided into groups so that the number of samples was not zero in any case.

Table 4: Range of the Score of Each Group

| No. of Groups | Group A | Group B | Group C | Group D | Group E |
|---------------|---------|---------|---------|---------|---------|
| 2             | 200~120 | 119~0   | -       | -       | -       |
| 3             | 200~135 | 134~120 | 119~0   | -       | -       |
| 4             | 200~140 | 139~130 | 129~120 | 119~0   | -       |
| 5             | 200~140 | 139~130 | 129~120 | 119~110 | 109~0   |

Note: The painted score ranges indicate a pass.

### 5.1.2 Data Preparation

Data for the results of all seven examinations were prepared as shown in Table 5. The pass-fail attributes were grouped in the same manner as in Table 4. Table 5 shows an example of a data set in the case of five groups.

Table 5: Example of a data set for Experiment 3

| Mock exam            | Sample No.        | Subject 1 | ... | Subject 14 | Total score in national exam | Group |
|----------------------|-------------------|-----------|-----|------------|------------------------------|-------|
| 1 <sup>st</sup> exam | 1                 | 6         | ... | 11         | 89                           | E     |
|                      | 2                 | 3         | ... | 7          | 119                          | D     |
|                      | ⋮                 | ⋮         | ⋮   | ⋮          | ⋮                            | ⋮     |
|                      | n <sub>1</sub>    | 7         | ... | 12         | 141                          | A     |
| ⋮                    | ⋮                 | ⋮         | ⋮   | ⋮          | ⋮                            | ⋮     |
| 7 <sup>th</sup> exam | n <sub>6</sub> +1 | 5         | ... | 10         | 89                           | E     |
|                      | n <sub>6</sub> +2 | 4         | ... | 8          | 119                          | D     |
|                      | ⋮                 | ⋮         | ⋮   | ⋮          | ⋮                            | ⋮     |
|                      | n <sub>7</sub>    | 8         | ... | 10         | 141                          | A     |

### 5.1.3 Procedure

As with Experiment 1, the correct identification rate was obtained for a different number of national examination score groups from 2 to 5 in two cases: the case where the score for each of the 14 subjects was used (case without the use of the number of days) and the case where the score for each of the 14 subjects and the number of days to the date of the national examination were used (case with the use of the number of days). In addition, pass-fail predictions were made for each group using Table 4. The predictions were compared with the actual pass-fail results, and the number of correct predictions was counted to determine the accuracy of the prediction.

## 5.2 Results

Table 6 shows the correct group identification rate and the correct pass-fail prediction rate for different numbers of national examination score groups. The group correct identification rate is the highest when the number of groups is 2 and decreases with an increasing number of groups. The

correct pass-fail prediction rate is higher for a larger number of groups and is the highest when the number of groups is 5. For all numbers of groups, the rate is slightly higher in the case with the use of the number of days.

Table 6: Results of Group Distinction and Pass-Fail Prediction

| No. of Groups | Without No. of Days to National Exam |                      | With No. of Days to National Exam |                      |
|---------------|--------------------------------------|----------------------|-----------------------------------|----------------------|
|               | Group Distinction                    | Pass-Fail Prediction | Group Distinction                 | Pass-Fail Prediction |
| 2             | 88.1                                 | 88.1                 | 89.3                              | 89.3                 |
| 3             | 68.1                                 | 89.7                 | 69.8                              | 91.1                 |
| 4             | 61.1                                 | 90.9                 | 66.1                              | 92.7                 |
| 5             | 64.3                                 | 96.0                 | 68.5                              | 96.8                 |

### 5.3 Discussion

The results of Experiment 3 show that if the number of national examination score groups is more than 2, the correct prediction rate based on score groups decreases. Therefore, it is difficult to use this method to make detailed predictions of examination results. Pass-fail predictions made based on the predicted groups are more accurate than those made based directly on the pass and fail groups. Particularly when the number of groups is 5, the correct prediction rate is at least 7 points higher than when the number of groups is 2. This indicates that pass-fail predictions based on the grouping of national examination results are useful.

As in Experiment 2, the accuracy of the prediction was slightly higher in the case with the use of the number of days to the date of the national examination in Experiment 3. However, as discussed in Section 4.3, whether to use the number of days to the date of the national examination as an attribute is an issue that needs to be examined.

## 6. Experiment 4: Pass-fail Predictions Without the Use of Mock Examination Data in the Same Session

Mock examination data in the same session as for the prediction sample cannot be used to make pass-fail predictions for a forthcoming national examination. The experiments conducted indicate (a) that the accuracy of pass-fail prediction increases due to the effect of the mock examination data in the same session and (b) that the accuracy of the prediction slightly improves because the effect of the data increases when the number of days to the date of the national examination is used. Therefore, a similar experiment to Experiment 3 was performed without the use of mock examination data in the same session as for the prediction sample.

### 6.1 Method

The grouping and data preparation were the same as in Experiment 3.

The following steps were performed for different numbers of national examination score groups from 2 to 5 in two cases: the case where the score for each of the 14 subjects was used (case without the use of the number of days) and the case where the score for each of the 14 subjects and the number of days to the date of the national examination were used (case with the use of the number of days).

The data in Table 5, excluding the first examination data, were used for discrimination. The Mahalanobis distance from the average for each group was calculated using discrimination data for each sample from the first examination. Predictions were made using the data for the group with the shortest distance as the data set. The results of the predictions were compared with the actual data for the group, and the number of correct predictions was counted for correct group discrimination. Pass-fail predictions were made based on whether the predicted group was a pass group or a fail group, and were compared with the actual pass-fail results. The number of correct predictions was counted for correct pass-fail predictions. The above steps were performed using the first to seventh

data sets. The correct group identification rate and the correct pass-fail prediction rate were obtained by dividing the number of correct group identifications and the number of correct pass-fail predictions by the total number of samples.

**Table 7: Results of Group Distinction and Pass-Fail Prediction Without Mock Examination Data to Which the Target Sample Belonged**

| No. of Groups | Without No. of Days to National Exam |                      | With No. of Days to National Exam |                      |
|---------------|--------------------------------------|----------------------|-----------------------------------|----------------------|
|               | Group Distinction                    | Pass-Fail Prediction | Group Distinction                 | Pass-Fail Prediction |
| 2             | 82.7                                 | 82.7                 | 84.3                              | 84.3                 |
| 3             | 50.0                                 | 82.9                 | 55.4                              | 84.9                 |
| 4             | 37.5                                 | 82.7                 | 41.1                              | 83.5                 |
| 5             | 39.1                                 | 88.5                 | 43.1                              | 89.3                 |

## 6.2 Results

Table 7 shows the results. Overall, the accuracy of the prediction was lower than in Experiment 3, in which all data were used. Unlike in Experiment 3, the correct pass-fail prediction rate did not necessarily increase with an increasing number of groups, but was the highest when the number of groups was 5. The accuracy of the prediction for all groups was slightly higher in the case with the use of the number of days.

## 6.3 Discussion

The correct prediction rate is about 5 points lower in the case without the use of mock examination data in the same session as that for the prediction sample, compared with the case in which the entire mock examination data are used. This indicates that the accuracy of the prediction will be 80 to 90% using discriminant analysis to make pass-fail predictions for the national examination. Since the level of difficulty of the questions in the national examination differs from year to year, we will continue to evaluate pass-fail predictions using data for several years.

The results of Experiment 4 indicate that the accuracy of the prediction slightly increases using the number of days from the date of the mock examination to the date of the national examination. This is because in Experiment 4, mock examination data in the same session as for the prediction sample were not used and the increased effect of the mock examination data in the same session on the accuracy of the prediction due to the use of the number of days did not occur.

## 7. Conclusions

In the initial stage of this study of pass-fail predictions for the national radiological technologist examination, we performed Mahalanobis distance-based discriminant analysis using data on examination results collected over a period of one year. Our analysis indicates that predictions can be made with an accuracy approaching 90% and has shown the following:

- The score for each of the 14 subjects in a mock examination should be used as a basic attribute.
- Pass-fail predictions can be effectively made by dividing national examination results into five groups.
- The number of days to the date of the national examination may be a useful attribute for pass-fail predictions.

Data collected over a period of two years will be available for a future study. We will evaluate the accuracy of the prediction by making pass-fail predictions for the following year using data for the current year. The next step is to make pass-fail predictions using other techniques such as multiple regression analysis, neural net analysis, and Bayesian analysis.

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# Altruistic behavior in a learning stage through social network

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**Abstract:** In recent years, we have seen that users edited and shared information actively on various Social Network Sites (SNSs) and those sites are getting richer and more interesting. We expect students can have this mindset similarly on our learning stage. Our study proposed a social networking site for education. Like a stage for students, they can watch and show themselves. We observed altruistic motive and behavior of students on the platform. There were 30 college students participated. We had found that there were six altruistic behaviors. And Students' altruistic motivations are enjoyment and self-development.

**Keywords:** altruistic behaviors, social network sites, networking learning, learning stage

## 1. Introduction

The rise of SNSs (e.g., Wikipedia, Facebook, YouTube), shortening the distance between people. We can keep in touch with friends more directly through SNSs. It is getting to be a new social way for people. SNSs are defined as web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system. (Ellison, N. B., 2007) Most of SNSs provide a function to allow users to communicate with each other, multimedia sharing, set personal profiles and even to make a friend with strangers. Moreover, it also has many applications on SNSs such as marketing, games and education. Those developments not only changed our way of life but also provided us a more convenient one. On these SNSs we can observe how user edit and share information actively. We proposed an educational SNS like a stage for students, and they can show themselves. Teachers can interact with students on our platform. Students can watch and learn other's achievement and give feedback for each other. We observed students' altruistic behaviors in this SNS on our study.

The origin of altruistic behavior is difficult to be traced. In different areas have different definitions, such as psychology, sociobiology and economics. There were lots of research in various areas. They had a formal definition of altruistic behavior that is carried out to benefit another from external sources without anticipation of rewards (Rushton, J. P., 1982). Students will do better and more detail assignments because of altruistic motivation, and benefit other students at the same time. That is one of altruistic behaviors on education. Even if other students did not get essentially help, that student who helped other still can learn thoroughly. Compared with consequence, we are more concerned about their altruistic motives. How to improve the learning motivation is an enduring issue. We expected taking the effect on social networking platform into teaching and trying a new teaching model. Let students can learn actively or pay more attention on learning. Therefore, we discussed the following issue and discuss the advantages, disadvantages and the future work in the end.

- (1) What kinds of altruistic behaviors students have when they learned on our learning stage?
- (2) What kinds of altruistic motives students have when they learned on our learning stage?

## 2. Related Work

### 2.1 The social networking sites



SNSs are the social tool for connecting our friends, classmates and share information. It changed some parts of our daily routine, and even in the social and politics. (Burke et al., 2009; Koh, Kim, Butler, & Bock, 2007). SNSs such as Myspace, Facebook and YouTube, not only have had great influence on millions of users but also have attracted many people to do research. Why did people love to use those SNSs? Nadkarni, A., & Hofmann, S. G. (2012) had concluded two reasons. Those were (1) the need to belong and (2) the need for self-presentation (Nadkarni, A., & Hofmann, S. G., 2012), and another paper mentioned that people who were higher in narcissism and lower in self-esteem were more interesting in SNSs. (Mehdizadeh, S., 2010) In addition, more and more applications were developed on the SNSs in education gradually. One study pointed out that SNSs could be easy to prepare course materials, teach, implement cross-platform device and discuss with others conveniently. (Shiu, H., Fong, J., & Lam, J., 2010) Another research showed that college students believed that the SNSs were helpful in learning English in their experiment. (Kabilan, M. K., Ahmad, N., & Abidin, M. J. Z., 2010). Social networks had more non-school time for extracurricular educational activities because it's highly informal learning environment. And that would enable users to cooperate with each other, involve actively, share resources and learn unintentionally. (Wang, C.-h., & Chen, C.-p, 2013)

As for why a user would share information and data on the Internet actively, That was an great issue and there were numerous studies (Ames & Naaman, 2007; Arakji, Benbunan-Fich, & Koufaris, in press; Cheshire & Antin, 2008; Kim & Han, 2009; Kuo & Young, 2008; Schroer & Hertel, 2009). One study indicated why users edited information on Wikipedia actively. That pointed out it was determined by the balance between costs and benefits, by the identification with the Wikipedia community, and by perceived task characteristics (Schroer, J., & Hertel, G., 2009). Another study indicated why users would share photos on social networks. There were four motives. Those were enjoyment, commitment to the community, self-development and reputation building. And we discussed what factors are associated with the sharing of information goods and participation in social structures of online communities? In addition, the extrinsic motive showed that when people got more than they paid, they might have contributed context. (Lerner & Tirole, 2002) And the intrinsic motive pointed out that people who felt enjoy would be more important than the result. (Torvalds & Diamond, 2001)

## 2.2 *The altruism*

People take the difficulties on themselves and make things easy for others. That is an example of altruistic behaviors. J. Philippe Rushton pointed out that one formal definition of altruistic behavior is carried out to benefit another without anticipation of rewards from external sources. In Zhang Huiping and Li Hong's (2006) study (Zhang Huiping, 2006), that analyzed the strength of people's performance of altruistic behavior and people were from different backgrounds. They classified motivation of altruism into two kinds. One is benefit another without anticipation of rewards and another one is with anticipation of rewards. They found that there was no significant difference in the comparison of boys and girls male and female. However, there was significant difference in the comparison of whether an only child or not and students from urban or rural areas. In addition, Klisanin (2011) reviewed fifty-four pages and conclude into different forms of altruism, and Klisanin (2011) considered that internet is indeed giving rise to new form of altruism. (Klisanin, D., 2011) In this study we want to show the altruistic behavior of students' on our social networking platform. Whether students would be happier to help others in the areas of their expertise on our learning stage? They would be willing to spend some time search information for others.

## 3. System Design and Implementation

### 3.1 *Learning stage*

Our study proposed a learning stage which teachers could interact with students. For teachers, they can teach and prepare materials on the platform. For students, they can learn from the others and get opportunities for self-reflection by watching other's achievements on the platform. Students are difficult to watch and learn from others' achievements on the traditional paper for learning. Our platform makes it easier for students because it can be presented by multimedia. Such as videos, pictures and so on. Greatly increase opportunities for students to watch and learn from each other. In addition, the system as the media for teachers and the status of learning, all the learning outcomes are

presented through a timeline. It will be easy to review in the future if we need. Teachers can also make the report card by the result of students' interaction through the system easily.

There are four main modules provided by our system.

- First, the Mission module:  
Teachers can set exam paper and teaching material by using the function, and also decide whether the rights access for specified users to watch content inside, set exam paper questions and so on. Mission environment is showed in Figure 1. For students, they can answer the exam paper on the system.
- Second, the Achievement module:  
When students complete a task, the learning stage will produce an achievement. The achievement is the content which students had made, or had learned. Students can review the content and watch the content which shared by others easily in the future if they need. They can also give comments and review to each other. For teachers, in this part, they can see all the learning achievement produced by students and manage students' learning situation. Students' interaction is showed in Figure 2.
- Third, the Collection module:  
Students can collect other students' achievements if they are interested in those, or impressed on those. With this, they can review easily in the future if they need.
- Fourth, the Announcement module:  
Teachers can announce news to students through the announcement function. Students can also leave messages for the information exchanging, and it will promote interactions between teachers and students.



Figure 1. Mission Environment.



Figure 2. Students' Interaction.

### 3.2 System Design

Our community platform is presented on the web so that it can be executed on a variety of platforms. With that, teachers, students, and even parents can use our platform without any geographical environment hindrance. They can learn on desktop computer, or in the classroom through connecting our system easily. Our web page is written in PHP. It can playback videos, audios, pictures and other multimedia files. On the implementation mainly divided into two parts, one is make out questions and answer the question, the other part is presentation and management. And then combine the two parts and back-end database into a complete system. We provide a wide measure of a classroom with educational content based on existing production through the above hardware and software architecture. So that students can present the learning outcomes in a different way compared with traditional ways through recording and typewriting. And make students' learning more diversity through peer observation and recommend mechanisms.

## 4. Experiments and result

### 4.1 Hypothesis

As we mentioned previously, we expected that students would be able to have behaviors and mentalities just like they were on SNSs. And we expected that those were in accordance with motives we mentioned previously. We also compared relationship between helping attitudes in daily life and altruistic behavior on our learning stage. We wanted to know whether some people are very indifferent, but they show lots of altruistic behaviors on Internet. Therefore, we assumed that:

- In education, students will show lots of altruistic behaviors on our learning stage.
- In education, students' altruistic motives will include Enjoyment, Commitment, Self-development and Reputation on our learning stage.

## 4.2 Procedure

We conducted an experiment at the university in Taiwan and participants were 30 college students. Students were divided into 8 groups and each group had four students. Two of the groups are only three students. Students' images would be projected onto a computer screen so that they could engage in a dialogue with the virtual character. Students performed in front of KINECT for learning English. Their Achievement will be watched and they can give comments for each other on our networking platform. The design of activities let students show themselves as possible. They will interact with virtual characters for learning English in different contexts. After that they integrate a series of continuous scripts and it will become a film. Then, they can watch other's achievements, give comments and leave a message for each other. In the end, they fill out the questionnaire and chose several students for interviews.

## 4.3 Questionnaire

### 4.3.1 The Helping Attitudes Scale

We reference questionnaires (Nickell, 1998). A 20-item measure of participants, helping, feelings, and behaviors. Each item is answered on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). For example: It feels wonderful to assist others in need \ Doing volunteer work makes me feel happy

### 4.3.2 Altruistic Behavior Questionnaire

It is used to view what students' altruistic behavior on our learning stage. We designed questionnaire and the internal consistency reliability coefficients  $\alpha$  is 0.842. And we measured the validity by factor analysis, the total explanation of variance have 63.5%. We have 30 samples. We can see in table1. There are total nine questions and the questionnaire is 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

### 4.3.3 Altruistic motives

In our study, to view the motivation, we followed the research model by Oded Nov et al (2009). The research model and questionnaires are used for analysis of participation in an Online Photo-Sharing Community. There are total 12 questions and they are divided into intrinsic motivations "Enjoyment" and "Commitment" and extrinsic motivations "Self-development" and "Reputation". We can see that in the table2.

- **Enjoyment:** In this paper, we view whether students show more altruistic behaviors because they feel fun and interesting. For example, I will feel happy when I find that my videos are seen by others on our learning stage.
- **Commitment:** We view whether students want to help others because of the commitment. For example, I will feel down if I can't use on the community platform.
- **Self-development:** We view whether students can learn something from others, make their technical skills better and would be willing to help others actively. For example, I think I can enhance some skills by uploading videos on the community platform.
- **Reputation:** We view whether students do better because they want to get higher reputation. For example, I think I get some reputations by uploading videos to be seen by others on the community platform.

Table 1: Students' altruistic behaviors on our platform.

| Question      |  | Mean | SD   |
|---------------|--|------|------|
| 1             | I will film the video richer because I know it will be seen by the others on the learning stage                      | 3.59 | 0.78 |
| 2             | I will be happier to help the others on the learning stage if it is my expertise areas.                              | 4.07 | 0.53 |
| 3             | I will take the initiative to review the others' films and give feedback to the others.                              | 3.41 | 0.73 |
| 4             | I will film the video more special because I want to get more attentions from the others.                            | 3.34 | 0.93 |
| 5             | I would like to film the video again when I watch the others' videos.  | 3.07 | 0.99 |
| 6             | I will pay more attention to perform because I know the video is public.   | 3.72 | 0.79 |
| 7             | I will be happy to spend some time to prepare information and let the others learn and save time.                    | 3.72 | 0.79 |
| 8             | I will film the video better because I want to get a higher rating.  | 3.66 | 0.97 |
| 9             | I will not try to let the video show error message because I know the others can see my video on the learning stage. | 4.21 | 0.56 |
| Total Average |  | 3.64 | 0.53 |

Table 2: Students' altruistic motives on out platform.

| Motives          | Mean | SD   |
|------------------|------|------|
| Enjoyment        | 3.70 | 0.66 |
| Commitment       | 3.06 | 0.62 |
| Self-Development | 3.76 | 0.44 |
| Reputation       | 3.01 | 0.90 |

## 5. Discussion

According to table 1, we can see that there are 6 mean values > 3.5 in the nine altruistic behaviors' questions. We take those as a positive result. And we can see that there are 3 mean values which are amount between 3 and 3.5. We take it as a non-significant result. The data show that students will try to avoid error messages when they make a film, or they will concentrate more on making a film and provide a richer message due to the film they made will be seen by others. However, we have non-significant results. Such as "It will make me re-film again if I see others' videos" and "I will take the initiative to score others' films and give feedback to others". By the interview, we know that the film's content are drab and it had nothing related with what they learned in school, so they didn't want to do it again.

In table 2, we can see the enjoyment and Self-development is a positive result. However, we can see the Commitment and reputation is non-significant results. According to interviews, students believe that they won't have chance to use our learning stage after this experiment, unlike other famous SNSs they use every day. (e.g., Facebook and YouTube). We believe that we can observe more positive result on our learning stage in the long-term observation. According to the interviews with students, they think if our learning stage have more users, they are more willing to use it. The activity design is that let students show themselves as possible so that they will get the others' attentions. Compared to traditional teaching material, multimedia our platform can show richer and unique contents. Students

will be immersed in it. Overall, Most of them believed that they would do better and learn something on our learning stage.

## 6. Conclusion and Future Work

We put that the initiative of users share and edit information actively on SNSs to the education. We observed altruistic motive and behavior of students on our learning stage. We carried out an experiment in April 2014. Result showed that there were six positive results in our 9 altruistic behaviors' questions. Students will pay more attention to their performances because they care how other students think. They will be happy to spend time to prepare information for others. Simultaneously, most of them believed that they have learned something in the process. Students' altruistic motivations, enjoyment and self-development also have a positive result. In the future, we will do more research and do a long-term and more people experiments. And try to realize how students' altruistic behaviors can help others effectively, find the suitable way for education in the school and design more reliability and validity questionnaires. We look forward to it can have more contribution in education.

## Acknowledgements

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# Analyzing Course Competencies: What can Competencies Reveal about the Curriculum?

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**Abstract:** The application of learning outcomes and competency frameworks have brought better clarity to engineering programs. Several frameworks have been proposed to integrate outcomes and competencies into course design, delivery and assessment. However, in many cases, competencies are course-specific and their overall impact on the curriculum is unknown. Such impact analysis is important for analyzing and improving the curriculum design. Unfortunately, manual analysis is a painstaking process due to large amounts of competencies across the curriculum. In this paper, we propose an automated method to discover their impact on the overall curriculum design. We provide a principled methodology for discovering the impact of courses' competencies using Bloom's Taxonomy and the learning outcomes framework.

**Keywords:** Competencies, Bloom's taxonomy, curriculum analysis, exploratory data analysis, competency cube, undergraduate information systems program

## 1. Introduction

Learning outcomes and competencies are employed in numerous education programs for achieving transparency and clarity in course design and delivery (Baumgartner & Shankararaman, 2013). Learning outcomes and competencies are not only beneficial to the teaching professionals for structuring the courses, but also for students to track their skills development.

Curriculum analysis unpacks the components of a curriculum to assess and improve it. The curriculum level analysis of competencies has been studied by (Brabrand & Dahl, 2009; Gnana Singh & Leavline, 2013). Nevertheless, there was no principled approach or framework defined for depth analysis at the overall curriculum level. Several researchers have proposed also frameworks or methods to apply learning outcomes and competencies for evaluating the students (Scott, 2003; Lister & Leaney, 2003), and course design and delivery (Hartel & Foegeding, 2004; Baumgartner & Shankararaman, 2013; Ducrot, et al., 2008; EU, 2014). However, the major drawback of these studies is that, they mainly focus at the course level and in many cases the impact on the overall curriculum level is unknown.

Analysing competencies at curriculum level has several advantages. Firstly, it aids in understanding the overall design of the curriculum in terms of skills progression. Secondly, it helps in discovering any discrepancies, blind spots or gaps in the program, and provides pointers for improving the curriculum. Thirdly, it helps in recommending the competencies for a new course.

Manual analysis of course competencies in a curriculum can be a tedious and painstaking effort due to three main challenges. Firstly, even in a small curriculum, the total number of competencies can reach few hundreds. Secondly, the competencies are verbose in nature and often multiple competencies are combined into a single statement. Thirdly, competencies tend to evolve, especially in technology curriculum where changes happen every two to three years.

In this paper, we propose a framework based on cube models (Khairuddin & Khairuddin, 2008), Bloom's taxonomy (Bloom, et al., 1956), Dreyfus' model of skill development (Dreyfus & Dreyfus 1986) and exploratory data analysis (EDA) (Cook & Swayne, 2007) to discover the impacts of courses' competencies on the curriculum. We evaluated our framework on an undergraduate core curriculum; Bachelor of Science (Information Systems Management) degree program BSc (ISM), offered by the School of Information Systems (SIS), Singapore Management University (SMU). Our results show that the curriculum is designed on both cognitive and progression functionalities.

Additionally, we observe some discrepancies in the curriculum design and propose suggestions for improvements.

The rest of the paper is organized as follows. In Section 2, we study some related work. We give some background Section 3 and Section 4 presents our solution framework. In Section 5, we describe our dataset, present our evaluation results, discussions and we conclude in Section 6.

## 2. Literature Review

Learning outcomes are statements of a learning achievement and are expressed in terms of what the learner is expected to know, understand and be able to do on completion of the program (Kennedy, et al., 2009). A competency is expressed for individual courses within the curriculum, using a vocabulary of learning outcomes (Kennedy, et al., 2009). For the quality of higher education, learning outcomes are becoming accountable and quality assurance frameworks (Wheeler, 2007). The Qualification Frameworks (EU, 2014) are based on learning outcomes and competencies. In (Ducrot, et al., 2008) paper, the learning outcomes are at the program level and the sub skills (competencies) are specified under them. However, (Hartel & Foegeding, 2004) defined competencies at a higher level than the learning outcomes. In this paper, we use the framework defined by (Ducrot, et al., 2008).

Several learning taxonomies have been recognized as important paradigms in planning and developing educational, training, and professional development curricula (Bloom, et al., 1956; Krathwohl, 2002; O’Neill & Murphy, 2010). Bloom proposed a simpler taxonomy for the cognitive domain, while Biggs’ SOLO taxonomy (O’Neill & Murphy, 2010) is more complex and detailed framework. Additionally, to understand the progress of skills learned, Dreyfus proposed a framework, skill development model (Dreyfus & Dreyfus, 1986), which overlaps with Bloom’s cognitive domain.

Bloom’s taxonomy has been applied in various aspects of learning and education. Examples include, computer science assessments (Scott, 2003), assessing the students based on their ability (Lister & Leaney, 2003), effective course design (Whetten, 2007), curriculum improvement problem (Wheeler, 2007) and generating customized tests (Raykova, et al., 2011). For our solution, we used Bloom’s taxonomy to analyse the curriculum on the cognitive functionality and Dreyfus’ model of skill development for progression functionality.

## 3. Background

### 3.1 Learning Outcomes Framework

Several frameworks have been proposed to integrate the learning outcomes in to the education (Hartel & Foegeding, 2004; Ducrot et al., 2008). In Figure 1 (a), we show the Learning Outcomes Framework implemented (LOF) at the School of Information Systems, Singapore Management University.

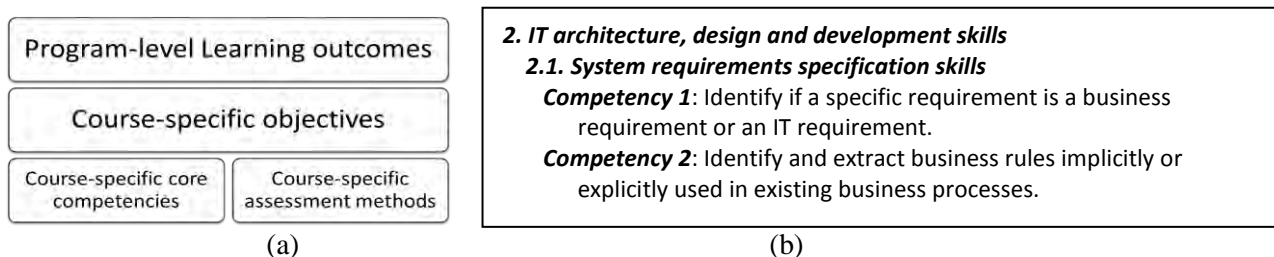


Figure 1. (a) Learning Outcomes Framework. (b) Sample competencies from Y2 course.

LOF consists of three major components: learning outcomes, competencies and assessments. While the learning outcomes have been established at the program level, competencies and assessment are defined at the individual course level. Figure 1 (b) shows an excerpt showing the learning outcome 2 with one of the associated 2<sup>nd</sup> level learning outcomes and the corresponding competencies for a second year course. For complete list, please refer to (Baumgartner & Shankarara man, 2013) and Ducrot et al., 2008. Though assessments play an important role in curriculum analysis, it is not the focus of our study and we leave it for future works.

### 3.2 Learning Taxonomies

Bloom's taxonomy divides the learning aspects into three domains; cognitive, affective and psychomotor. Cognitive domain focuses on the thinking level and has been widely applied in several domains including software engineering (Khairuddin & Khairuddin, 2008) and engineering (Gnana Singh & Leavline, 2013). It provides variety of action verbs to write the competencies for a course (Krathwohl, 2002).

In addition to having standard method to facilitate course design and assessment on the cognitive scale, understanding the progressive stages for learning and skill development by individual learners is also important. Dreyfus proposed a skill progression model from awareness to mastery (Dreyfus & Dreyfus, 1986). The skill progression model stages from novice to expert. The three main stages play major role in tracking the progress of the learners; awareness, proficiency and mastery (Judith et al. 2008).

## 4. Method

In this section, we describe our method to discover the impact of competencies on the curriculum.

### 4.1 Competency Cube

A competency cube is a conceptual integrated model which integrates the essential elements in design or assessment of learning aspects (Khairuddin & Khairuddin, 2008). Recall that our data consists of three components; learning outcomes (subsumes the competencies), cognitive levels, and skill progression levels. We integrated all these three essential components as shown in Figure 4. Each of the learning outcomes, as depicted on the z-axis of the cube, can be classified in relation to the level of cognitive functioning (see Figure 3, y-axis) as well as each learning outcome can be classified to the specific skill progression level (Dreyfus' model of skill development, x-axis).

The competency cube is similar to data model, where the cube can be sliced and diced across the dimensions to summarize the data. Therefore, when the cube is sliced we can classify the outcomes by cognitive levels and when diced, we can classify the outcomes by progression levels. This cube can be now integrated into a process framework for detailed data analysis.

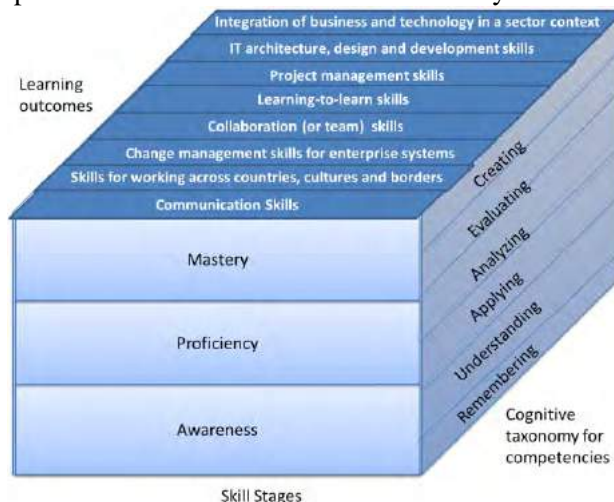


Figure 4. Competency cube – an integrated model of learning outcomes, Bloom's taxonomy and Dreyfus' skill development model

### 4.2 Automated Curriculum Analysis Framework

We now describe the process framework for curriculum analysis using the competency cube. Figure 5 depicts the sequential process of curriculum analysis framework. Given the full list of competencies expressed by the instructors, in the first stage, the competency cube generates the competencies that are aligned cognitively. To achieve this, Bloom's action verbs (Krathwohl, 2002) are used.



A simple text search is executed on each competency to discover verbs for every cognitive level and the competency is aligned to the corresponding cognitive level. In this process, if multiple verbs are found, the competency is aligned to multiple competencies. For example, “Create and evaluate the business process model for a given real world scenario”, consists of two cognitive functions; *Creating* and *Evaluating*. Therefore, we align the competency to both levels. The competencies will also be categorized and aligned by skills stages - progressively. In the above example, the competency will be aligned to the progression level, “*Mastery*”.

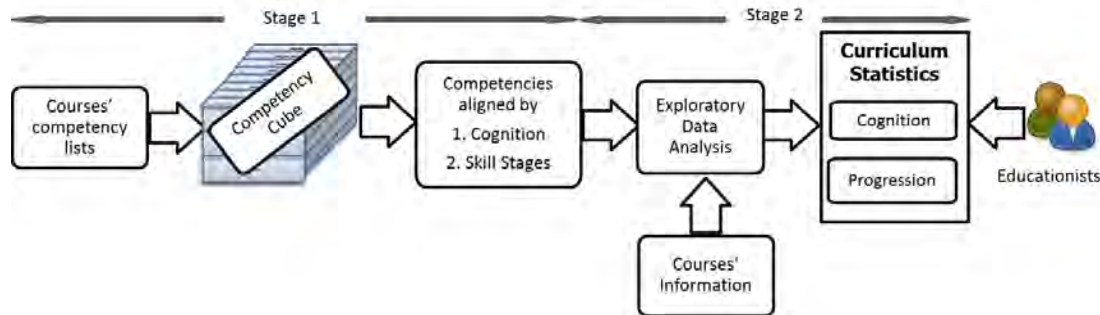


Figure 5. Automated curriculum analysis framework (ACAF)

In the second stage, exploratory data analysis (EDA) (Cook & Swayne, 2007) is executed on the course information (year, term, level, etc.) and on the processed competencies to generate the statistics on the overall curriculum. EDA is useful in summarizing the data using various graphical techniques such as box plots, line graphs, bar graphs, etc. These visuals aid the educationists to analyse the curriculum and make decisions. In summary, cognitive statistics aids in analyzing the curriculum by thinking levels, while skill progression statistics aids in analyzing the curriculum by skill development levels.

## 5. Experiments

### 5.1 Dataset

For our experiments we used the undergraduate core curriculum courses from School of Information Systems, Singapore Management University; 14 courses (Year1=4, Year2=6, Year3=4). The course coordinators for each course are required to provide the list of competencies (raw competencies) and map them to program-level learning outcomes. Initially, there were 398 raw competences and after applying the alignment process (Stage 1) discussed in Section 4.2, the total number of aligned competencies increased to 578. All our experiments are based on the processed competencies.

### 5.2 Cognitive Analysis Results

Recall that applying EDA on competencies which are cognitively aligned yields the curriculum analysis by thinking levels. Figure 6 shows the curriculum cognitive analysis by year.

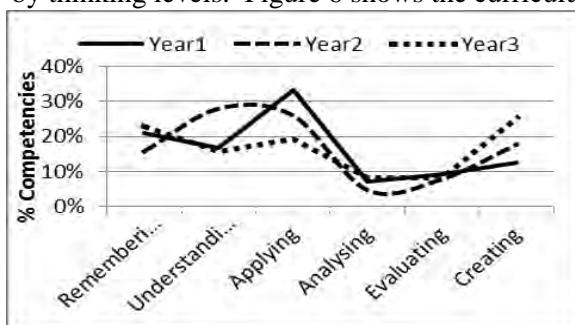


Figure 6. Cognitive: Curriculum analysis by year

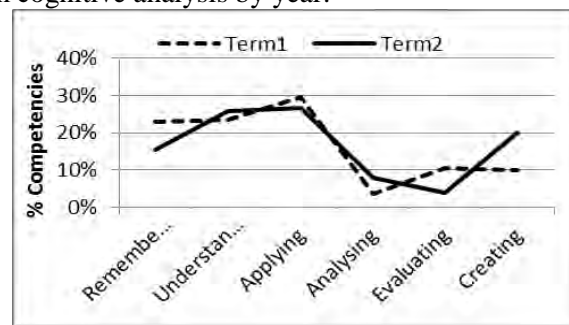


Figure 7. Cognitive: Curriculum analysis by term

We observe that year 1 (Y1) courses majorly focus on remembering and applying. This is because, Y1 courses such as software foundations and data management are technical in nature and are

designed to emphasize learning by application component. Y2 courses majorly focus on understanding and applying. At the same time, they introduce mastery by creating or developing new products. Y3 courses focus on mastery while testing the users' remembering capability. Figure 7 shows the curriculum cognitive analysis by term. We observe that term 1 (T1) courses focus on awareness by remembering and in contrast, term 2 (T2) courses focus on mastery by creating. Both the terms emphasize applying as the curriculum is mainly based on business application of technology.

Next, we evaluate the impact of competencies on curriculum by course level (foundation vs. advanced) as shown in Figure 8. Foundation courses focus on remembering and applying. In contrast, advanced courses focus on mastery by creating. We also observe that advanced courses also emphasize on understanding and applying.

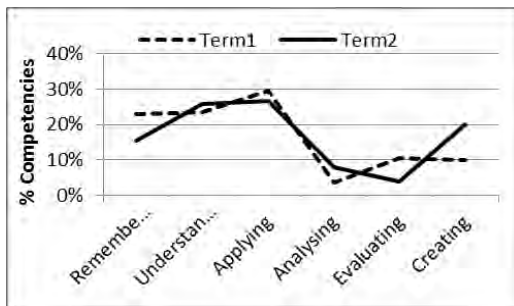


Figure 8. Cognitive: Curriculum analysis by level

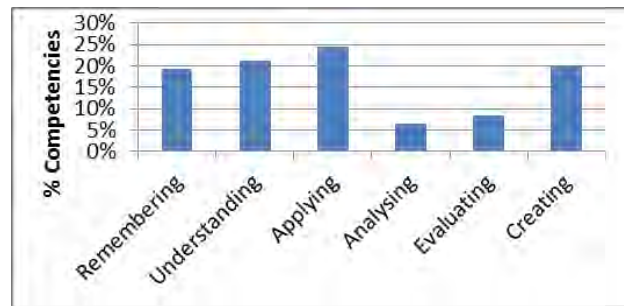


Figure 9. Cognitive: Overall curriculum analysis

Figure 9 shows the average cognitive analysis for curriculum. We observe that, in general the curriculum gives importance to remembering, understanding, applying and creating thinking levels. Evaluating and analyzing components are at a low level, less than 10%. This can be an aspect where the educationist might need to intervene to make decisions on the curriculum design for its improvements.

### 5.3 Progression Analysis Results

Figure 10 shows the overall curriculum progression analysis. We observed that, proficiency appears to be centered across the curriculum. Mastery appears to be similar to proficiency except for it has lower number of competencies (mean is lower). Awareness has excess variation. Some courses gave major emphasis on awareness while others don't. We observe that, for all years, awareness is given similar importance. However, the focus on proficiency skills decreased from Y1 to Y2. In contrast, focus on mastery skills increased from Y1 to Y2.

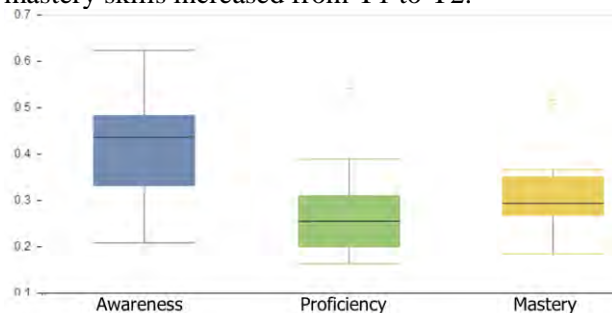


Figure 10. Progression: Overall curriculum analysis

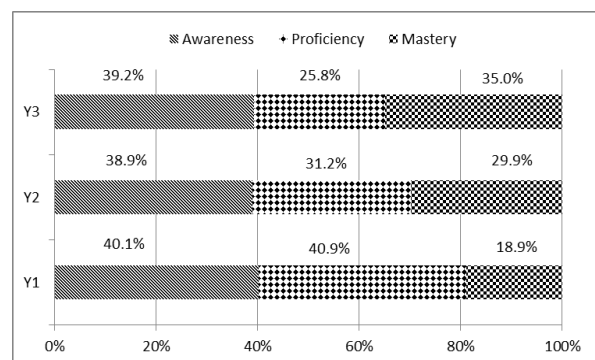


Figure 11: Progression: Curriculum analysis by year

Figure 10 and Figure 11 shows an inconsistent output for awareness. Figure 11 shows that the awareness component is similar for all the years. In contrast, Figure 10 shows that the awareness component has the highest variation.

### 5.4 Threats to Validity

Curriculum analysis consists of three high level dimensions; design (e.g. course design), impact (e.g. job placements) and policy (e.g. vision). In our paper, we only focused on the design analysis. In

particular we exploited the competencies for the analysis as they are the building blocks for the course design. The results from our experiments on the undergraduate curriculum show the strengths of the curriculum such as balanced cognition levels across the curriculum over the years. At the same time, the experiments identified some of the blind spots in the curriculum such as missing thinking levels for certain courses and low emphasis on evaluation and analyzing across the curriculum. However, the curriculum analysis at the design dimension is incomplete without studying the impact by other course components such as assessments, resources etc., and we leave such analysis for the future studies.

## 6. Conclusion

Analyzing curriculum is important to not only understand if the current goals are met but also to identify potential problems as early as possible and recommend possible solutions. In this paper, we attempt to analyse an undergraduate core curriculum based on the course competencies. The framework proposed can also be extended to recommendation system where the competencies can be recommended for a new course. In future it is also interesting to study the application of this framework on other curricula. Curriculum analysis is incomplete without analyzing other important components of the curriculum such as course delivery, assessments, resources etc., For example, one can extend the competency cube for assessment analysis and to recommend competencies for new courses.

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# Applying an Extensible Learning Support System to Learning by Problem Posing

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**Abstract:** This paper describes an investigation in which the Extensible Learning Environment with Courseware Object Architecture (ELECOA) was applied to a learning environment where problems are posed by learners. The aim of ELECOA is to provide a flexible learner-adaptive system that ensures both function extensibility and content reusability. To achieve this goal, the concept of a “courseware object” has been introduced to allow incremental implementation of various educational functionalities. Several learning environments have been based of this concept, including a self-learning environment compliant with the SCORM 2004 specification and a group-learning environment based on the Learning Design specification. This paper reports the results of a prototype implementation of ELECOA in an environment for learning by problem posing that is a mixture of self-learning and group-learning.

**Keywords:** Learner adaptation, extensible learning support system, courseware object, group learning, problem posing by learner

## 1. Introduction

Learning by question generation or problem posing is recognized as an effective way to enable learners to achieve a deep understanding of their studies (Brown and Walter, 2005). Recently, various learning environments have been designed and implemented to support problem posing by learners (Hirai, Hazeyama, and Inoue, 2009; Takagi and Teshigawara, 2006; Yu and Wu, 2012; Yamamoto, et al., 2013). These environments can be categorized into two types. In the first type, the system, equipped with certain domain knowledge on the study subject, supports and diagnoses questions generated by a learner (Yamamoto, et al., 2013). In the second type, the system provides a group learning environment in which learners can generate questions, share them with each other, and discuss how to improve them (Hirai, Hazeyama, & Inoue, 2009; Takagi and Teshigawara, 2006).

This study deals with the second type in which questions are generated in a group learning environment. As for the question generation environment, we used the Extensible Learning Environment with Courseware Object Architecture (ELECOA), which is capable of both function extensibility and content reusability (Nakabayashi, Morimoto and Hada, 2010). ELECOA is based on the concept of a “courseware object”. A courseware object is a program module that is used to incrementally implement various educational functionalities. In our previous study, ELECOA was applied to several learning environments (Nakabayashi, Morimoto and Aoki, 2012), including a learner-adaptive self-learning environment compliant with the SCORM 2004 specification (ADL, 2006) and a group-learning environment based on the Learning Design (LD) specification (Koper and Tattersall, 2005; IMS, 2003). In this study, a learning environment for question generation was designed by exploiting existing courseware objects for self-learning and group-learning in combination with newly developed courseware objects for the question generation functionality.

The following section explains ELECOA and the concept of a courseware object. After that, the courseware objects for question generation and their prototype implementation are introduced. Several possible designs of learning environments for question generation and future issues are discussed in the last section.

## 2. Extensible Learning Environment with Courseware Object Architecture (ELECOA)

To let content designers create educational content to achieve their learning objectives without requiring deep programming knowledge, conventional self-learning systems usually use an architecture in which the content is clearly separated from the platform. The content is an aggregation of learning materials related to a certain learning subject, whereas, the platform is equipped with generic functionalities, such as learner management, learning log recording, and learner adaption, that are common to the various study subjects. The drawback of this architecture is the lack of function extensibility. If content designers or instructional designers want to create content with new educational functionalities, it is quite difficult to extend the platform once it has been implemented. This is because there is no mechanism to assure that the existing learning content for the original platform will work correctly on the extended platform.

ELECOA was proposed as a way to overcome the drawbacks of conventional systems and achieve both function extensibility and system interoperability (Nakabayashi, Morimoto and Hada, 2010). ELECOA is characterized by its modular system architecture shown in Figure 1. It employs the concept of a “courseware object”, a building block that implements various educational functionalities, such as sequencing strategies of learning materials. As shown in Figure 1, the courseware object is clearly separated from the platform, thereby enabling incremental function extension by adding new courseware objects. Since the existing courseware objects and new courseware objects do not interfere with each other, the existing content will work correctly after the function extension.

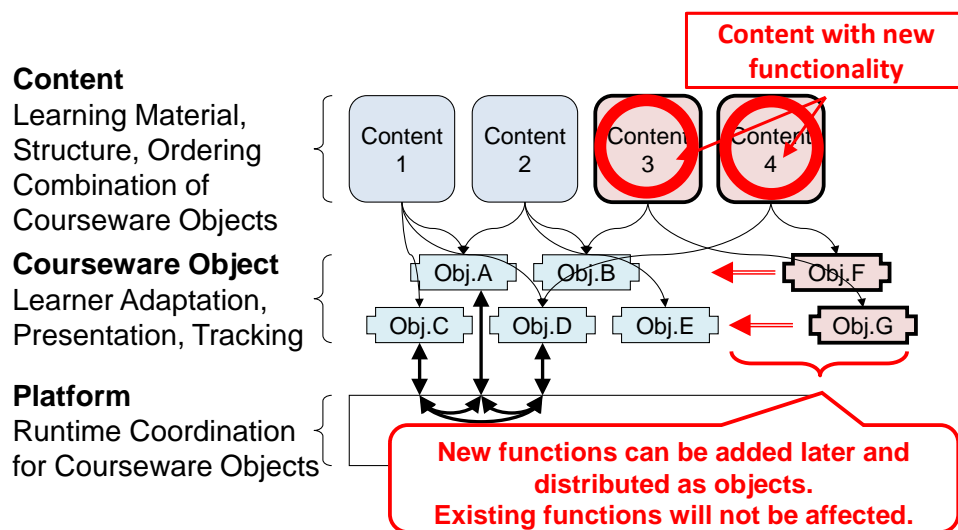


Figure 1. ELECOA framework.

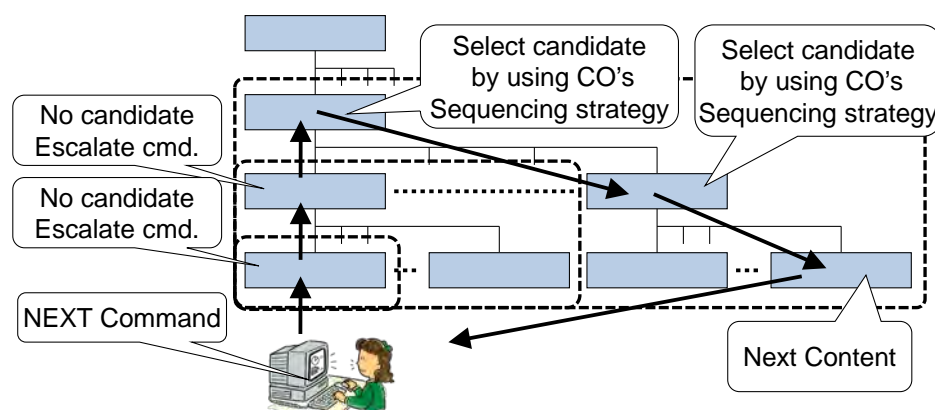


Figure 2. ELECOA for content with a tree structure.

ELECOA has been applied to both self-learning and group-learning environments with tree-like learning-flow control structures (Nakabayashi, Morimoto and Aoki, 2012; Nakabayashi and Morimoto, 2013). In these applications, courseware objects are allocated to the tree nodes, as shown in Figure 2. Each courseware object then manages the sequencing of the sub-tree under its node. According to the sequencing strategy implemented in it, the courseware object is responsible for selecting the most suitable node from among its child nodes. This sort of configuration makes it possible to implement different pedagogical strategies in different sub-trees. To achieve interoperability between courseware objects created by various implementers, the communication between courseware objects is limited to only between parents and children. The basic communication patterns and interface between the courseware objects have been designed within this limitation, and defining these basic communication patterns and the interface maximizes the interoperability of courseware objects. As the example of a self-learning environment, the SCORM 2004 specification, a standard for learner-adaptive content, has been implemented according this configuration (Nakabayashi, Morimoto and Hada, 2010). The implementation was successfully examined against test cases of the SCORM 2004 3rd edition test suite.

To apply ELECOA to an LD-specification-based group learning environment, we exploited the fact that the LD specification, which is capable of formally describing a group learning sequence, uses a tree format, like the self-learning environment (Nakabayashi, Morimoto and Aoki, 2012; Nakabayashi and Morimoto, 2013). The implementation is shown in Figure 3. A tree-like learning flow control is assigned to each individual learner. The courseware object allocated at each tree node controls the learning sequence of each individual learner by taking into account the learner's status such as learner's level and accomplishments. This is the same manner as the original ELECOA for self-learning. Thus, it is possible to implement a learning path control based on each individual's status as required by the LD specification. In addition, a courseware object can reflect the statuses of multiple learners in order to select each individual learning path. This is possible by designing the courseware object to be able to exchange information with other courseware objects assigned to other learners. This means that each learner's learning path can be controlled by his or her own learning status as well as those of other learners. Regarding communication tools, these are associated with the leaf node of the hierarchical structure as learning resources. This is a requirement of the LD specification, and at the same time, it is consistent with the original ELECOA self-learning environment in which learning resources are assigned to the leaf nodes of the content tree.

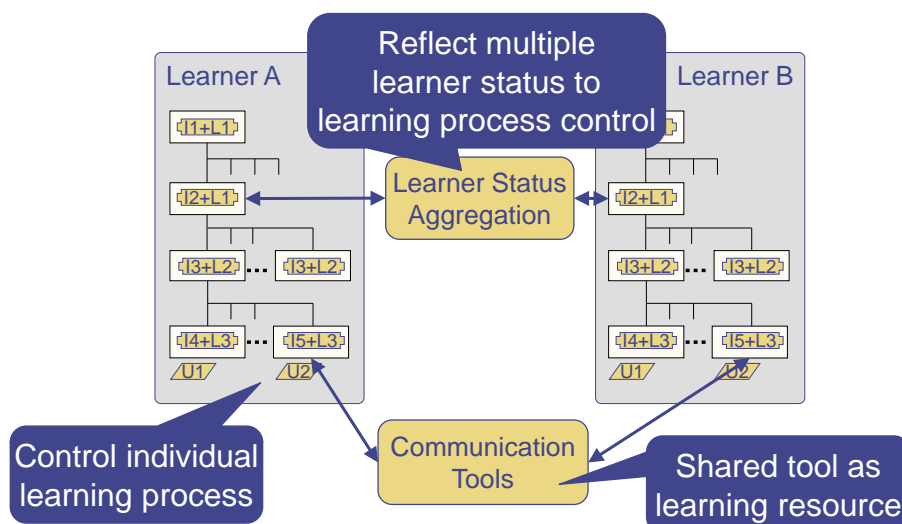


Figure 3. Implementation of group learning environment with ELECOA.

### 3. Application of ELECOA to Problem Posing

This section discusses an application of ELECOA to a problem-posing environment. The target is an environment in which a group of learners generates questions, then other learners and teachers share,

review, and improve the questions. The generated questions are sometimes utilized as course materials (Hirai, Hazeyama, and Inoue, 2009; Takagi and Teshigawara, 2006). It is not in the scope of this study but rather a potential future work item to implement the function to support or diagnose the problem-posing activities by using domain knowledge about the specific subject. Rather, this study proposes a generic group learning framework for problem-posing environments based on ELECOA courseware objects that were designed in accordance with common basic function requirements extracted from existing problem-posing environments which were implemented ad-hoc.

Problem-posing group learning environments require three basic functions:

- (1) Control of discussions associated with problems,
- (2) Generation and modification of questions as well as generation of associated discussions, and
- (3) Utilization of questions as materials

The first requirement is common to the group learning environment described in the previous section. In the problem-posing environment, however, the role of the learner who creates the problems may be different from other learners and teachers. There can be a pre-defined sequence of discussions that is used to control the discussions associated with each generated problem. The second requirement is specific to problem-posing group learning environments. The original ELECOA architecture assumes that the learning control tree and associated learning resources are defined before the start of learning. Problem-posing group learning environments require a capability that lets learners generate questions dynamically while they are learning and to share and modify these questions based on discussion. The third requirement is that the generated questions should be able to be dynamically utilized as conventional self-learning materials.

Figure 4 depicts the ELECOA-based problem-posing group learning environments designed according to the above requirements. The “Problem list” courseware object has “problem” courseware objects as its child nodes. Each problem courseware object has a “problem content” learning resource and “discussion” courseware object as its children. The “Discussion” courseware object has “discussion content” learning resource. This tree structure is assigned to every learner participating in the group learning.

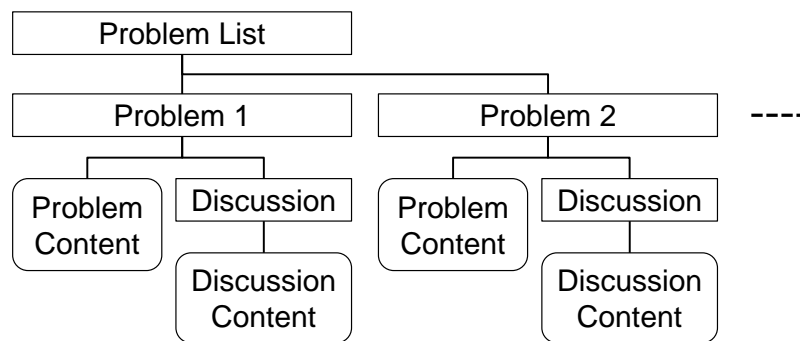


Figure 4. Implementation of problem posing group learning environments with ELECOA.

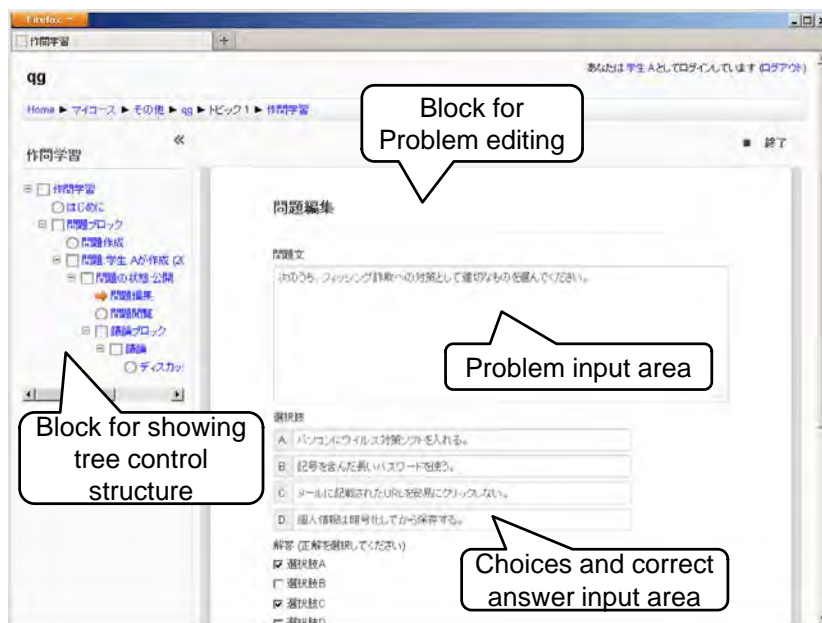
The problem list courseware object accepts and executes commands from learners, including “create new problem”, “list problems” and “select problem”. In particular, the “create new problem” command generates a new problem courseware object as the child of the problem list courseware object. The problem courseware object executes commands such as “edit problem content”, “view problem content” and “submit problem”. The discussion courseware object executes commands such as “submit comment” and “view comment”.

The problem courseware object and discussion courseware object manage the state transition table to control the problem-posing learning scenario. For example, a certain problem-posing learning strategy may require the following learning process:

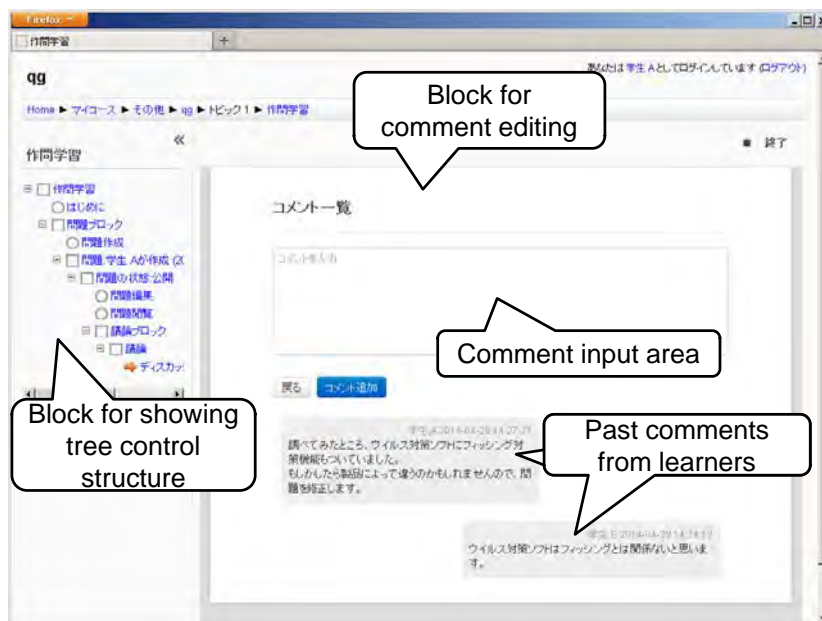
- (1) A learner creates a new problem,
- (2) Other learners answer the problem,
- (3) Other learners evaluate and give comments on the problem,
- (4) The learner who created the problem modifies the problem,
- (5) The learner may ask for comments from the teacher before he/she modifies the problem,
- (6) These steps are repeated until there are no comments to be reflected.

In this learning scenario, the learner who created the problem must modify question by him-/herself. There can be other learning scenarios in which every learner has an opportunity to give comments and modify the problem at any time. It is possible to implement an appropriate state transition table to be managed by each courseware object according the chosen learning scenario.

Figure 5 shows screenshots of the prototype implementation. The left area of each window is the tree control structure corresponding to the one shown in Figure 4. From this area, the learners can take commands to create new problems, modify problems, and participate in discussions. The prototype was developed as a Moodle plugin so that the Moodle learner group assignment is inherited by the developed environment.



a) Problem editing window



b) Comment editing window

Figure 5. Screenshots of prototype implementation.



## 4. Conclusion

This paper described an investigation and prototype application of ELECOA to a learning environment for problem posing by learners. The aim is to provide a generic system framework for problem-posing environments. Several courseware objects were developed according to the requirements and a prototype system was implemented. In the future, we will deploy this system in an actual classroom environment and assess how it works. It will also be necessary to improve the communication protocol between newly developed courseware objects so that they are consistent with the existing self-learning courseware objects to develop an unified learning environment capable of integrating self-learning and group learning.

## Acknowledgements

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# AR based Skill Learning Support System with Velocity Adjustment of Virtual Instructor Movement

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**Abstract:** In this paper, we propose the skill learning support system to give learner the real time feedback information. In this system, to construct feedback, the virtual room based on recorded user's image is used. In virtual room, instructors bone model is displayed too. In learning process, learner imitates displayed bone model to get the knowledge about skill corresponding to instructor's movement. By displaying virtual instructor and learner's body in the virtual room, learner can see virtual instructor's movement and learner's posture. Additionally, virtual instructor's speed can be adjusted by learner's intention. To control virtual instructor's speed, learner's voice is used as input information. To get user's voice and record image, Microsoft Kinect sensor is used as a camera and a microphone in the developed prototype system. To evaluate this approach, the prototype system for learning skill of soft tennis (swing form) was developed. So, evaluations experiments were conducted by using the prototype system of soft tennis and effectiveness of adjustment of virtual instructor's speed in learning process was shown.

**Keywords:** Skill Learning, Augmented Reality, Velocity Adjustment, Soft Tennis

## 1. Introduction

Recently, in support of skill learning techniques, measurement devices have often been used to record learner movements. Many studies have developed supportive learnings to enhance the skill learning techniques. Gotoda conducted research on a training support method using measurement technologies (Gotoda, Matsuura, Nakagawa, Miyaji, 2013); this method provided the learners with a real-time system for learning the shot timing in tennis. The system predicted the trajectory of the ball by measuring the position of the ball from the moving image and by analysing the change in position of each frame. By using the system, a learner can easily learn appropriate shot-timing. However, motion capture in support of skill learning techniques remains very expensive. One example of a motion-capture device is the Microsoft Kinect sensor. Kinect can measure joints without markers, and therefore, Kinect is widely used to develop learning support system (Hamagami, Matsuura, Kanenishi, Gotoda, 2012; Tamura, Uehara, Maruyama, Shima, 2013; Chuang, Kuo, Lee, Tseng, Hsu, 2013) and rehabilitation system (Meng, Fallavollita, Blum, Eck, Sandor, Weidert, Waschke, Navab, 2013) and learning support system (Akawaza, Takei, Nakayama, Suzuki, 2013; Anlauff, Cooperstock, Fung, 2013; Iwane, 2012; Mitsuhara, 2012; Shih, Wu, Chen, 2013; Thakkar, Shah, Thakkar, Joshi, Mendjoge, 2012). In particular, Ochi et al. (2013) proposed the air squat training support system using the Kinect to measure user movements. By using the Kinect, the system obtains skeletal information from the side suitable for an air squat. The system can create feedback from the skeletal information for the learner. Yamaoka et al. (2012) proposed a system for the flying disc throw; the proposed system captures a learner's arm movements, checks their height, and displays feedback messages to adjust their actions.

On the other hand, in our research group, we proposed a skill learning support method, in which the learner imitates a display showing arm movements (Sumimoto et al., 2013). Our method presents the orbit of the bending and stretching motions of the arm to the learner. In this paper, through experimental results, we show our method for skill learning in slow motion. Thereby, we prove that the presentation velocity affects learning. Therefore, in this study, we propose a skill learning support method that considers velocity adjustments of the virtual instructor. By adjusting the velocity of the virtual instructor, our system teaches at a suitable rate based on the time of learning. While learning, a learner can adjust the virtual instructor's speed in order to successfully imitate the instructor's

movements. As feedback, the virtual instructor is displayed using AR-technology (Augmented Reality-technology). In this paper, we describe the prototype learning support system for soft tennis, and detail our experiments using this prototype system.

## 2. The AR Based System for Skill Learning Support System

### 2.1 System Summary

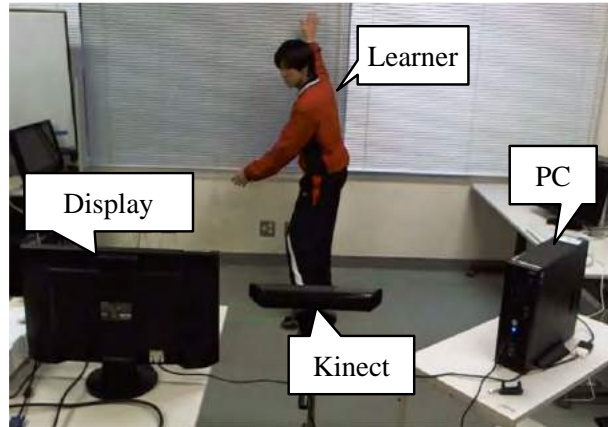


Figure 1. Overview of the Proposed System.

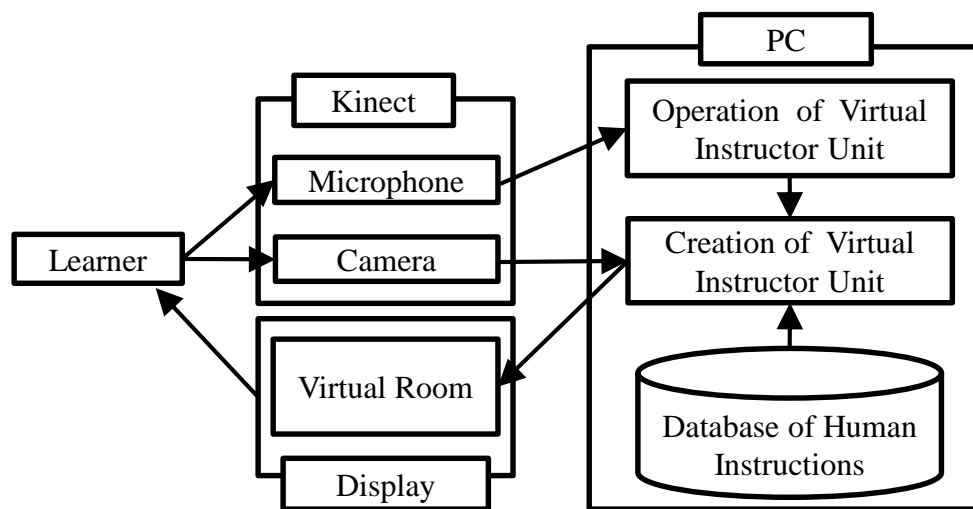
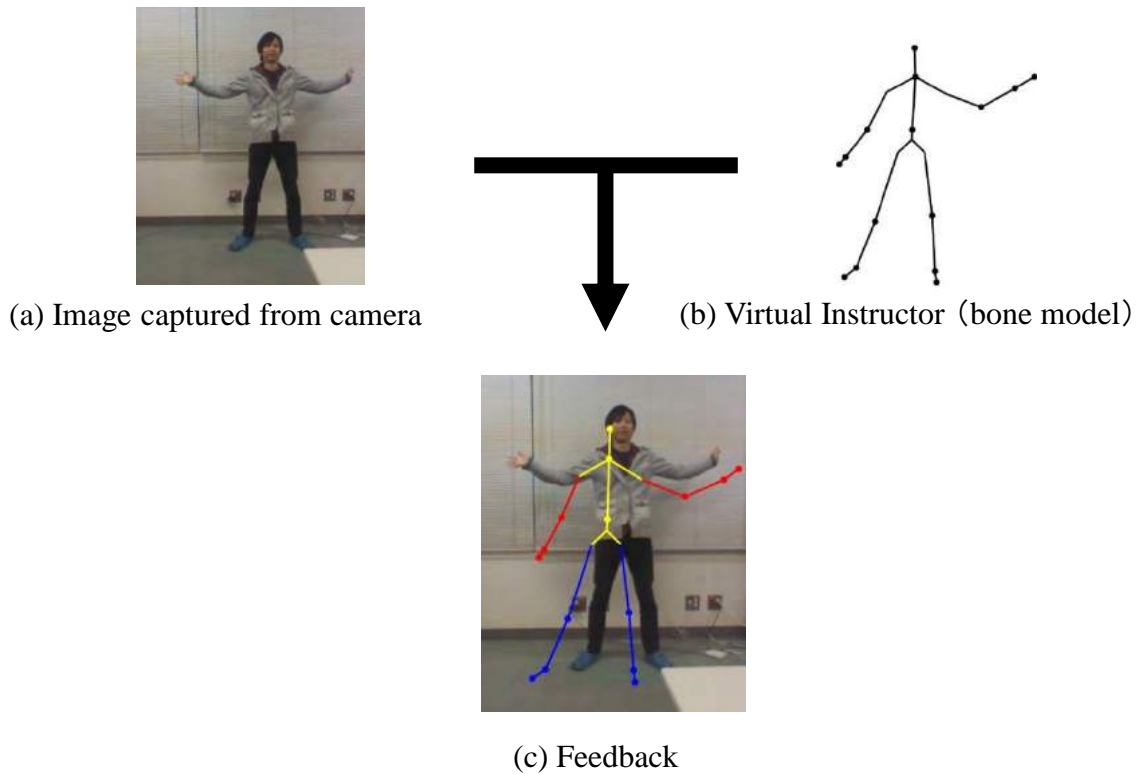


Figure 2. Framework of Proposed System.

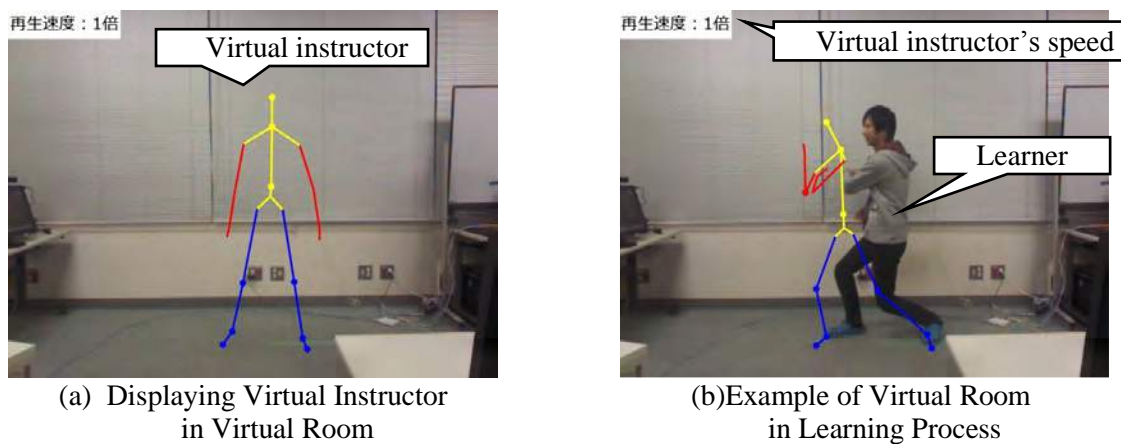
Figure 1 shows the overview of the proposed system. The system consists of the display, Kinect and PC. Figure 2 shows the framework of the proposed system. The system has two units: the operation of virtual instructor unit and the creation of virtual instructor unit. The operation of virtual instructor unit adjusts the velocity of the virtual instructor via instructions from the microphone. Feedback is sent on the display. Figure 3 shows the feedback. The system develops the feedback by adding the virtual instructor to the image captured by the Kinect. The virtual instructor is displayed as a skeleton, and makes some soft tennis swing motions.

### 2.2 Virtual Room and Velocity Adjustment of Virtual Instructor

Figure 4 shows the virtual room presented on the display. Figure 4 (a) is the display of the virtual instructor in the virtual room. The virtual instructor presents the movement instructions. Figure 4 (b) is an example of the virtual room during learning. The learner learns soft tennis skills by imitating the movement of the virtual instructor. The virtual instructor's current speed is displayed in the left corner



**Figure 3.** The Feedback Image for the Learner.


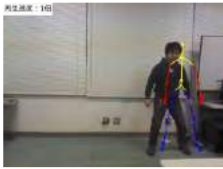







**Figure 4.** Virtual Room Produced by The System.

of the virtual room, as shown by Figure 4 (b). In the virtual room, adjusting the virtual instructor's speed changes the virtual instructor movement.

In this system, the learner can adjust the speed of the virtual instructor movement. The adjusted movement of the virtual instructor and its normal movement are shown in Table 1. From the images in Table 1, at first, the learner cannot obviously imitate the virtual instructor movement at normal speed. By adjusting the virtual instructor's speed, the learner is expected to imitate the movement. This adjustment is conducted by learner's verbal instructions. Therefore, the learner can adjust the velocity without using his or her hands.

**Table 1. Differences of displayed time**

| time(sec) | adjusted movement(slow)   | normal movement   |
|-----------|---|---|
| 1         |    |  |
| 2         |    |  |
| 4         |    |  |
| 8         |    |   |
| 12        |   |   |
| 16        |  |   |

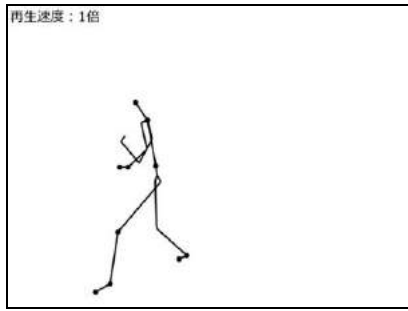
### 3. Evaluation experiment

#### 3.1 Purpose and Condition

We conducted an experimental evaluation of the system, wherein three types of virtual instructors were prepared (to teach back swing, fore swing and smash). The subjects were three college students (A, B and C) who were inexperienced at soft tennis. The velocity of the virtual instructor for subjects A and B was set at slow speed. The velocity of the virtual instructor for subject C was set at normal speed. The velocity of the slow subject was one-quarter of the normal speed. The subjects imitated the virtual instructor's movement 60 times for each form (total of 180 movements).

#### 3.2 Result

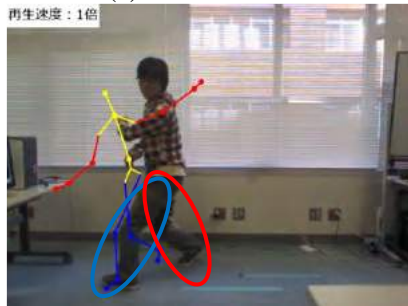
As examples of results of experiment, virtual instructor and subjects' steps about back swing are shown in Figure 5. Red circle and blue circle corresponded to left foot and right foot respectively. Foot positions of subject A and B are similar to the virtual instructor. However foot position of subject C is reverse. By slowing the virtual instructor movement, it was found that the subject can imitate the movement more easily. In addition, examples of subject C are learning results of fore swing and smash are shown in Figure 6 and 7 respectively. In particular, the wrong movement of subject C shows in



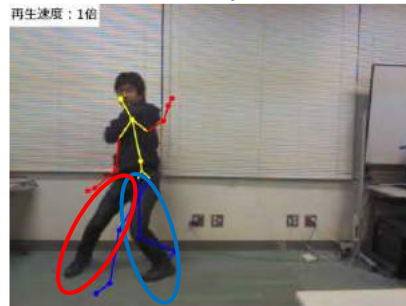
(a) Virtual Instructor



(b) Subject A

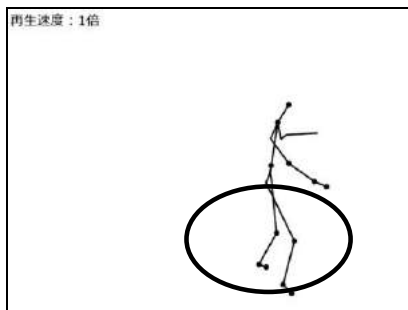


(c) Subject B

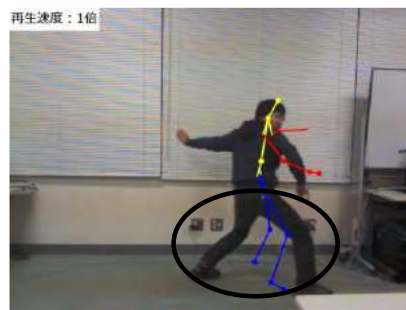


(d) Subject C

Figure 5. Difference of Subjects' Step (form: back swing, time: 3sec).

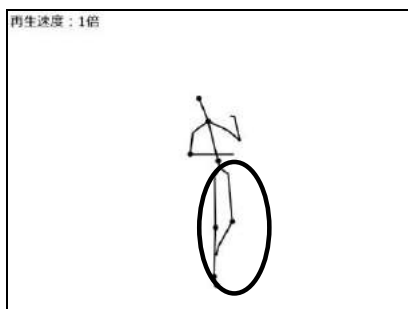


(a) Virtual Instructor



(b) Subject C

Figure 6. Wrong Step of Subject C (form: fore swing, time: 3sec).



(a) Virtual Instructor



(b) Subject C

Figure 7. Wrong Step of Subject C (form: smash, time: 4sec).

circles in these figures. Although, subject C cannot imitate the virtual instructor movement, it is expected that other subjects can get knowledge of suitable movement from given the virtual instructor. Right movements (fore swing, back swing, smash) have 21 important points (such as positions of feet). By using developed system with slow speed virtual instructor, it is found that subject A can get all points knowledge. Subject B can get 16 knowledge (76%). On the other hand, subjects C can get only 10 knowledge (47%). From these results, it is expected we confirmed possibility that the learner can acquire the skill by imitation the virtual instructor at the slow velocity.

From these results, it is expected possibility that the learner can acquire the skill by imitation the virtual instructor at the slow velocity.

## 4. Conclusion

This study proposed a skill-learning support method considering the velocity adjustment of the virtual instructor. We developed a system that presents the virtual instructor with velocity adjustment. From the results of the evaluation experiment, we confirmed the possibility that the learner can acquire skills by imitating the virtual instructor at the slow velocity.

In future works we will improve the system by adding other feedback methods (such as voice feedback). In addition, we will need to conduct a detailed evaluation experiment to verify what skills can be taught when a subject chooses to run the virtual instruction at full speed.

## Acknowledgements

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# Audio Subtitle Mapping System between Slide and Subtitles by Co-occurrence Graphs on VOD Lecture

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**Abstract:** Many VOD lectures are played alongside a video, making it difficult to understand some content due to mishearing something or not catching the sound on a slide. Therefore, the ability to display audio subtitles that explain data or paragraphs on slides may improve student understanding of some lectures. This system will generate co-occurrence graphs for each paragraph and subtitle on a slide (Microsoft PowerPoint), and depending on the type of co-occurrence graph, and seek correspondence relations. These correspondence relations are used to support understanding of audio information by converting it to textual data and presenting displays and printouts of explanatory information on subtitles for each part of a slide.

**Keywords:** VOD Lecture, Co-occurrence Word, Mapping Subtitle to slide

## 1. Introduction

Presentation of video and slides is a basic function of e-learning systems. E-learning systems are increasingly being provided according to SCROM formats (Advanced Distributed Learning; Fallon & Brown, 2003), like Moodle (Dougiamas). Moreover, the effectiveness of e-learning systems has been developed many researches (Kitagawa & Onishi, 2007; Matsumoto, Miyauchi, & Koga, 2010). Moodle is a management system for e-learning systems, and they are continuing to develop a variety of features for it. However, its main purpose is the development of systems and lecture management functions.

In the form of studies related to research concerning lecture content, systems have been developed to conduct summaries of streaming data utilizing colors, caption information, and animation information (Watanabe, Wu, & Yokota, 2010), but the information utilized is unsuitable for use in ordinary lectures. Speech retrieval systems based on techniques utilizing the degree of relevance of subtitles (Itou, Fujii, & Ishikawa, 2001; Mouri, Funabuki, & Nakanishi, 2008), as well as video segment inference systems utilizing techniques that apply statistical processing based on frequency information (Kobayashi, Koyama, Shiina, & Kitagawa, 2011), are under development. Moreover, research on helping students understand content is being conducted with respect to assignment submission management systems (Seki, Matsui, & Okamoto, 2008) as well as writing assignment problems. However, these systems are intended to improve post-lecture understanding. In addition to these, systems development is also being conducted with respect to authoring systems for instructors.

One of the advantages for students taking courses in e-learning systems is the ability to pursue learning in a free environment over a network. For many VOD lectures, content is considered difficult to grasp because the viewer does not know what he or she has missed or how the slides correspond to what is said, as the lectures are simply played back in time with the video. It is thought that development has been slow on systems for making it as easy as possible to understand VOD lectures while watching them, by making lectures more comprehensible using information provided via e-learning systems. Therefore, the ability to display subtitles that explain data or paragraphs on slides may improve student understanding of some lectures. This system will generate co-occurrence graphs for each paragraph and subtitle on a slide (Microsoft PowerPoint, later "PPT"), and depending on the type of co-occurrence graph, seek correspondence relations. These correspondence relations are used to support



understanding of audio information by converting it to textual data and presenting displays and printouts of explanatory information on subtitles for each part of a slide.

## 2. Audio Subtitle Mapping System Development for VOD Lecture

The system created in this study is being developed as an add-on to an e-Learning lecture system through a VOD system that uses a credit transfer system in an education consortium composed of six universities that centers on okayama university science in Japan.

The system retrieves slide data and audio data from content in the e-learning system, and after converting the audio data into text, associates utterance times and executes a similarity analysis of the slide and subtitles. The system is structured to present video, subtitles, and slide data of VOD lectures stored in a database. Videos display as is, and slides switch in sync with change times while subtitles matching slide text boxes are simultaneously displayed.

As an addition to standard VOD lectures, this system displays video of a lecture with subtitles on the upper left of the screen (Figure 1). In addition, it displays slide on the upper right side and mapping subtitle to text box of PPT.

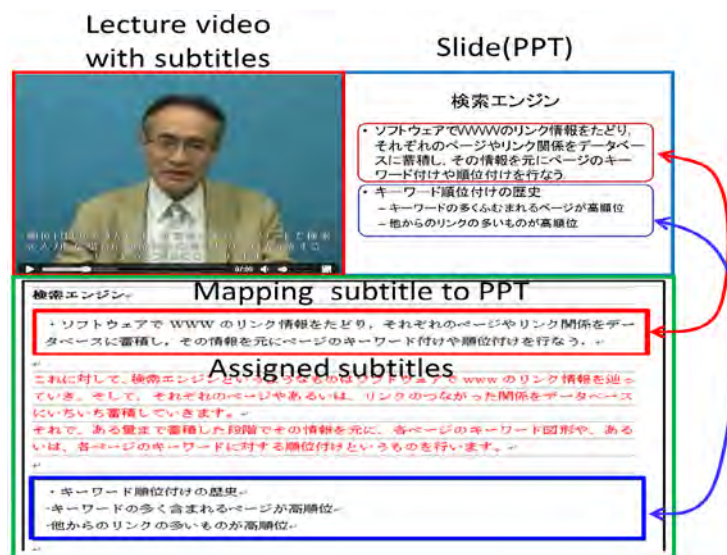


Figure 1. Screen of audio subtitle mapping system.

## 3. Mapping Subtitles in PPT

### 3.1 Co-occurrence Words and Co-occurrence Graphs

Co-occurrence words are generally considered words that appear alongside one another in the same text. A co-occurrence graph is generated using each page of a PPT and the subtitles corresponding to each PPT page as targets.

#### (1) Extracting PPT Co-occurrence Graphs

All descriptors in the PPT are divided into individual text boxes(Figure 2(a)), the retrieved text is partitioned into morphemes using morphological analysis(Figure 2(b)) (Kudo, Yamamoto & Matsumoto, 2004), and a co-occurrence graph(Figure 2(c)) is generated.

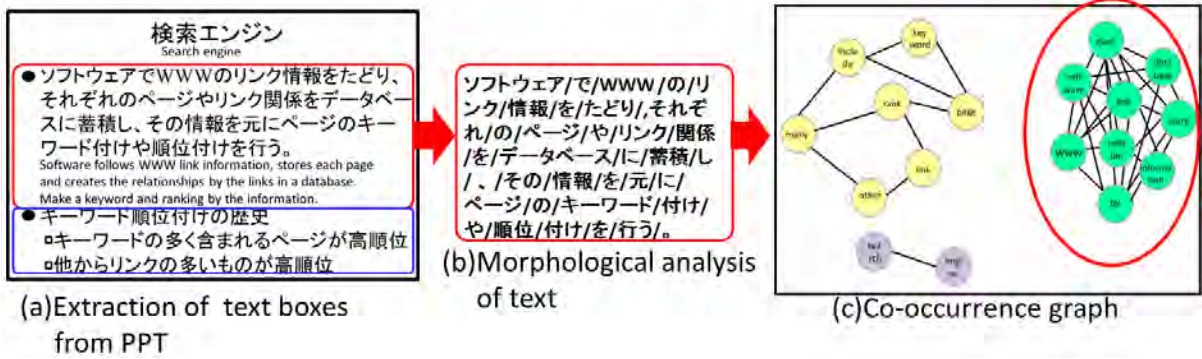


Figure 2. Generation Process of co-occurrence Graph by extracting PPT.

(2) Extracting Subtitle Co-occurrence Graphs

Subtitle co-occurrence graphs are generated by partitioning morphemes in subtitles for individual PPT pages. Then, a graph is generated by linking words that have co-occurrence relations using node and word proximities. Since the word count of a co-occurrence graph of the subtitles on each PPT page can be high, making it more complicated, the word count is refined. Refinement is executed using strength of co-occurrence between words by Jaccard similarity coefficient (Jaccard, 1921; Romesburg, 2004; Tan, Steinbach, & Kumar, 2005), and it eliminates edges of co-occurrence graphs. Finally words with less sum of Jaccard similarity coefficient are also eliminated.

For example, the relations between subtitles and co-occurrence graphs in Figure 3 are used the subtitles from section 2, page 6 of the VOD lecture “Database”. The left side table is list of subtitles, it is divide into each PPT pages. The right side is the co-occurrence graph which is assigned the refined co-occurrence graph to subtitles.

A part of co-occurrence graph which is created from subtitle is eliminated by Jaccard similarity coefficient, some subtitle is also eliminated in mapping system. We are considering that eliminated subtitles are not important. In case of co-occurrence graph is created from some subtitles, these subtitles assign to co-occurrence graph. Then mapping system assign these subtitle to text block of PPT.

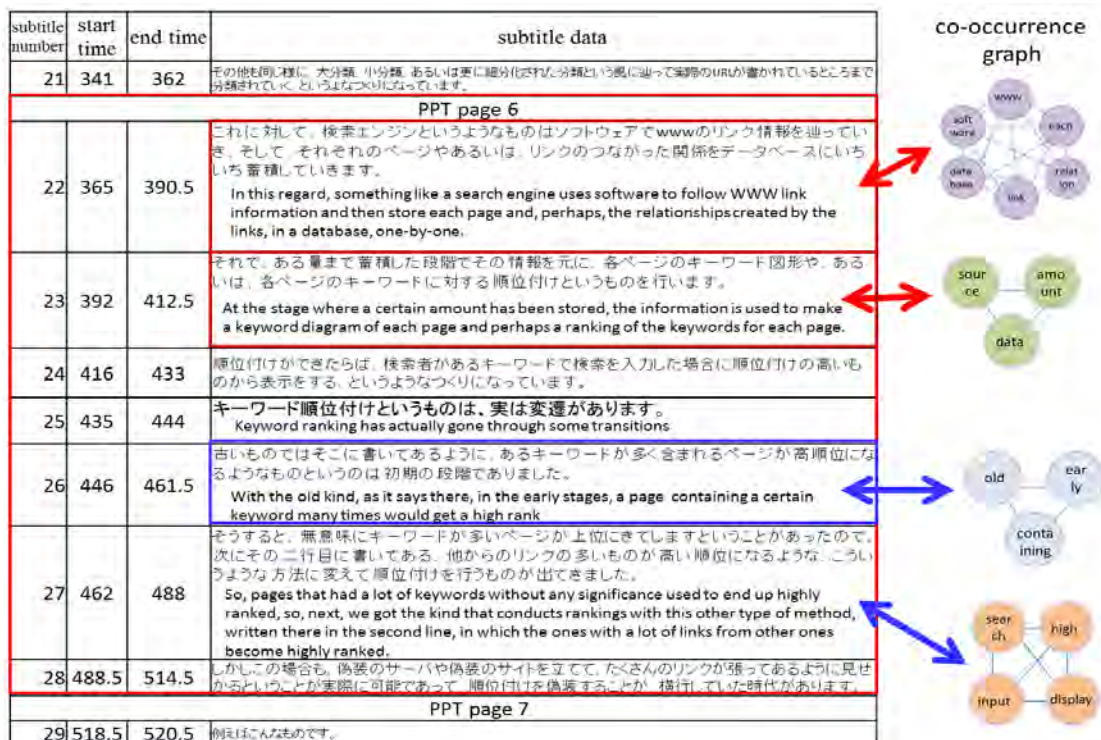


Figure 3. Mapping subtitles to refined co-occurrence graphs.

### 3.2 Co-occurrence Graph Corresponding Ratios

Based on a search of a corresponding count for the words in a subtitle co-occurrence graph and the words in a PPT co-occurrence graph, a corresponding ratio for the PPT co-occurrence graph and subtitle co-occurrence graph is generated with the following method.

Let  $C_{PPT}$  be the number of co-occurrence words in PPT,  $C_{Sub}$  be the number of co-occurrence word in subtitles, and  $CP(G_{PPT}, G_{Sub})$  be corresponding ratio of  $G_{PPT}$  and  $G_{Sub}$ .

$$CP(G_{PPT}, G_{Sub}) = \frac{|C_{PPT} \cap C_{Sub}| \times 2}{|C_{PPT}| + |C_{Sub}|}$$

In the PPT and its subtitles from section 2, page 6 of the VOD lecture “Database”, for example, when the word set for the co-occurrence graph created from the PPT  $C_{PPT} = \{\text{software, database, WWW, storage, data, relation, source, each, execute}\}$ , and the word sets for three types of co-occurrence graphs  $G_{Sub1} = \{\text{relation, WWW, software, follow, each, database}\}$ ,  $C_{Sub2} = \{\text{amount, data, source}\}$ ,  $C_{Sub3} = \{\text{search, high, input, display}\}$  the agreement ratios between co-occurrence graphs are  $CP(G_{PPT}, G_{Sub1}) = 5 \times 2 / (9 + 6) = 2/3 = 0.6667$ ,  $CP(G_{PPT}, G_{Sub2}) = 2 \times 2 / (9 + 3) = 1/3 = 0.3333$  and  $CP(G_{PPT}, G_{Sub3}) = 0 \times 2 / (9 + 4) = 0/13 = 0.0000$ . Figure 4 shows relation between co-occurrence graphs of PPT and subtitles.

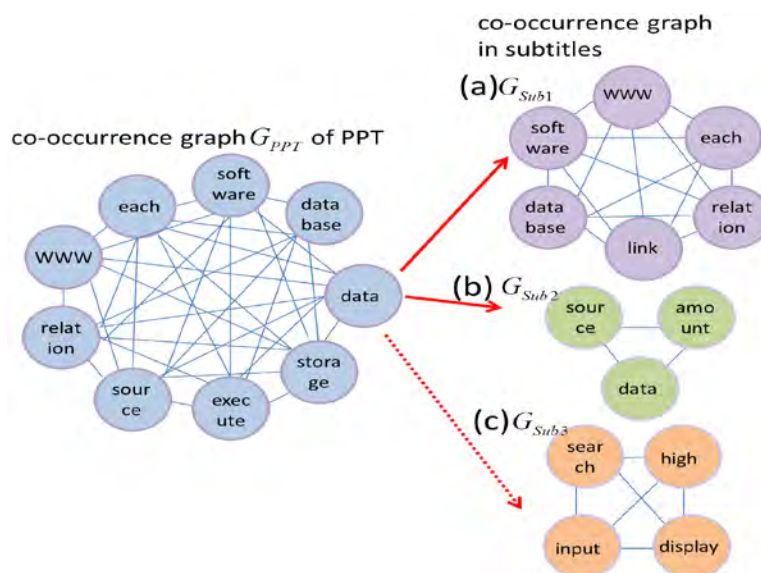


Figure 4. Corresponding ratio between PPT and subtitles

Summary which is not assign to text block of PPT is created. The ratio of summary original subtitles is defined the number of subtitle of summary divided by the number of original subtitles.

### 3.3 PPT and Subtitle Co-occurrence Words

Lastly, subtitle co-occurrence graphs with higher thresholds are correlated with PPT co-occurrence graphs, and subtitle co-occurrence graphs with lower thresholds are eliminated.

In the PPT and its subtitles from section 2, page 6 of the VOD lecture “Database”, for example, while the agreement ratios between co-occurrence graphs are 0.6667, 0.3333, 0.0000, co-occurrence graphs with an agreement ratio with a threshold lower than 0.2 are removed from correspondence relations with PPT. An example of a PPT and subtitle co-occurrence graph is shown in Figure 5. In Figure 5, subtitle co-occurrence graphs corresponding to PPT co-occurrence graphs are encircled by the same color.

Summary which is not assigned to text block of PPT is created. The compression ratio of summarization is defined as the ratio of number of sentences in assigned subtitle to the number of sentences in the original subtitles. In an example of the compression ratio of summarization for subtitles from section 2, page 6 of the VOD lecture “Database”, the compression ratio of the subtitles except the page only for title page and figures was: minimum is 0.167, maximum is 0.6 and average is 0.38.

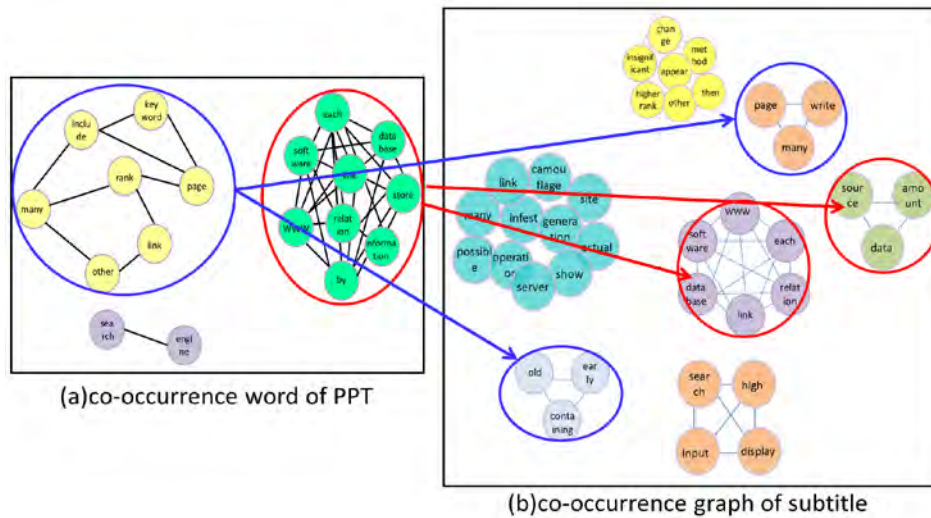


Figure 5. Refined mapping co-occurrence graph of PPT and subtitles.

#### 4. Evaluating Subtitle and PPT Correspondence Relations

Correspondence relations between PPT and subtitles from section 2, page 6 of the VOD lecture “Database” were evaluated by Japanese students. The evaluation method was in two parts. The first was to rate the match level of corresponding subtitles at one of four levels: skewed, slight, frequent, and consistent. The second was to evaluate them as captions by assigning a rating out of five (1, 2, 3, 4, 5). Table 1 is result of evaluations.

Table 1: Evaluation by questionnaires.

| PPT page number     | Evaluation1 |    | Evaluation2 |    |
|---------------------|-------------|----|-------------|----|
|                     | P1          | P2 | P1          | P2 |
| No. 1(title page)   | -           | -  | -           | -  |
| No. 2               | consistent  | 5  | consistent  | 5  |
| No. 3               | slight      | 3  | slight      | 3  |
| No. 4               | slight      | 3  | slight      | 4  |
| No. 5               | consistent  | 5  | slight      | 2  |
| No. 6               | slight      | 2  | slight      | 2  |
| No. 7               | slight      | 2  | slight      | 2  |
| No. 8               | slight      | 3  | slight      | 3  |
| No. 9               | slight      | 1  | slight      | 1  |
| No. 10              | slight      | 5  | skewed      | 4  |
| No. 11              | skewed      | 1  | skewed      | 1  |
| No. 12              | consistent  | 5  | consistent  | 5  |
| No. 13(figure page) | -           | -  | frequent -  | -  |
| No. 14              | frequent    | 4  | slight      | 4  |
| No. 15              | slight      | 3  | slight      | 4  |
| No. 16              | consistent  | 5  | consistent  | 5  |
| No. 17              | slight      | 4  | consistent  | 5  |

Ratings as captions were given according to the degree that the subtitles adhered to the content, with half or greater adherence receiving a rating of three or higher. For correspondence relations in

which the level of corresponding subtitles were judged “slight,” strict refinement when generating a co-occurrence graph was also taken into consideration.

## 5. Future Works

This system generates co-occurrence graphs from PPT and subtitles in PPT of VOD lecture for the purpose of facilitating student comprehension of lectures. Going forward, this system must be used, with foreign students as a target user ship, in order to evaluate its efficacy. We would also like to create a system that helps students gain a deeper understanding of lectures by generating summaries from PPT-compatible subtitles.

As future works, the subtitles will also possess the ability to add readings of kanji (Chinese characters) to assist foreign students. In addition, research of learning of terminology has been derived (Sun, Kashiwagai, Kang, Kiyomitsu, & Ohtsuki, 2011). As future research, we are considering that extracting data of terminology from actual lecture and developing learning system for terminology using its extract data.

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# Code Reading Environment according to Visualizing both Variable's Memory Image and Target World's Status

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**Abstract:** In this paper, we describe the code reading environment according to visualizing both variable's memory image and target world's status. We had constructed those environment that have two important function. One is the function by which the teacher can reflect his/her intention for instruction on the view of target world's status. Another is the function by which the programming beginner can more deeply understand a program using our proposed environment.

**Keywords:** Code reading environment

## 1. Introduction

We think that it is for novice programmers important to understand the relationship between the algorithm and the program in code reading phase observing both memory image of variables in program and status of target worlds. In typically, almost all of novice programmer attend a lecture using educational materials that is included in target world dependency. The beginner can reproduce the status of target world (STW) using the materials. In contract, expert programmer also can analyze a memory image of variables (MIV) in programs step-by-step using typical debugger. In case of simple calculation's task, the representation of STW and MIV are almost same. Although, in case of complex algorithm or data structure, the STW have different representation from MIV. The expert programmer can estimate the STW by observing the MIV using debugger in a program that includes complex algorithm or data structures. Although the beginner programmer cannot because he/she cannot understand the relationship among program, STW and MIV.

Many systems that support to understand the program and algorithm for novice programmer had constructed by many researcher (Fossati *et al.* (2008), Gabor (2009), Kogure *et al.* (2013), Malmi *et al.* (2004) and Noguchi *et al.* (2010)). We think that these systems have two issues. First issue is that the teacher cannot freely decide the format visualizing the STW. Some systems can reproduce the STW in any step in programs. In those system, although, the teacher cannot reflect his/her intent for instruction to the view of STW. Second issue is that the learner cannot show the STW and MIV synchronously. Almost all system can show the STW for particular algorithm. In the other hand, typical debugger can show the MIV for almost all program that is written for a variety of algorithm. Although, some systems and debugger cannot display the relationship among program, STW and MIV.

The aim of this study is to solve the issues. We had constructed new code reading environment according to visualizing the relationship among a statement of program, STW and MIV for novice learner. This environment has two important function and three basis function. One important function is the function that gives the teacher an environment by which he/she can define the view of STW according to his/her intent. Another is the function that gives the learners an environment by which they can understand the relationship among program, STW and MIV.

## 2. Fundamental Consideration

### 2.1 Definition of the State of Target World and the Memory Image of Variables

We think that there are two views for visualizing a behavior of program. One is a state of target world (STW) and another is a memory image of variables (MIV). Figure 1 shows an example of STW and MIV for task of sorting values in array list. As mention in Figure 1, it is easy for novice programming learners to understand a behavior of algorithm using a view of STW instead of a view of MIV. In fact, many systems that support to understand the program and algorithm for novice programmer support a view of STW (Fossati *et al.* (2008), Gabor (2009), Kogure *et al.* (2013), Malmi *et al.* (2004) and Noguchi *et al.* (2010)). In contrast, programming learners must observe a view of MIV to deeply understand a behavior of program or to fix a program that includes a bug.

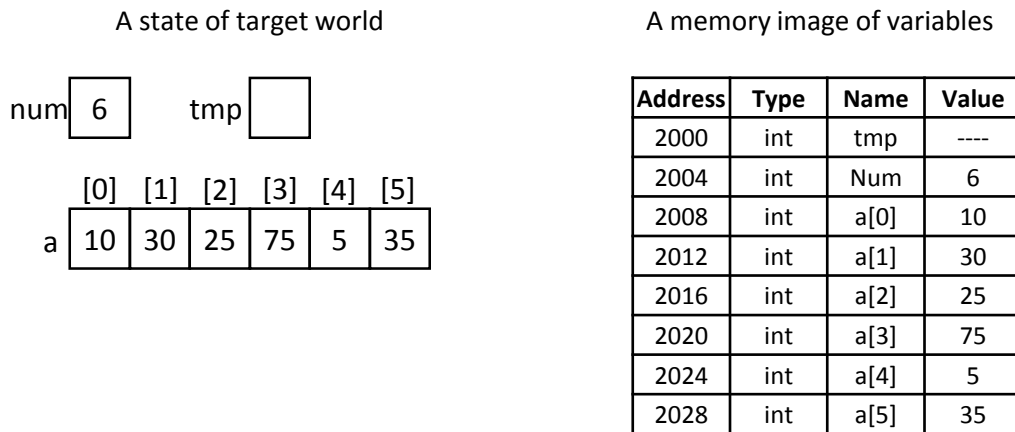


Figure 1. An example of a state of target world and a memory image of variables.

### 2.2 The Issue that the Teacher cannot Freely Decide the Format Visualizing the STW

Almost all of studies for viewing a STW was for particular algorithm. Some studies' STW don't depend on a particular algorithm but also teacher cannot define a view form of STW. In a case of displaying array list for sorting task, teacher maybe display the array list on horizontal layout (in Figure 1). In contrast, he/she maybe display the array list on vertical layout for stack. Furthermore, the teacher want to change a view of each variable to emphasize the particular variable or to hide some variables. For example, the teacher maybe think that he/she want to hide a view of the variable "tmp" (in Figure 1) for swapping the values of two variable from programming learners. Therefore, we gives the teacher an environment by which he/she can define the view of STW according to his/her intent.

### 2.3 The Issue that the Learner cannot Show the STW and MIV Synchronously

Almost all of exist studies can show a statement of program and STW synchronously. Typical debugger can show a statement of program and MIV synchronously. Although almost all of exist systems cannot display a statement of program, STW and MIV synchronously. Novice programming learners can easily understand a behavior of program using exist systems that can display a view of STW. Although he/she maybe not understand a behavior of program using debugger that can display a view of MIV. In contrast, an expert programmer maybe understand a behavior of program using debugger. The difference of novice and expert is whether to be able to understand the relationship among a statement of program, STW and MIV or not. Therefore, we gives the learners an environment by which they can understand the relationship among program, STW and MIV.

### 3. Required Functions for Our Proposed Environment

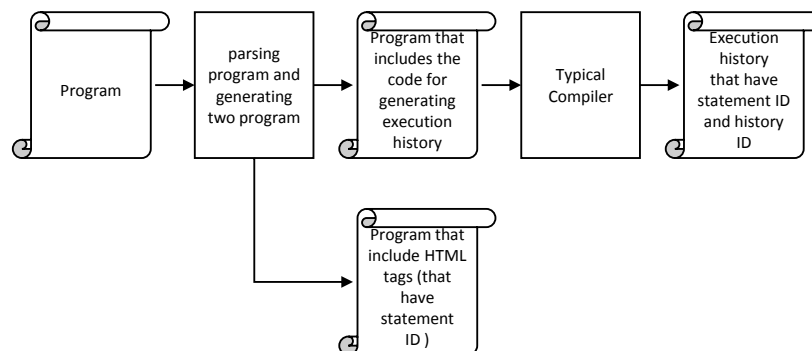
In order to solve two issues, we define the following five functions for code reading environment:

- Func.1. A function that extracts execution history (EH) from a program and generates a program embedded HTML tags for each statement
- Func.2. A function that reproduce MIV by using extracted EH
- Func.3. A function that give the teacher the environment by which he/she can set the form for the view of the STW for solving first issue.
- Func.4. A function that reproduce STW by using MIV and the rule for the view of the STW
- Func.5. A function that displays the statement in program, MIV and STW synchronously for solving second issue

There are two types of functions; basis function and important function. Func.1, 2 and 4 are basis functions that we implement using exist methods. Func.3 and 5 are important functions for solving two issues.

#### 3.1 *Func.1: A Function that Extracts EH from a Program and Generates a Program embedded HTML Tags for Each Statement*

This function is the function that translates a program into two different programs shown in Figure 2. First program includes the code for generation execution history including statement ID and dynamic history ID. The module for this function gives the fragment of statements the unique statement ID when parsing original program. In contrast, the module generates the statement for observing execution state and insert observation statement in original programs. The observation statement dynamically generates history ID when revised program executes. Second program includes the HTML tags for each fragment of statements. The proposed system can display the fragment in program embedded HTML tags and memory image of variable referring execution history synchronously because the statement ID in program embedded HTML tags correspond to the statement ID in execution history.



**Figure 2.** Overview of extracting execution history from a program and generating a program embedded HTML tags.

#### 3.2 *Func.2: A function that Reproduce a MIV by Using Extracted EH*

This function reproduces the state of executing program by referring execution history (Func.2.1) and displays the memory image of variables (Func.2.2). Func.2.1 generates a set of memory image of variables *MIV* by referring *EH* ( $EH = \{eh_1, eh_2, \dots, eh_n\}$ ) shown in Figure 3.

The certain memory image of variables  $miv_i$  includes a set of the four variable information; defined variables' name, types of variables, addresses of variables and values of variables when the system executes from  $eh_1$  to  $eh_i$ . EH includes five fundamental operation as follows:

- An operation that allocate memory region for new variable
- An operation that assign new value



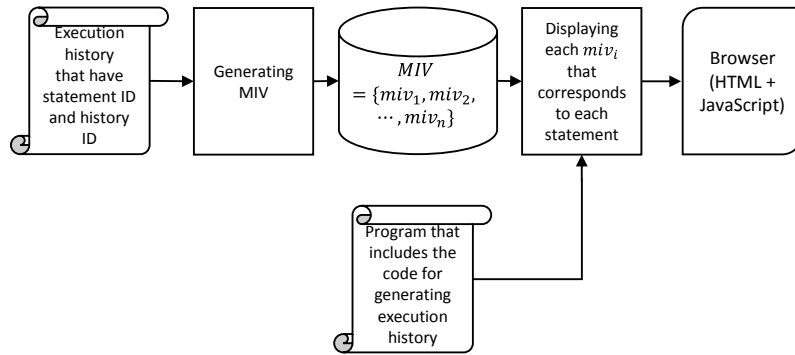


Figure 3. Overview of reproduce MIV by using extracted EH.

- An operation that allocate memory region for new instance of certain structure (e.g. “struct” in C language, “class” in Java language, etc.)
- An operation that clear memory region for exist variable
- An operation that clear memory region for exist instance

This function is generate the MIV set using the Algorithm 1.

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Algorithm 1: generating the MIV

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- 1:  $EH \leftarrow \{eh_1, eh_2, \dots, eh_n\}$ : execution history
  - 2:  $MIV \leftarrow \{\}$ : set of memory image of variables
  - 3:  $cmiv \leftarrow \{\}$ : a memory image of variables after executing from  $eh_1$  to  $eh_i$
  - 4: **for**  $i=1$  **to**  $n$  **do**
  - 5:     Emulate  $eh_i$  on memory image  $cmiv$ .
  - 6:     Push emulate result to  $cmiv$ .
  - 7:      $miv_i \leftarrow clone(cmiv)$
  - 8:     push  $miv_i$  to  $MIV$
  - 9: **end for**
- 

### 3.3 Func.3: A Function that Give the Teacher the Environment by which he/she can Set the Form for the View of the STW

First, we define the two types of object that the teacher use for composing a view of STW. First type is a main object that directly correspond to a variable in program. Second type is a sub object for explaining a role of a main object, explaining a relationship between a main object and other main object, or setting an array/table layout of each object. The teacher can specify each attribute value (e.g. object’s position, size, color, and so on) of each object. Therefore, the teacher can set a timing in which an object creates, deletes, shows and hides by using statement ID or history ID.

The teacher prepares the configuration file for a view of STW described above paragraph. Table 1 shows the content of configuration that teacher describes for main/sub objects and timing of creating/deleting/displaying/hiding each object.

Table 1: Types of object and Attributes for Configuration of STW.

|             | Operations               | Types                                    | Common Attributes  |
|-------------|--------------------------|--|--|
| Main Object | Create, Delete<br>Update | Circle, Square<br>Rectangle              | Corresponded variable,<br>Position, Width, Height,<br>Color, Line weight<br>Line style |
| Sub Object  | Create, Delete<br>Update | Connector, Table<br>Label, Line, Balloon | Target main object ID,<br>Position, Width, Height,<br>Color, Line weight<br>Line style |

The teacher can use three types of actions described in Table 1. “Create” action of main object is an action when observing an execution history in which a new variable is created. “Delete” action of main object is an action when observing an execution history in which an existed variable is cleared. “Update” action is an action for changing any attribute (e.g. color for emphasizing) at any timing that the teacher decides using statement ID or history ID).

The teacher can also use sub object in Table 1 for explaining a role of a main object or a relationship between a main object and other main object. For example, “Connector” type is a connector that connect a main object to other main object. The teacher can present the reference relation using attribute “Line style” (e.g. arrow). “Balloon” type is a balloon help for a main object.

The a rule description of rule set for a view of STW includes five items; “condition”, “operation”, “object name”, and “set of attribute-value”. “Condition” item is for specifying a timing of adapting the rule. The teacher can use six comparison operation; “==”, “!=”, “>=”, “<=”, “>” and “<” and three types of operands; “immediate number”, “variable in program” and “statement or history ID”.

### *3.4 Func.4: A Function that Reproduce STW by using MIV and the Configuration for the View of the STW Created by the Teacher*

The system reproduce certain  $stw_i$  according to  $miv_i$  and configuration rule set for the view of the STW created by the teacher. The system find rules in which a comparison operation is satisfied. If the system find match rule, the system executes this rule. If this rule is “create” operation’s rule for main object, the system retrieve a value of variable corresponding the rule from  $miv_i$  and display a main object according to object name, variable value and a set of attribute-value.

### *3.5 Func.5: A Function that Displays the Statement in Program, MIV and STW synchronously*

Learners can show a reproduced execution process of program code using our proposed environment. Our proposed system have execution history, EH, as common knowledge that each function use for executing own affair. Learners can use “next” or “prev” command for moving focused execution history  $eh_i$  to next execution history  $eh_{i+1}$  or previous execution history  $eh_{i-1}$ . Therefore, the system reproduces  $miv_{i+1}$  or  $miv_{i-1}$  for memory image of variables and also reproduces  $stw_{i+1}$  or  $stw_{i-1}$  for a state of target world.

## **4. Implementation**

Figure 4 shows an overview of our proposed environment. First, the left side area is for displaying program. Second, the right/top side area is for displaying a memory image of variables. Last, the right/bottom side area is for displaying a state of target worlds. In this study, target programming language is C language. We implement the parser of C language using Parse::RecDescent (Perl module for generate recursive-descent parser, referring <http://search.cpan.org/~jtbraun/>) and we implement the other module using HTML and JavaScript. We use JSON format as the representation of execution history.

For primary evaluation, we monitored what minutes the one of author spends creating the rule set for a view of STW. We select three situation; binary search task, linked list task, and other linked list task. As a result of evaluation, we obtained 36, 48 and 37 minutes, respectively. Therefore, we suggest that the teacher and learners maybe can use our environment in real classroom lecture.

## **5. Conclusion**

We had constructed new code reading environment according to visualizing the relationship among a statement of program, STW and MIV for novice learner. This environment has two important function. One important function is the function that gives the teacher an environment by which he/she can define the view of STW according to his/her intent. Another is the function that gives the learners an

environment by which they can understand the relationship among program, STW and MIV. We easily evaluate first important function. As a result, we suggest that the teacher and learners maybe can use our environment in real classroom lecture.

In the future, we will refine the second important functions. Therefore, we will evaluate the advantage of our proposed two function on real classroom lectures.

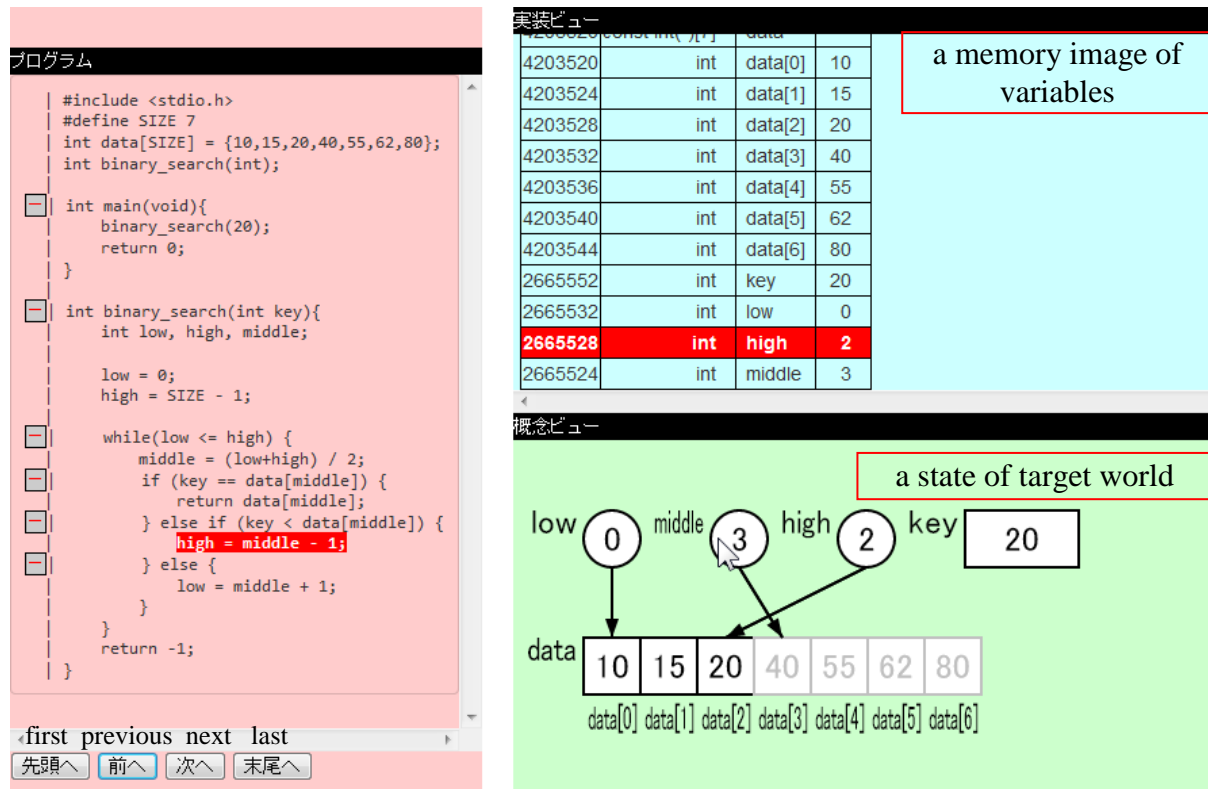


Figure 4. Overview of our proposed environment.

## Acknowledgements

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# Computer Assisted Learning based on ADDIE Instructional Development Model for Visual Impaired Students

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**Abstract:** With the advancement of technological innovations for ICT in education, this study focuses on building effective computer assisted learning based on the framework of ADDIE instructional development model to improve visual impaired students' conceptual learning progression on Marketing course. To examine the effectiveness of the developed computer assisted learning, an experiment was conducted by assigning twenty-four diploma students into three groups consisting of five blind students, seven partial visual impaired students, and twelve non-visual impaired students. They are permitted to select the learning instructions regarding to their vision level. The results of this study show that the developed computer assisted learning could help the students improve their conceptual learning progression. Additionally, the students reveal positive satisfaction towards the developed computer assisted learning.

**Keywords:** visual impairment, computer assisted learning, diploma program, ICT in education

## 1. Introduction

With the advancement of technological innovations for information technology and communication (ICT) in education, current research indicates a great impact on education, especially, computer assisted learning (CAL) can help improve the ability of students who have the different educational levels. (Basturk, 2005; Chang, Sung, Chen, & Huang, 2008; Denny, 2003; Ecalle, Kleinsz, & Magnan, 2013; Liu, 2010; Seo & Woo, 2010). Recently, a number of educators have attempted to study technological innovations for ICT to improve learning performance of visual impaired students (Ager & Aalykke, 2001; Douglas, 2001). There are two types of visual impaired students such as blind and partially sighted who have different learning patterns and difficulties, and may require different kinds of support (Shepherd, 2001). Several studies suggested that learning objects could engage the visual impaired students and promote their learning performance (Barak & Ziv, 2013; Basturk, 2005; Gaeta et al., 2004; Pinhati & Siqueira, 2014; Shepherd, 2001)

In Thai educational contexts, an attempt to provide learning support to the visual impaired students and non-visual impaired students has been promoted continuously. They are anticipated to be able to learn together. In addition to this context, Nakornluang Polytechnic College, one of many educational institutes in Thailand, offers educational system to both visual impaired students and non-visual impaired students learning together in the same classroom. However, it has been found that there are insufficient supplement learning materials and learning contents for visual impaired students. This is might be because of the lacking of well-designed learning materials.

Researchers have attempted to design learning objects based on instructional development models, for example, Bloom's Learning Taxonomy (Chyung & Stepich, 2003), Gagné's Nine Events of Instruction (Gagne, Wager, Golas, & Keller, 1992). Such models help educators to manage learning unit for the most effective learning environments. Among the instructional development models, the ADDIE instructional design model represent a more dynamic and flexible guidance for developing learning objects (Melanie, 2008; Ozdileka & Robeckb, 2009). Consequently, we developed a computer assisted learning environment for visual impaired students. Much than that the ADDIE instructional development model has been applied to the environment to form supplement

learning materials which are used to facilitate visual impaired students learning and promote their conceptual learning progression.

## 2. Development of computer assisted learning

In the process of developing computer assisted learning (CAL), we applied five steps of the ADDIE instructional development model, including Analysis, Design, Development, Implementation, and Evaluation (Melanie, 2008; Ozdileka & Robeckb, 2009). The analysis phase involves the investigation of students; we analyze content and presentation in order to design learning instruction appropriately. For the design phase; we designed the learning objects. In the development phase; the interactive instructions were created by Adobe Flash CS5.5 program, Adobe Photoshop CS5.5 program, and Nero Wave Editor program. In the implementation phase; this addresses the execution of the instructions. Finally, in the evaluation phase; the summative assessment function has been embedded.

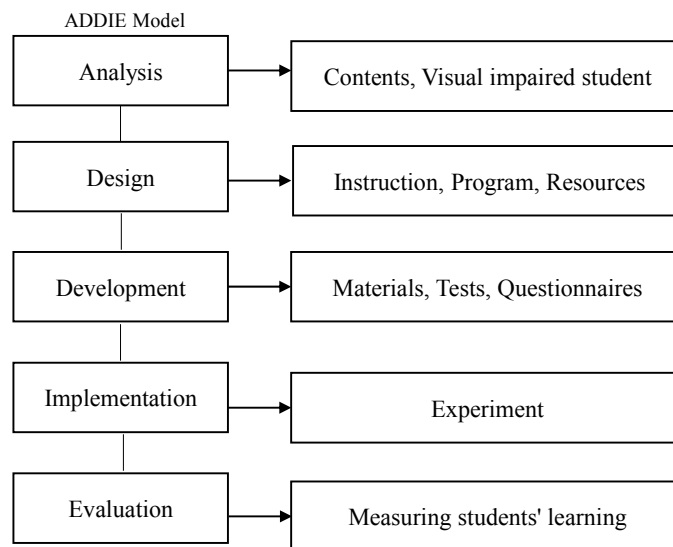


Figure 1. Development of computer assisted learning based on the ADDIE model

This paper presents CAL to help the visual impaired students and non-visual impaired students to learn together in a Marketing Course. The learning contents were separated into three units consisting of Unit 1: the importance of selling and marketing concepts; Unit 2: the types and characteristics of the selling; and Unit 3: the basic of products and business.

From analysis, we found the non-visual impaired students can learning normally while partial visual impaired students can see in certain conditions but they take longer to read it. The blind students like to have to rely on listening rather than watching. Therefore, the researchers developed instructional materials appropriately each student' types.

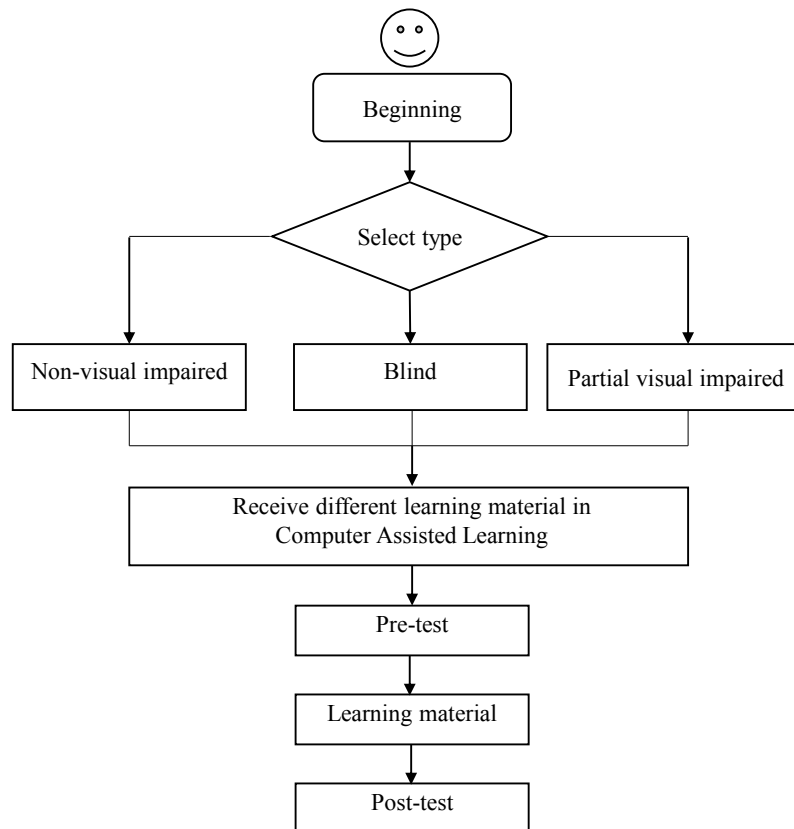


Figure 2. Design model of computer assisted learning system

Figure 2 shows that the students can select the appropriate instruction fit with their level of vision. Non-visual impaired students participated in instructions which are normal texts, pictures and sound, in which they can interactive via monitor as shown in Figure 3. The partially visual impaired students participated in instructions which are larger texts, pictures, and sound in which they can interactive via monitor as shown in Figure 4. On the other hand, the blind students participated in instructions which are only sound in which they can only interactive via keyboard; if they want to link to other pages, they can press button on keyboard following the listening instruction. Every type of instruction has different activities to enhance students' remembering as well.

### 3. Research design and method

Twenty-four visual-impaired Thai students from a University of Technology were recruited in this study to examine the effectiveness of the developed CAL. They were diploma students and were divided into three groups consisting of five blind students, seven partial visual impaired students, and twelve non-visual impaired students. They are permitted to select the learning instructions regarding to their vision level. One group pre-and post-test research design was used in this study. Before participating the developed CAL, they took a pre-test to measure whether they had equivalent prior knowledge. After taking the developed CAL, they took a post-test to evaluate learning performance, followed by the satisfaction questionnaire toward the developed CAL.



Figure 3. Illustrative examples of instructions for non-visual impaired students

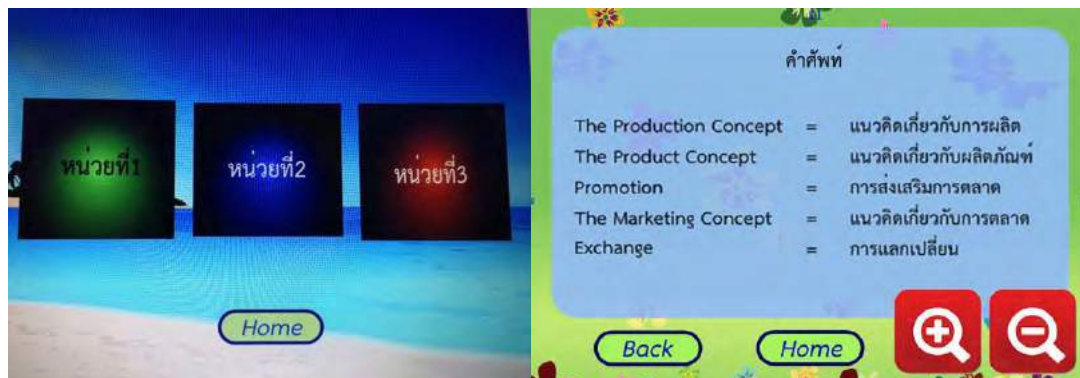


Figure 4. Illustrative examples of instructions for partial visual impaired students

#### 4. Results

Table 1 shows the mean scores and standard deviations of the pre-test scores of non-visual impaired students, partial visual impaired students, and blind students, which are 9.67, 9.43, and 9.8, respectively. The researchers have found that three groups of students had equivalent prior knowledge before participating in the learning activity. After finishing the learning activity, the post-test scores were 20.67, 22.71, and 23.6 for non-visual impaired students, partial visual impaired students and blind students, respectively.

The normalized gain ( $\langle g \rangle$ ) (Hake, 1997, 2002) is employed to investigate students' conceptual learning progression. The range is that if the  $\langle g \rangle \geq 0.7$  meaning High progression, while  $0.7 > \langle g \rangle \geq 0.3$  meaning Medium progression, and  $\langle g \rangle < 0.3$  meaning Low progression. Observing the Table 1, the results shows that all groups of students gained better conceptual knowledge after participating in the developed CAL and the progression of their knowledge was reasonably medium, indicating that they gain conceptual knowledge of the importance of selling and marketing concepts, the types and characteristics of the selling, and the basic of products and business in the medium size.

**Table 1: The student scores in this study**

| Group                   | N  | Tests     | Mean  | SD   | Normalized gain | Interpretation     |
|-------------------------|----|-----------|-------|------|-----------------|--------------------|
| Non-visual impaired     | 12 | pre-test  | 9.67  | 2.96 | <g> = 0.54      | Medium progression |
|                         |    | post-test | 20.67 | 3.39 |                 |                    |
| Partial visual impaired | 7  | pre-test  | 9.43  | 2.23 | <g> = 0.65      | Medium progression |
|                         |    | post-test | 22.71 | 2.56 |                 |                    |
| Blind                   | 5  | pre-test  | 9.80  | 2.59 | <g> = 0.68      | Medium progression |
|                         |    | post-test | 23.60 | 2.61 |                 |                    |

Moreover, when we asked the participating students to report their own satisfactions about the developed CAL, we found that they had positive satisfaction toward the developed CAL which fit with their learning as shown in Table 2.

**Table 2: The students’ satisfactions toward the developed CAL**

|                                  |  |
|----------------------------------|--|
| Non-visual impaired students     |  |
| Student A                        | “I like the CAL, I can learn and repeat instruction every time.”                               |
| Student B                        | “It makes the learning interesting.”   |
| partial visual impaired students |  |
| Student C                        | “CAL, it is convenient for me to learning, I can zoom in and zoom out the pictures and texts.” |
| Student D                        | “I enjoy the CAL.”   |
| Blind students                   |  |
| Student E                        | “I think I can learn instruction seem my friends and it easy for me to use computer.”          |
| Student F                        | “Normally, I don’t have instruction. I like it, CAL.”  |

## 5. Conclusions

This study developed the computer assisted learning (CAL) based on the five phases of ADDIE instructional model: Analysis, Design, Development, Implementation, and Evaluation for non-visual impaired students, partial visual impaired students, and blind students on marketing course of Diploma program. The results showed that the developed CAL has been considered as a critical factor not only to improve the students’ conceptual learning progression but also promote positive satisfaction. This is because the instruction reminds the students (readers) what has been remembering and helps them learning together.

With the suggestions from the students to improve CAL for example using game-based learning, cleaning sound noise, embedding more multimedia, the enhanced CAL has been developing. The experiment with larger size of participants is going to be conducted as well. The successful of this study might be an alternative way for educators/ researchers/ practitioners to develop CAL for visual impaired students in which the CAL is used to improve their conceptual learning progression.

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# Learning Cinema Authoring System in the Classroom

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**Abstract:** Nowadays, it's more and more important to have authentic instruction which lets students interact with learning context and apply their knowledge into real life. In this research, we construct a learning cinema authoring system. Teachers may edit backgrounds, characters and dialogues to construct a situation which is based on teaching context. Moreover, students could have an opportunity to learn in an authentic situation. After experiment, we discover that the system could help teachers on preparing authentic learning material. Students also have better motivation when they learn in the authentic situation.

**Keywords:** Authentic learning, authoring tools, digital learning playground

## 1. Introduction

Teaching material is the medium of instruction between students and teachers, but the interaction between students and teachers is sometimes not enough. With the development of technology, teachers can bring multimedia to the class and offer more interesting educational materials. However, these teaching tools cannot provide a vivid situation in the classroom, and students cannot get immersed in those learning contents. Recently, many governments build English villages for students to learn foreign language and culture in a language immersion environment. However, building various scenes costs a significant amount of money and students rarely have an opportunity to learning in the English village and thus, we use existing facilities in the classroom (projector and projection screen) along with tablet and Kinect to build an immersive learning environment.

In this research, we construct an authoring system for situational teaching material. Teacher may use the system to meet the needs of individual students or classes and integrate with different teaching strategies. Moreover, the system helps teacher creates situational learning environment that is not only distinctive but also related to the content of textbook.

## 2. Related Work

### 2.1 Authentic Learning

Brown, Collins and Duguid (1989) considered that knowledge is developed through situation and activity. They also advocated that learners should learn in the real situations because the situation provides learner with practical experience which makes learning more concrete. Moore et al. (1994) thought that although authentic learning emphasizes the authenticity of learning activities. A learning activity is authentic if it is related to the real situation and is goal-oriented, for example, learning cooking. Moreover, Choi and Hannafin (1995) believe that the learning would be effective when the meaningful situational occurs. Lave and Wenger (1991) proposed the situated learning theory as a community of practice and considered that learning is fundamentally a social process. Learners need to learn through participating in communities of practice and creating relations between newcomers and old-timers. Based on situated learning theory, Herrington and Oliver (2012) proposed a real situation module.

According to researches above, it is necessary for learners to gain knowledge through participating in activities of real-life situation. Therefore, we construct a situational environment which help students apply knowledge flexibly in real life.

## 2.2 Authoring Tools for Teaching

Several researches constructed authoring tools for instruction.

Cloze (Hutchful, Matur, Cutrell, & Joshi, 2010) is an authoring tool for creating content for multiple mice applications. Based on the needs of teachers with low computer proficiency, Cloze simplified the editing process of digital learning materials. In this study, they concluded some design considerations of designing authoring tools for teachers with low computer proficiency: consider task-oriented interfaces, consider providing content primitives and incorporate pedagogy.

EasyAuthor (Chimalakonda & Nori, 2013) is an authoring tool for teacher to create and manage learning content for adult illiterates in India. The main goal of EasyAuthor is to support easy editing of teaching materials and integrate literacy learning methodologies at the same time.

These authoring tools cannot provide an easy editing environment for situational learning, and students can't immerse in these contents.

In addition, Murray (1999) concluded that an authoring tool has the following goals:

- Decrease the effort (time, cost, and/or resources) for making intelligent tutors.
- Decrease the skill threshold for building intelligent tutors
- Help the designer/author articulate or organize her domain or pedagogical knowledge.
- Support good design principles (in pedagogy, user interface, etc.).
- To enable rapid prototyping of designs.

## 2.3 Background of Digital Learning Playground

Wang et al. (2010) built an interactive learning stage called Digital Learning Playground (DLP) that turns learning content into an authentic, task-oriented learning scenario. They placed a robot as learning companion on the stage table. The robot let students pay attention to target knowledge. Then, JIANG, CHEN, WU, and LEE (2011) applied augmented reality (AR) code to flash cards as a tool to trigger virtual objects on the screen. They found that it was not easy to gather younger learners' attention. Kuan-Chang, Chia-Jung, and Gow-Dong (2011) applied board-game mechanics on the interactive whiteboard and presented situational scenarios on the screen. They conducted an experiment in a high school setting and observed that the effectiveness and engagement of learning outperformed than traditional classroom teaching. However, learners would take significance of time to explore and deal with problems in educational simulation like board game with authentic situations. In order to make instruction process more efficiently. Chen et al. (2013) utilized existing facilities in the classroom and content of textbook to construct an immersive learning environment. By integrating student's image into learning context and using body motion as a way of interaction, students can get immersed into teaching content.

Based on the accumulated experience from previous studies, we separated the scene in DLP into three elements: background, character, and dialogues. In addition, the interactive whiteboard is heavy and expensive, so we replace interactive whiteboard with tablet and build an authoring system which lets teacher design scenes as teaching contents.

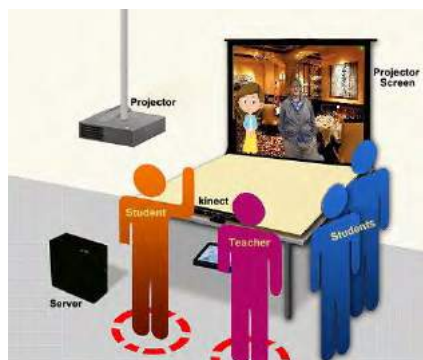


Figure 1. Device settings

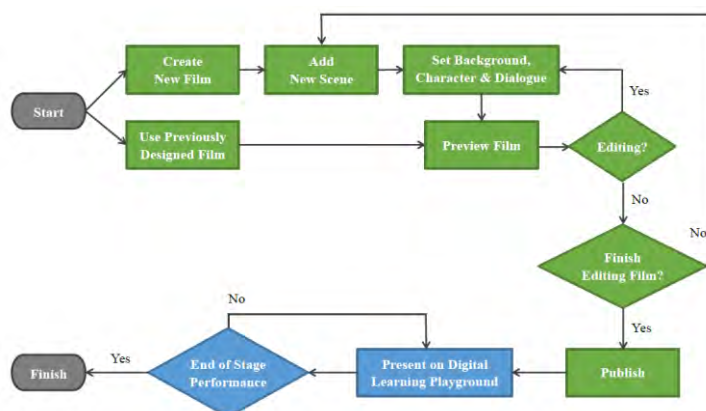


Figure 2. Procedure of Learning Cinema

### 3. System Design and Implementation

#### 3.1 System Architecture

The settings of the system is shown in Figure 1. We construct a situational stage using projector, projection screen, Kinect and speaker. Projector presents situational scenes and virtual characters on the screen. Kinect captures student's body motion and integrates it into the scene. Speaker plays dialogues of the scene. Besides, the authoring tool on tablet is used as a manipulation tool of the stage.

#### 3.2 Learning Cinema

The procedure of Learning Cinema is shown in Figure 2. The system lets teacher design situational teaching material for English or other language courses. Teacher may choose one of the scenario as teaching theme (such as ordering food in a restaurant). Next, teacher could design and arrange the scenes in the film. After editing, teacher presents situational teaching material through Digital Learning Playground (DLP) and allow students to have a stage performance. Students can practice listening and speaking skills on stage.



Figure 3. Setting background of the scene.



Figure 4. Previewing the scene.

##### 3.2.1 Authoring Tool

In order to allow teacher who uses computer less often to make situational learning contents easily, we implement authoring system on the tablet. Teacher could create new film or edit previously created film. See Figure 3 as an example, each film is composed of multiple scenes, teacher may set background, character and dialogue of each scene. In addition to materials provided by system, teacher can shoot photos, searching pictures on the Internet or record dialogues then upload to material library for later use. Material library makes the content more diverse and allows teachers to design more flexibly. As shown in Figure 4, teacher could preview whole scene or film and make proper adjustment after editing. When all of the editing is done, the film is published to database.

##### 3.2.2 Presentation

Film will present on DLP. Students may interact with the character and get immersed into the virtual scenes presented. Authoring system on the tablet is used as manipulation tool which enables teachers to switch between scenes and play dialogues of that scene to practice making conversations with students, and the subtitle of dialogues will display on the tablet when playing. Moreover, the system will record students' presentation on stage.

### 4. Experiment

We proposed the following two hypotheses:

- Students have better learning motivation when they are learning in authentic situation.
- Our system can help teachers to prepare and do authentic learning in the classroom.

## 4.1 Procedure

First experiment was held in one of the university in Taoyuan, Taiwan. Subjects were 12 university students who aged between 18 and 23. They were divided into 4 groups and there were 3 or 4 people in each group. In a 30-minutes experiment, we taught students some basic conversations in textbook and how to use our system. Then each group had a stage performance of situational film previously edited by teacher. After the presentation, students conducted an IMI questionnaire.

Second experiment was held in a primary school in Taichung, Taiwan. Subjects were 11 teachers who teach either English or Taiwanese. The experiment took about one hour. At first, we introduce the system and have a tutorial on it. Then, teachers would use our system to design teaching material for one of the situation. Next, teachers filled in a questionnaire edited by ourselves. At the end of experiment, we randomly chosen five teachers to conduct unstructured interviews.

## 4.2 Questionnaire

### 4.2.1 Intrinsic Motivation Inventory (IMI) Questionnaire

IMI questionnaire (Ryan, 1982) has seven subscales to measure participants' intrinsic motivation and self-regulation. We use the IMI Questionnaire to measure students' learning motivation. We choose four of seven subscales: Interest/Enjoyment, Effort/Importance, Pressure/Tension and Value/Usefulness. The participants had to rate each question by using the Likert seven-point scale, ranging from very true to not at all true (very true=7, not at all true=1).

### 4.2.2 Self-edited Questionnaire

The purpose of this questionnaire is to understand the mechanism and functions in this system via taking teachers' advice. The questionnaire have 8 questions, and the participants have to rate each question by using the Likert five-point scale, ranging from very true to not at all true (very true=5, not at all true=1).

## 5. Results and Discussion

### 5.1 Questionnaire

#### 5.1.1 IMI Questionnaire

We use Cronbachs' alpha ( $\alpha$ ) coefficient to examine reliability of the questionnaire. As shown in Table 1, the reliabilities of subscales are over 0.7 except Interest/Enjoyment subscale, we speculate that all participants are college students who played many multimedia games and the situation provided by our system may not be exciting enough for them. The discussion of each subscale is presented below.

##### 5.1.1.1. Interest/Enjoyment

This subscale investigating whether participants feel interesting and enjoyable in the situation. The higher score is better and the average score is 5.22. It represents that the participants feel pleasure when they do learning task. One participant said, "I am learning with the computer and I still think that it would be more interesting to learning with real people." We speculate that our system didn't provide learner to have body interaction with virtual character, so the participants may feel unreal.

##### 5.1.1.2. Effort/Importance

This subscale figures out how much effort did participants put on learning. The higher score is better and the average score is 5.02. We observed that some participants mimicked the sound of the role and they tried their best to perform better in the situation.

### 5.1.1.3. Pressure/Tension

This subscale investigating how much pressure the participants feel in the situation. The lower score is better. We observed that some participants were shy when they were talking to virtual character. But the statistics show that participants who took learning activity before are less nervous. We speculate that it was their first time using our system and they have to speak loudly and present in front of other unfamiliar people so they would under pressure.

### 5.1.1.4. Value/Usefulness

The subscale finds out whether the contents that participants learn from the realistic situation are helpful or not. The higher score is better. According to the interview, most of the participants believed that the learning mechanism is very helpful. One of participant said, “It can practice speaking and listening which is very helpful for me.” On the other hand, some participants thought that the mechanism did not help for them. We speculate that participants are used to learning with textbooks and the mechanism provided by our system is unfamiliar for them.

Table 1: Reliability and average scores of IMI questionnaire.

| Subscale           | Cronbachs' alpha ( $\alpha$ ) | Mean | Standard Deviation |
|--------------------|-------------------------------|------|--------------------|
| Interest/Enjoyment | .48                           | 5.22 | 0.65               |
| Effort/Importance  | .86                           | 5.02 | 1.07               |
| Pressure/Tension   | .94                           | 2.87 | 1.24               |
| Value/Usefulness   | .89                           | 4.79 | 0.94               |

### 5.1.2 Self-edited Questionnaire

The result of self-edited questionnaire is shown in Table 2. The average score is 4.43, it is a positive evaluation overall. And we discover that the score of question number 1 is 3.91. According to interview, some teachers had years of teaching experience and they didn't spend much time preparing teaching material. If they use our system, they would spend more time on preparation.

Table 2: Average scores of self-edited questionnaire.

|              | Question  | Mean        | Standard Deviation |
|--------------|---|-------------|--------------------|
| 1            | Compare with traditional way, using this system would enable me to accomplish authentic learning material more quickly. | 3.91        | 1.04               |
| 2            | Compare with traditional way, using this system would assist me to accomplish authentic learning material better.       | 4.27        | 0.65               |
| 3            | I can do more diverse teaching activity by using this system.   | 4.64        | 0.51               |
| 4            | Templates provided by system can help me reduce time to prepare authentic learning material.                            | 4.55        | 0.52               |
| 5            | I'm glad to share my situations to other teacher.   | 4.73        | 0.47               |
| 6            | It is very convenient to edit situation by tablet.  | 4.27        | 0.65               |
| 7            | It is easy to control teaching process through tablet.  | 4.18        | 0.98               |
| 8            | Integrating students' image into the situation would be more fun in teaching.   | 4.91        | 0.30               |
| <b>Total</b> |   | <b>4.43</b> | <b>0.51</b>        |

## 5.2 Teacher Interview

### 5.2.1 Integrate Students' Image into Authentic Scenes

Some teachers believed that it can attract students at the first time. When they are familiar with this learning mechanism, they might lose interest. On the other hand, most of teachers thought that students will be very excited to see their classmate or themselves in the scenes at first, even disrupt the class. But they believed that it will be better after implemented few times.

### 5.2.2 Students Having Better Learning Motivation

Every teacher has his own way to attract students' attention and motivation. Most of teachers thought that the learning mechanism provide by our system is very attractive and let students have better motivation.

### 5.2.3 Editing and Reusing Teaching Material

Some teachers don't spend much time preparing teaching material before the class. They would spend more time if they use our system. Teachers said that if the system provide a large amount of templates, it may reduce time for preparation. Besides, most teachers are willing to share situation films to other teachers.

## 6. Conclusion

In this research, we provide a system which can help teachers to construct corresponding authentic situations and provide an opportunity for students to learn in an authentic situation. Students immersed in teaching content by integrating student's image into learning context. Teachers believed that the learning mechanism provided by our system will attract students' attention and have better learning motivation. Moreover, the system can help teachers on preparing authentic learning material. Results of IMI questionnaire show that students have better motivation when learning in the authentic situation. The teachers' opinions are consistent with students' questionnaire result. In addition, both of teachers and students thought our system not only can use in language learning but also can apply in scientific experiments, self-introduction or interview simulation.

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# Presentation Reconstruction Method for Peer Review Support in Presentation Rehearsal

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**Abstract:** We have proposed a computer assisted peer review in a presentation rehearsal. In order to help the peers review the presentation, it reproduces the presentation mainly with the information embedded in the visual slides. However, the presenter generally uses not only the slides but also oral explanations in the presentation to transfer his/her knowledge and opinions to the audiences. The reproduction is accordingly inadequate for the peer review due to the lack of the oral information. This paper discusses how to reproduce a presentation with the slide and oral information.

**Keywords:** presentation rehearsal, peer review, support system, slide contents, oral explanation

## 1. Introduction

Presentation is one of knowledge communication, in which a presenter generally transfers his/her knowledge and opinions. It is recently conducted by means of presentation software, such as “PowerPoint” or “Keynote”, on laptop computers. We have proposed a presentation rehearsal support system (Okamoto and Kashihara, 2007), and have developed and tested the system in these seven years.

Presentation rehearsal gives a presenter an opportunity to refine his/her knowledge with review comments obtained from the peers. However, it is not easy for the peers to make comments while listening to the presentation. To address this issue, we have proposed the “time-shifting method” in which the peers could make their comments after the presentation with the slide data and presentation movies etc. (Okamoto and Kashihara, 2007). In this method, the presentation is reproduced mainly with the information involved in the slide. However, the reproduction seems insufficient because it does not use the information included in oral explanations. In order to get the peers’ comments that are fruitful for improving the presentation, it is necessary to reproduce the oral information in addition to the slide information.

There are a lot of related works on methods for supporting presentation. Shibata, Kashihara and Hasegawa have proposed the method for creating the presentation slides with the semantic structure embedded in a presentation document (Shibata, Kashihara and Hasegawa, 2012). Noguchi et al. have also used presentations for educational materials of meta-learning (Noguchi et al., 2010). Berena et al. have developed a system for online presentations (Berena et al., 2010). However, these methods mainly use the slide information to reproduce the presentations, and have little concern about the oral explanations. The oral information is just recorded as video movies at the most.

In this paper, we propose a method of the presentation reproduction, which uses slide contents and oral explanations. We call it “Presentation Reconstruction Method”, in which the presentation is divided into slide contents and oral explanations and is then reconstructed by making the correspondence between the divided contents and explanations. In the following, let us describe the method, a tool for reconstructing the presentation, and case studies with the tool.



## **2. Issue of Review Support in Presentation Rehearsal**

Presentation rehearsal is a kind of peer reviews, which helps the presenter to improve his/her presentation skill through the review work by the peers. The peer review also allows the presenter to be aware of an insufficiency or an incompleteness of his/her knowledge (Kashihara and Hasegawa, 2003). Thus, review comments from the peers are essential for the knowledge refinement.

In order to support the presentation rehearsal, we have developed a peer review client with visual-oriented annotation method (Okamoto, Watanabe and Kashihara, 2013), a back-review client for supporting a revise work of the presentation (Okamoto and Kashihara, 2012), and so on. The system can reduce cognitive load on review work and help the presenter to revise the contents of the presentation. The system also utilizes textual information in the slides to reproduce the presentation. Although it has just recorded the presenter's talk as video movies, it has not utilized the oral information for the presentation reproduction.

Through the test use of the system, we found that the system had difficulties in facilitating the peer review in the following two cases. The one was the case where the presenter gave supplemental explanation about the information that was not included in the slide. The other was the case where the information described in a slide was omitted in the oral explanation. The result of review comments from the peers accumulated in the system, in addition, suggests that 19% of the comments are related to oral explanations (Okamoto, Watanabe and Kashihara, 2013), which cannot be ignored for supporting the peer review.

In order to obtain instructive review comments from the peers, it is important to allow them to review the presentation appropriately with the information accumulated by the system. We accordingly attempt to use the oral explanations in addition to the slides to improve the previous approach for the presentation reproduction and try to. The issue addressed here is to reproduce the presentation with the slide information and the oral explanations adequately.

## **3. Reproduction of Presentation**

The reason why oral explanations have not been utilized in our study is a technical difficulty of accumulation of the oral explanations as text data directly. In this study, at first, we had considered how to handle the contents of oral explanations.

### *3.1 Conversion of Oral Explanations to Text Data*

Primarily, we focused on a voice recognition technology. Recently, services with the voice recognition, such as "Siri" and "Google Voice Search", become common. In a scene that is required real-time property like a presentation, it is ideal to use the voice recognition. Though, in the present technology, it is difficult to deal with continuous speech recognition. According to the experiment in Kawahara, the rate of the word recognition in a 90 minutes lecture in Japanese was 70% on average, and he reported that the modification of the recognized text was necessary to use as the captions (Kawahara, 2013). For this reason, it is not practical to utilize the voice recognition. Thus, we decided not to use the recognition method to convert oral explanations to text data.

Secondly, we focused on presenter notes. A presenter which has little experience in a presentation frequently writes a script in the presenter notes. A cost to convert the oral explanations may be reduced with a text in the presenter notes. Therefore, we tried to use the presenter notes. If the contents of the utterance which is not described in the presenter notes includes in the presentation, we convert it manually.

### *3.2 Method of Presentation Reproduction*

Assuming that it is possible to convert oral explanations to text data as previously mentioned, we examine how to reproduce a presentation with two types of data. We focused on correspondences between oral explanations and slide contents. In general, a presenter makes a presentation projecting slides supplementary and explaining what he/she should to talk. Therefore, for example, in the case of reading slide contents, it is possible to link between the oral explanation and the certain point of the

slide contents. By revealing the correspondences between the slide contents and the oral explanations, the review work is supported in the following two points.

- Comprehension of a structure in a presentation
- Collective review both of the slide contents and the oral explanations

According to the above reasons, the load of the review work by peers should be reduced.

#### 4. Presentation Reconstruction Method

Based on the discussion in chapter 3, we considered the specific method of the presentation reproduction. There are two processes, “dividing” and “combining”, for the reproduction. In the process of “dividing”, the slide contents and the oral explanations should be divided into certain grain size to make clear a target for linking. In the “combining” process, the divided contents, which were transferred to peers at the same time, are linked as appropriate. And, finally, linked contents are summarized into one combination as a presentation sequence. In this study, the above method of the reproduction is called “Presentation Reconstruction Method”. The schema diagram of the presentation reconstruction method is shown in Figure 1. The details of two processes are as follows.

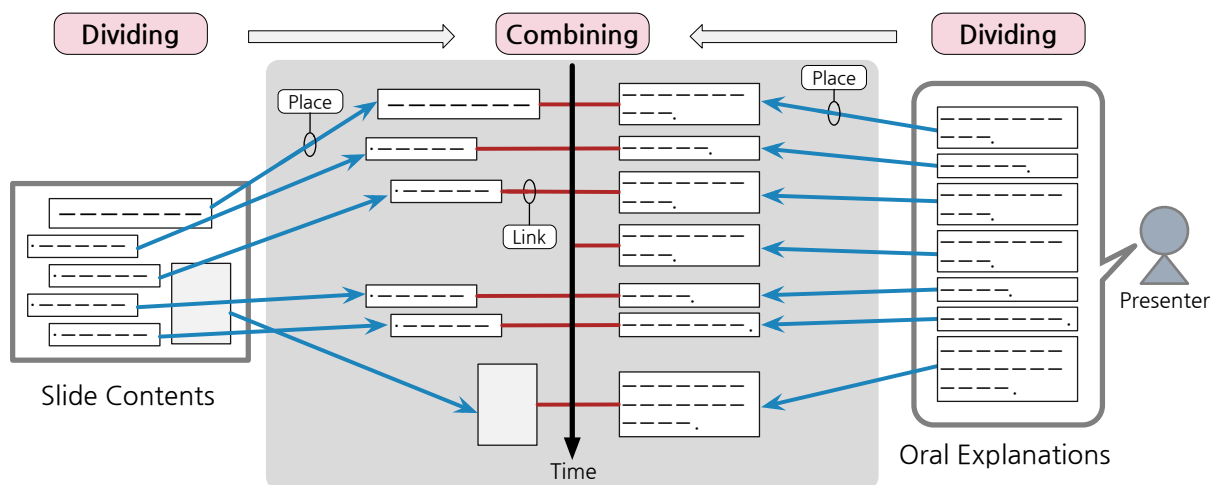


Figure 1. Schema of Presentation Reconstruction.

##### 4.1 Dividing of Slide Contents and Oral Explanations

To elucidate how a presenter described in a certain slide, it is necessary not just to divide a presentation by slides but also to divide the slides adequately. We defined a means of the dividing as follows.

###### (1) Slide Contents

A slide is basically constructed of a title and a body part. Thus, the slide is divided these two. And, the body is constructed of texts, figures and tables. A text is generally described in the form of a bulleted list, and an item of the list is a smallest unit which has a set of a lexical meaning. Therefore, the texts are divided in each item of the lists. The figures and the tables are divided into some areas in an optional way. These divided slide contents are collectively called “slide elements”.

###### (2) Oral Explanations

At the time of dividing oral explanations, it is desirable to divide the explanations depending on a quantity of the slide’s text. Because an item of a bulleted list often corresponds to a sentence in the explanations, the explanations are divided into each of sentences. We collectively call these divided explanations “oral elements”.

## 4.2 Combining of Divided Elements

In the next step, the divided elements are combined. The following are procedures to combine the elements.

- (1) Place slide elements and oral elements separately in time-series order
- (2) Link slide elements and oral elements that are transferred at the same time

Actually, the presenter often explains about two or more items of the bulleted list in one sentence, or explains one list in several sentences on the contrary. In order to show a correspondence between slide elements and oral explanations clearly, it is desirable that each of elements has one-to-one correspondence. Therefore, in the former, the oral element is divided additionally, and the divided elements are linked to their respective slide elements. In the latter, the several oral elements are joined together, and the element is linked to a slide element.

## 5. Development of Presentation Reconstruction Tool

We have been developing a presentation reconstruction tool. The tool works on “Mac OS X”, and it supports “Keynote”. Presently, the tool is developed independent from the presentation rehearsal support system. An interface of the tool is shown in Figure 2.

The tool is equipped with an automatic dividing function to parse slides' data and presenter notes in Keynote file. The function almost works well in dividing of bulleted lists and oral explanations. Each of divided elements is displayed on “slide view” or “oral explanation view”. The location of the each slide element in a slide is drawn in a red rectangle. The oral elements are displayed as a shape of a balloon and listed vertically in the right side of the window. At present, the view of the elements depends on the layout of slides, namely, the elements is not completely listed along time sequence. Thus, we are planning to change the design of the view.

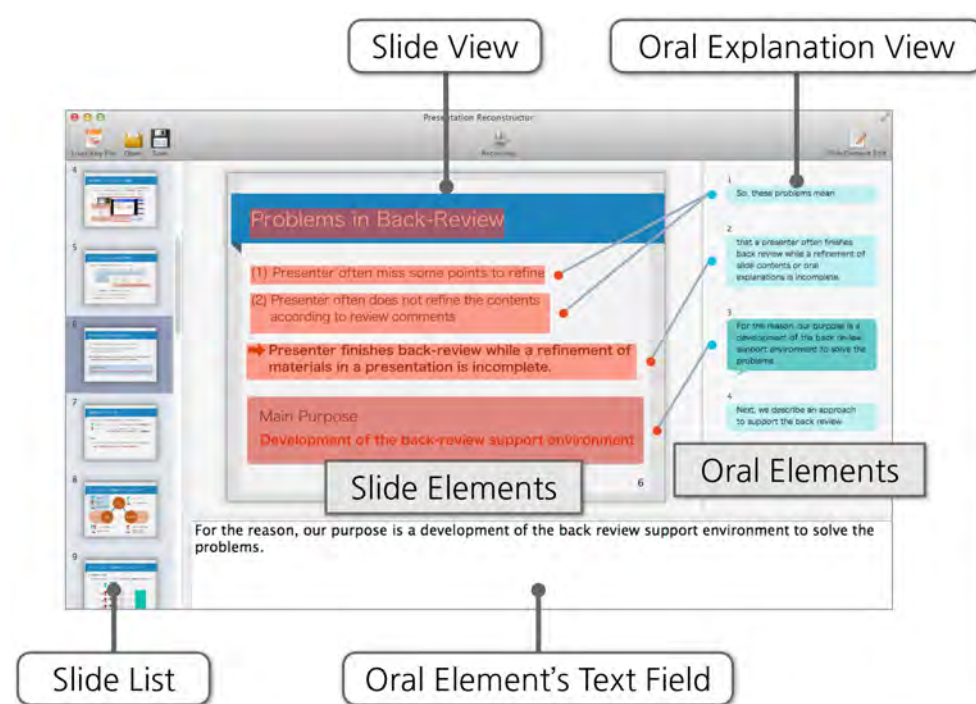


Figure 2. Interface of Presentation Reconstruction Tool.

After loading Keynote file, the elements are already displayed in a divided state. After that, a user performs following three types of works in sequence.

### (1) Editing of Oral Elements

Because texts in presenter notes are different from each utterance in an actual presentation, the tool has a function of editing the oral explanation's text. The user selects an oral element in the "oral view", and adds, deletes or corrects the text of the element in the "oral element's text field".

### (2) Additional Dividing of Slide Elements

The automatic dividing function for figures and tables are not supported at present. For this reason, the tool is equipped with a function to divide the figures or the tables into the slide elements manually. To divide the contents, the user can select a certain point where he/she wants to specify as a slide element with rectangle selection.

### (3) Combining of Elements

The user makes a link between a slide element and an oral element to drag each other. A relation of the elements is drawn as a connected line.

## 6. Case Study

For the test use of the tool, we have reconstructed and analyzed six presentations which were accumulated by the presentation rehearsal support system. In this chapter, we introduce a case of the rehearsal for the presentation of a graduation thesis by an undergraduate student. Figure 3. shows parts of the reconstructed data in the presentation. An expression of this figure is modified from the data in the tool to make easy to see the relationship between the elements.

In the case A, a user can see the timing that these elements transferred and the amount of each oral explanation which is connected to the corresponding slide element. Also, the 7th oral element in the slide is not linked to any slide elements. It means that the element was transferred only by the utterance. In consequence, the reconstruction of the presentation shows the information that has not been visible so far.

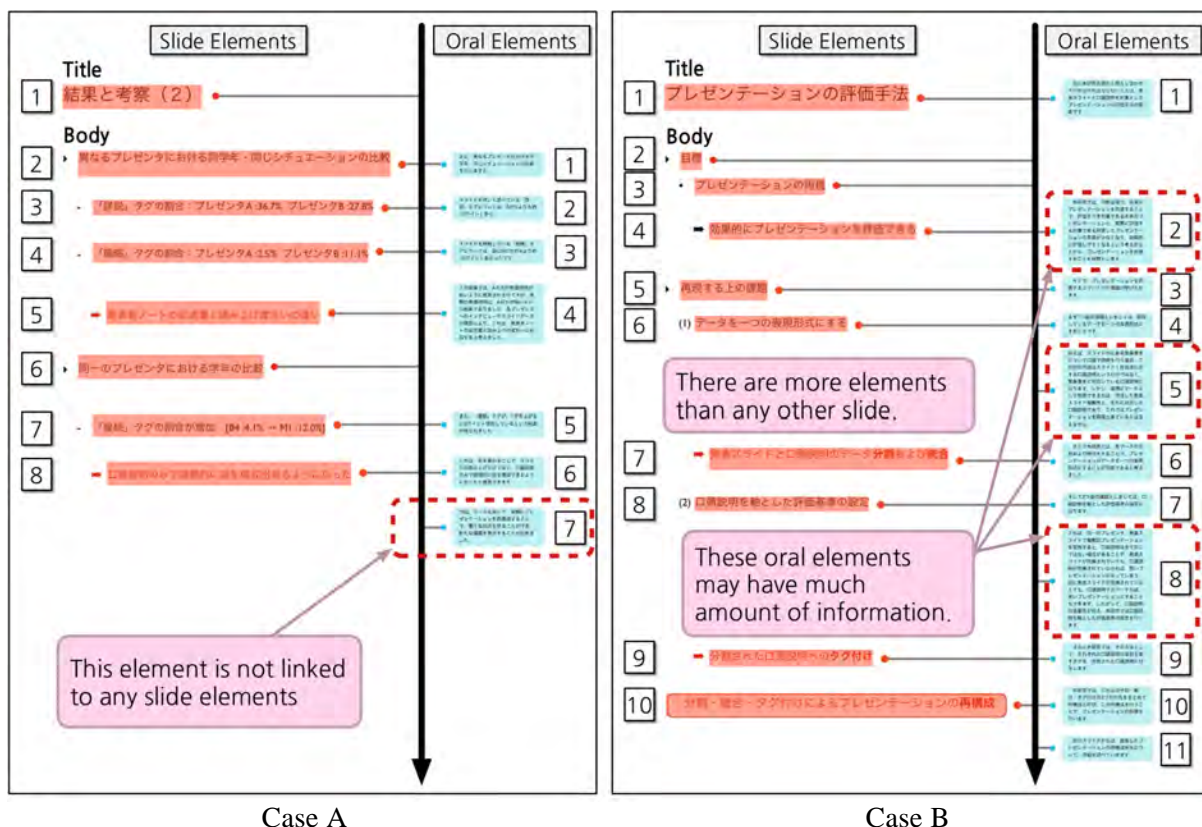


Figure 3. Relationship between Slide Elements and Oral Elements

Table 1: Aggregate Results of Elements in Presentation by Undergraduate Student.

|                       | Number of slide elements | Number of oral elements |
|-----------------------|--------------------------|-------------------------|
| Case A                | 8                        | 7                       |
| Case B                | 10                       | 11                      |
| Average in all slides | 6.0                      | 5.9                     |

In the case B, according to Table 1., the number of the elements in the slide is more than any other slide. Actually, in the rehearsal, a peer made a comment “*This slide has much amount of information. And also, there were too many contents explained only by the oral explanation. So, I didn’t comprehend the details.*” This means that the number of the elements substantiates a reason of the comment. There is a possibility to evaluate presentation by an aggregate of the elements because contents of slides and oral explanations are divided into elements by the reconstruction.

## 7. Conclusion

In this paper, we described a presentation reconstruction method by dividing and combining of slide contents and oral explanations for a presentation reproduction. And we developed the tool based on the consideration. Through the case studies, the tool almost works well. As our future work, we add the function of the tool into the presentation rehearsal support system, and conduct experiments with the system in actual rehearsals. As mentioned earlier, about this time, we used presenter notes to convert oral explanations to text data, and we manually converted the explanations which does not include in the notes. In the method, a user can confirm a presentation after the rehearsal. Though, the user cannot confirm the presentation instantly in the rehearsal. Therefore, it is required to further consider the method for the conversion of the explanations. Also, we would implement additional functions which are not implemented in the current tool yet.

## Acknowledgements

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# Probabilistic Question Selection Approach for AR-based Inorganic Chemistry Learning Support System

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**Abstract:** In this paper, we proposed AR-based learning support system using user's learning history information for inorganic chemistry with probabilistic question selection algorithm based on learner's operation in the virtual environment. In order to perform experiments in the virtual environment, markers and USB camera are utilized as input interface. By using this interface, a learner can perform the chemical experiments in the virtual environment. For chemical experiments, the proposed system gives some questions to a learner. These questions are selected based on a learner's learning history information. This selection algorithm helps a learner performing the experiments corresponding to suitable questions for his/her learning about inorganic chemistry. For selecting a set of questions, probabilistic question selection algorithm is proposed. By using this selection algorithm, a learner can learn repeatedly about inorganic chemistry in the virtual environment. The validity of the proposed system and algorithm was shown as experimental results of subject's learning result.

**Keywords:** Augmented Reality (AR), Experiment-based Learning, Selection of suitable Questions, Inorganic Chemistry, Probabilistic approach

## 1. Introduction

In Japanese high school, chemical education consists of 3 parts (theoretical chemistry, organic chemistry and inorganic chemistry). Particularly, it is important for learners to perform various chemical experiment in the classroom for learn chemical reaction. However, it is too difficult for learners to learn all knowledge about chemical reaction in one experiment. And it is impossible that all experiments are repeatedly performed until all students memorize all chemical reactions. In order to improve these problems, learning support systems using virtual experiment are developed (Konishi *et al.* (2010) and Nanko *et al.* (2008)).

On the other hand, it is important for learners to observe an experimental result (for example, colors) and process of experiments in Japanese high school education. Before now, in order to learning the inorganic chemistry based on virtual experiment, we developed AR-based learning support system (Sumida *et al.* (2012)). AR is helpful in order to make a natural user interface which integrated VR and real world (Asai *et al.* (2011), Iwasaki *et al.* (2010), Sano *et al.* (2010), Santos *et al.* (2014) and Okada *et al.* (2013)). In order to perform experiments in virtual environment, markers printed on papers are utilized as control interface. By user's operation of markers, user can perform various experiments (such as flame test). Additionally, so the system can give questions and hints, user acquires knowledge of chemical reaction by solving questions in virtual environment. However, for learning the knowledge of inorganic chemistry using only this AR-based learning support system, learners have to select some question about inorganic chemical reactions. Then we developed question recommendation method for this system (Okamoto *et al.* (2013)). By using this approach, it is expected that they can perform their learning process more effectively. However learner has to solve paper test to give the system some information about learner understands.

In this paper, we proposed probabilistic question selection method based on learner's operation in the virtual environment for AR-based learning support system. Given questions are probabilistically determined by learner's operation information. This information is calculated from user's operation in the virtual environment. By learning repeatedly using this system and given questions, it is expected that the learner can memorize all chemical reactions corresponding to prepared questions.

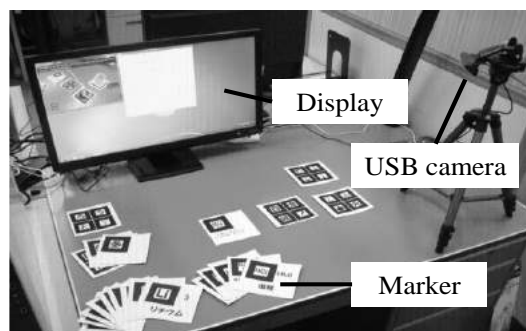


Figure 1: The Overview of the Proposed System.

## 2. 2. Inorganic chemistry learning management system using AR-based virtual laboratory

### 2.1 System Structure

Figure 1 shows the overview and structure of the proposed system respectively. As shown in Figure 1, this system has three devices (1: USB camera, 2: computer and display, 3: markers for input interface). USB camera records image of user's operation in order to create the virtual environment for experiments based on real image and CGs. Simulation of experiments and creation of virtual environment are carried out by computer. In order to construct the virtual laboratory from real image recorded by USB camera, user's operation must be recognized from real image. Then various markers are utilized for recognition of user's operation. By putting and moving markers in recorded area, user's operation are easily recognized by the system. For recognition of markers from image recorded by USB camera, ARToolKit library and markers are utilized. Table 1 shows examples of markers used in the virtual environment. By putting these marker in recorded area, this system understand that user utilize the corresponding instruments. Additionally corresponding CGs are displayed near the marker in virtual environment (shown in Figure 1). Then, solutes and water solutions have to be selected for performing experiments which user wants to conduct. The operation markers shown in Table 2 are used for showing user's intention of operation.

Table 1: Examples of Markers Corresponding to Instruments and Item for Experiment.

|                             | Instruments | Solutes | Water solutions |
|-----------------------------|-------------|---------|-----------------|
| An Example Image of Markers |             |         |                 |

Table 2: Examples of Markers Corresponding to Operation by Learner.

|                             | Operation for water solutions | Adjustment of Solutes' parameters | Checking learner's result of experiment as answer |
|-----------------------------|-------------------------------|-----------------------------------|---|
| An Example Image of Markers |                               |                                   |   |

## 2.2 AR-based Virtual Environment with Giving Questions Function

In this system, in order to perform the chemical experiments, the virtual environment is utilized. By using this environment, learner can perform three chemical experiments (1: flame color test, 2: precipitation of ion, 3: positive ion analysis). The system understands the type of experiments which learner wants to conduct from the arrangement of the instruments markers. Next, an example of the virtual experiment is described.



(a) Preparation of water solution which contain ferric ion

(b) Adding the precipitating agent for making precipitation of ion

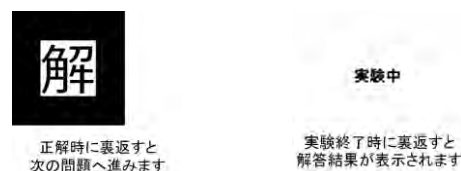
**Figure 2:** Example of Experimental Process about Precipitation of Ion.

An example precipitation of ion experiment is shown in Figure 2. In this experiment, user has to investigate the phenomenon about the color precipitation of ion, used precipitating agent and so on. In order to conduct this experiment in virtual environment, user should use the three kinds of marker (instruments marker, solutes marker and water solutions marker). In the example of experiment shown in Figure 2, at first, water solution that contains the ferric ion is prepared in beaker (Figure 2(a)). For this preparation, ferric ion marker is put and moved near the beaker marker. In next process, by adding the precipitating agent into the beaker, user can check the precipitation of ion. Then a water solution maker is put and moved near a beaker marker (Figure 2(b)). By this operation, corresponding water solution (hydrogen sulfide solution) is added into prepared solution in virtual environment. By conducting the experiment corresponding to phenomena which can indicate the information that user wants to know, user can learn about precipitation phenomena through the experiments.

## 2.3 Giving Questions Function



(a) An example of presentation of a question in virtual environment



(checking the result of experiment)

(during experiment)

(b) Checking marker

**Figure 3:** Question and Marker for Checking Answer.

In this subsection, question-based learning approach is described. The question is displayed on the upper part of virtual environment. Figure 3(a) shows an example of presentation of question in virtual environment. In this question, “What is ion which can change the color of flame into blue-green?” is written in Japanese. When checking marker (Figure 3(b)) is turned, system



evaluates the answer (result of experiment). If user makes mistake, hint is displayed on the underside of virtual environment and user perform experiment again based on given hint. After having a correct answer, by turning this marker again, next question is given for user.

#### 2.4 Probabilistic Questions Selecting Approach based on Learner's Process of Experiment

In the proposed system, a set of question is given to each learner for leaning the chemical reactions through answering process. To performing learning effectively, suitable questions have to be selected. By finding answers of given questions through experiments in the virtual environment, it is expected that the learner can acquire the knowledge corresponding to given questions. Questions selection algorithm is shown as below. Then, in this algorithm, the number of questions in one set is set as  $Q$ .

1. At first, parameters  $V_1(l)$ ,  $V_2(n)$ , and  $V_3(m)$  are initialized.
2. A learner performs experiment in the virtual environment for answering given questions.
3. After experiment, parameter  $V_1(l)$  is calculated. If experimental process of each given questions is applied for some conditions, the corresponding weights are added to each parameter  $V_1(l)$ . The all conditions and corresponding weights are shown in Table 3.
4. The parameters  $V_2(m)$  are calculated. Then  $m$  is a number of the question which is not applied to all conditions in Table 3. And the parameters  $V_3(n)$  is determined, where  $m$  is question number which is not given once. Then,  $V_2(m)$  and  $V_3(n)$  are constant number.  $V_2(n)$  is set as  $\alpha V_3(n)$  ( $0 < \alpha \leq 1$ ).
5. The parameters ( $V_1(l)$ ,  $V_2(m)$ ,  $V_3(n)$ ) and the probabilities for all questions ( $P_1(l)$ ,  $P_2(m)$ ,  $P_3(n)$ ) are calculated as follow equations.

$$V_1(l) = \begin{cases} 0, & q = 0 \\ \sum_{d=1}^D W(d)count_d(l), & o.w. \end{cases}$$

$$V_2(m) = \begin{cases} \alpha, & q = 0 \\ \frac{\alpha(Q-q)\sum_{l \in L} V_1(l)}{q(\alpha\|\mathbf{M}\| + \|\mathbf{N}\|)}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

$$V_3(n) = \begin{cases} 1, & q = 0 \\ \frac{(Q-q)\sum_{l \in L} V_1(l)}{q(\alpha\|\mathbf{M}\| + \|\mathbf{N}\|)}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

$$P_1(l) = \begin{cases} 0, & q = 0 \\ \frac{V_1(l)}{V}, & o.w. \end{cases}$$

$$P_2(m) = \begin{cases} \frac{\alpha}{V}, & q = 0 \\ \frac{V_2(m)}{V}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

$$P_3(n) = \begin{cases} \frac{1}{V}, & q = 0 \\ \frac{V_3(n)}{V}, & 0 < q < Q \\ 0, & o.w. \end{cases}$$

, where  $q$  is the number of questions selected from a set of the question applicable to the conditions of the Table 3.  $\mathbf{M}$  and  $\mathbf{N}$  are set of  $n$  and  $m$  respectively. Intersection of  $\mathbf{M}$  and  $\mathbf{N}$  is empty set. And  $V$  is calculated as follow equation.

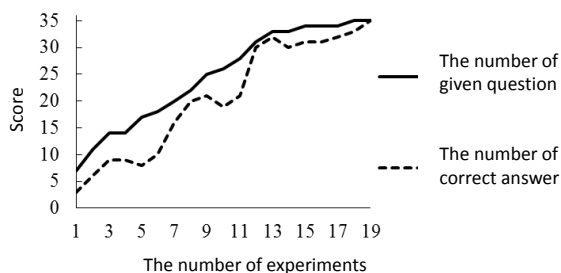
$$V = \sum_{l \in L} V_1(l) + \sum_{m \in M} V_2(m) + \sum_{n \in N} V_3(n)$$

- Based on calculated probabilities  $P_1(l)$ ,  $q$  questions are selected. And,  $Q-q$  questions are selected based on Probabilities  $P_2(m)$  and  $P_3(n)$ . In the next experiment, selected questions are given to learner in the virtual environment.

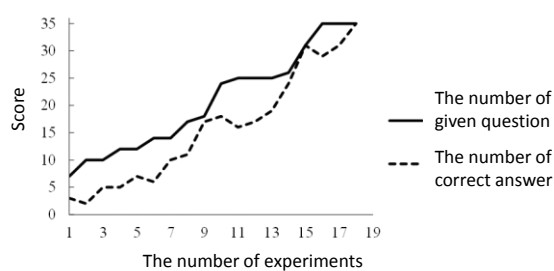
**Table 3: Conditions and Corresponding Weights for Probabilistic Estimation.**

| Conditions  | Weights(W(d)) |
|---|---------------|
| Condition 1: The number of times of trial is larger than one.                                   | W(1) = 6.8    |
| Condition 2: Experiment time is 11.75 seconds longer than the average of other experiment time. | W(2) = 3.4    |
| Condition 3: Answer time is 18.1 seconds longer than the average of other answer time.          | W(3) = 5.0    |
| Condition 4: The number of incorrect answer is larger than one.                                 | W(4) = 7.8    |

### 3. Evaluation Experiment



**Figure 4: Experimental Results of Subject A in Paper Test.**



**Figure 5: Experimental Results of Subject B in Paper Test.**

In order to evaluate the effectiveness of proposed probabilistic selection of given questions and learning process using virtual environment, learning experiments about chemical reaction were conducted. Two subjects (A and B) participated in the experiments. Subject A learned about the knowledge of the chemical reaction using the proposed system. As a candidate for comparison, subject B used the previous systems (Okamoto (2013)). The previous system uses the paper test result of learner to determine the set of questions. And,  $Q$  was set as 7. The total number of given questions in this experiment is 35.

The results of the experiments of subject A is shown in Figure 4. For comparison, Subject A took paper test after each experiment. By learning repeatedly, in the 19<sup>th</sup> experiment, the subject A has acquired all the knowledge of chemical reactions corresponding to all questions given to subject A in the virtual environment. Next, to compare with a proposed system,

experimental result of Subject B is shown in Figure 5. As shown in this figure, the subject B's learning experiment is ended by 19 times too. The learning result of Subject B is similar to Subject A's result. However, total learning time of Subject B using the previous system is longer than Subject A's total time using the proposed system, because by using the proposed system, the questions are given to learner's without performing some paper test before each virtual experiments. From these results, by performing repeatedly learning using proposed questions selection algorithm and virtual environment, there is possibility that a learner can get all knowledge of inorganic chemical reaction which the Japanese high school students have to study.

#### 4. Conclusions

This paper proposed probabilistic question selection approach based on a learner's learning history in the virtual environment. For chemical experiments, the proposed system gives some questions to a learner. These questions are probabilistically selected based on a learner's learning history information. The validity of the learning system based on proposed approach was shown as experimental results of 2 subjects' learning result. In future works, we would like to perform additional experiments to show the statistical analysis of proposed approach and system.

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# The effect of discourse analysis activity with KBDeX on students' understanding about collaborative learning

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**Abstract:** (350 words) It is known that collaborative learning enhances deepening participants' understanding because there are iterative processes of questioning and answering about subjects. One person finds incomplete points and asks questions about his/her partner's explanation, and the asked person answers the questions. Although such iterative processes improve deepening understanding, Japanese first-year undergraduates typically divide tasks among group members and have little discussion. It suggests that students have difficulty to recognize the effect of collaboration because its processes are complicated. We provided following ones to the students to help analysis of constructive interaction: a simple discourse data of constructive interaction, discourse analysis support tool called KBDeX, and DASK which suggests the important points when analyzing constructive interaction. Students in 2013 "Learning Management" class studied the effect of collaborative learning through discourse analysis activity of constructive interaction. On the other hand, students in 2012 class only learn theories about the effect of constructive interaction from texts. The students in the 2013 class compared with the 2012 class using design research. We analyzed the students' beliefs about collaborative learning using their reports. 38 reports in the 2013 and 41 reports in the 2012 were analyzed. The result is that the students of 2013 changed their beliefs from "dividing tasks" to "exchange one's own thinking" than the students in the 2012 class. KBDeX and DASK supported finding characteristics of constructive interaction.

**Keywords:** KBDeX, Discourse Analysis, Constructive Interaction, Deep understanding.

## 1. Introduction

Students have been expected to have the skill of deepening their understanding in recent years, and the skill is claimed to be one of the important "21<sup>st</sup>-century skills" (Griffin, McGaw and Care, 2012) for creating an innovative future society, but it is not easy. We focused on the mechanism of "constructive interaction" (Miyake, 1986) as a way of deepening one's understanding in collaborative learning. When a student gives his/her opinion to his/her collaborator, the collaborator may ask questions about the student's incomplete opinion. The student rethinks his/her opinion and answer the collaborator. The processes of questioning and answering will continue iteratively through exchanging questioner and answerer. Such interactions enhance each participant's deepening understanding of the subject, not lead convergence of understanding (Miyake & Miyake, 2014). This effect of constructive interaction is shown in many learning situations (CoREF, 2013), but first-year undergraduates think that a group activity consists of dividing tasks among group members with little discussion, even when they had experienced group activities before entering the university (Matsuzawa, Tohyama and Sakai, 2013). We think that students miss numerous opportunities for deepening understanding because they do not know the relationship between collaborative learning and deepening understanding. However, if we lecture the students on the relationship between collaborative learning and deepening understanding, the students tend to forget it in the future because this type of knowledge is easy to disappear (Clement, 1987). We can observe the mechanism of constructive interaction when we analyze discourses from meta point of view (Tohyama, 2013). Thus, we provided KBDeX (Knowledge Building Discourse

eXplorer) and DASK (Discourse Analysis Sheets for KBDeX) to help students' own discourse analysis activity for understanding the characteristics of constructive interaction. We analyzed the students' beliefs about collaborative learning in the 2012 class and the 2013 class, focusing on changes in the Learning Management class curricula using design research (Brown, 1992).

## 2. Experiment Design

Our target was first-year undergraduates who studied "Learning Management" which held in 2013 at Japanese University during the autumn term as required classes. The students were expected to learn how to reflect their own study processes from meta points of view. In this study, we targeted the initial phase of the Learning Management because the students learn about merits of group work. The classes were also held in 2012 with the same form, and the 2013 class was the experiment group in this study. There were about fifty students in the 2012 class and the 2013 class. These students had their own laptop computers that were connected to the Internet. The second author was a class teacher, and the first author assisted him in both classes.

The activity for learning the merits of collaborative learning in the 2013 class differed from that in the 2012 class. We asked the students in the 2013 class to analyze a discourse of constructive interaction using KBDeX and DASK. The students in 2013 installed KBDeX on their own laptops along with sample discourse about a bobbin's rotation mechanism recorded by Yamanaka (2002). This bobbin problem looks simple but difficult to explain correctly. In the discourse, two master course's students discuss about the mechanism of a bobbin's rotation when its string is pulled (Figure 1). At first, their understanding levels of bobbin's mechanism were level 1 and 2, but at the end, both of them reached level 3 (highest) of understanding. The discourse was made by 235 lines. Each line was separated by the speakers' pause. The discourse could read on KBDeX, but we provide printed version to the students for improving its readability.

To emphasize characteristics of constructive interaction, twenty-seven keywords which were selected by the authors were loaded into KBDeX. These keywords were deeply concerned with the changing levels of understanding of two speakers. And we provided DASK to describe characteristics of each phase of the discourse using KBDeX. The discourse was separated into 11 phases based on the change in the speakers' levels of understanding, and KBDeX draw each phase of graphs.

The centers of two circular frames are interconnected by an axle, and a string is wound round it as illustrated in the figure. What will happen if you pull the string as shown below? The discs may roll, but never slide.

Mark the number that you think correct.

- (1) The bobbin rolls to the left.
- (2) The bobbin rolls to the right.
- (3) The bobbin does not move.
- (4) Others. (Write down your answer concretely.)

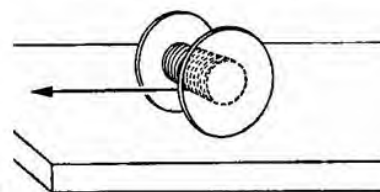


Figure 1. Bobbin problem.

On the other hand, we produced a collaborative text comprehension activity called "Jigsaw" (Aronson, 1978) for the 2012 class. In the jigsaw, the students were divided into four groups and provided one of four texts. Each text concerned the effects of collaborative knowledge building from the viewpoint of 21<sup>st</sup>-century skills (ITL Research, 2013). The students read the text within each group. After that, the students from each group made new groups and explained the texts to each other.

We provided "introduction activity" to both the 2012 and the 2013 classes before the jigsaw or discourse analysis. The activity was called "Collaborative Figure Description Building" (CFDB) (Araki *et al.*, 2008) and its reflection. The objective of CFDB and its reflection is to present the students a variety of ways of understanding clearly; this diversity of understanding contributes to the creation of new ideas and to using KBDeX. It took 180 minutes for the activities in 2012 and 2013. We also provided "wrap-up activity" to both the classes; a jigsaw activity using four texts for learning how to make collaborative learning more effective. The four texts were the mechanism of constructive interaction, functional fixedness in collaborative problem solving, nursery kids' collaborative learning,

and the conformity experiment. After the jigsaw is over, we expected the students to gain skills of building an effective collaborative learning environment.

The target activities - jigsaw or discourse analysis -, introduction activity, and wrap-up activity were shown in figure 2. The target activity in the 2012 class took about 90 minutes, while the 2013 class took 120 minutes because the students solve the bobbin problem before the discourse analysis activity in 2013. Needless to say, there were a lot of differences between the 2012 class and the 2013 class about target activity, so we regards a difference of post-reports between 2012 and 2013 as summative data and show the results of detailed analysis in 2013 as the effect of discourse analysis activity.

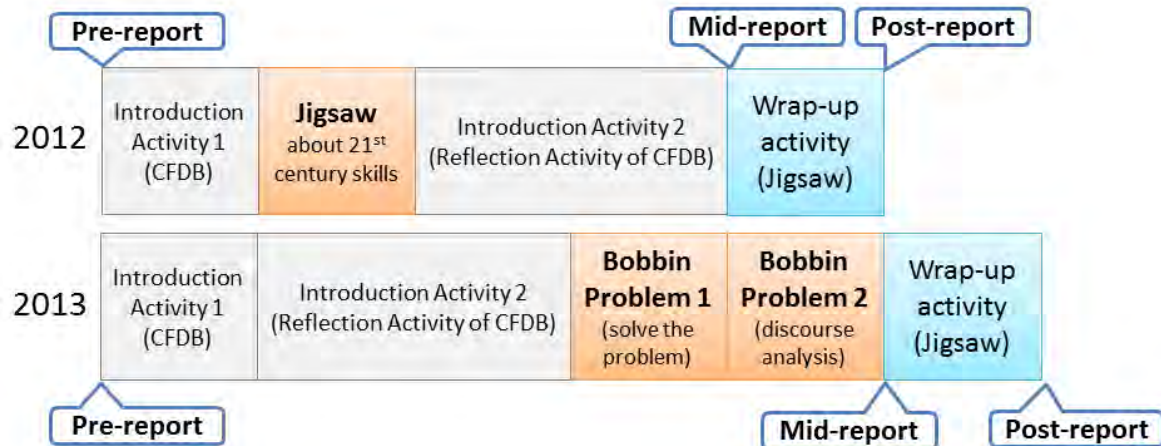


Figure 2. Activities in the 2012 and the 2013 classes.

### 3. Support Tools

KBDeX supports discourse analysis in collaborative learning from the perspective of complex network science (Oshima, Oshima and Matsuzawa, 2012) by visualizing network structures of discourse based on a bipartite graph of words × discourse units (e.g., conversation turns or sentences). The network structures are: (1) the speakers' network structure, (2) the unit network structure, and (3) the network structure of the target words (Figure. 3). We input discourse data (in .csv format) and a list of target words for bipartite graph creation (a text file). If we click a speaker in (1), KBDeX will mark units using red color in (2) and words in (3) which were referred by the selected speaker. Red nodes in figure 3

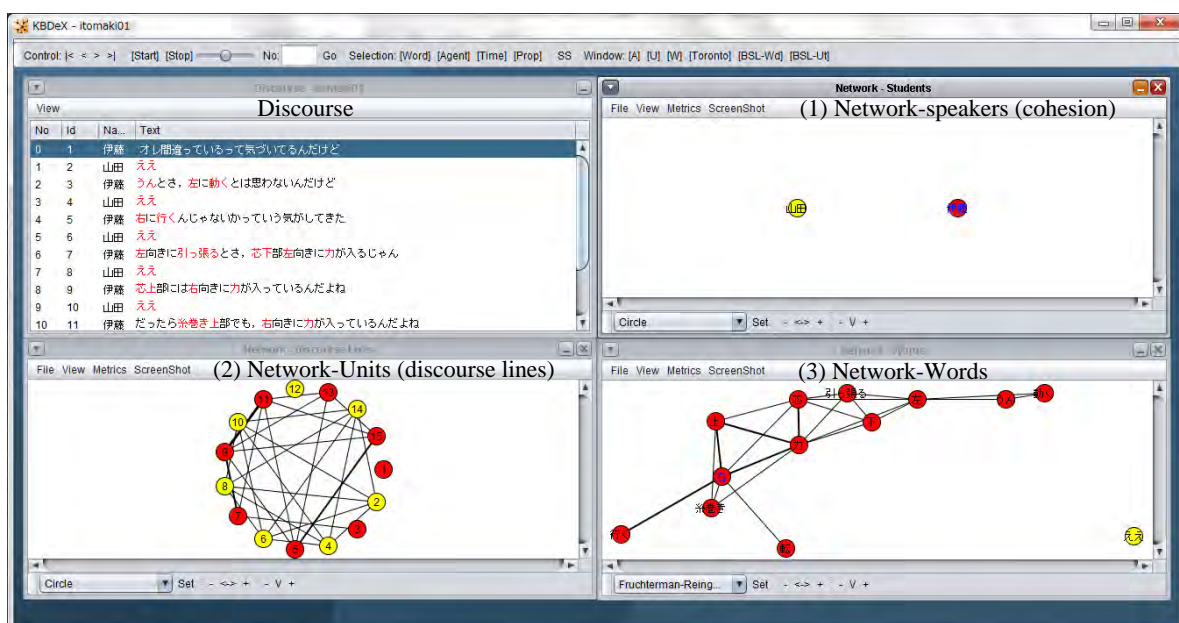


Figure 3. KBDeX Software Interface.

show units and words referred by “Itoh”, and we could guess that Itoh is a main speaker of this phase.

DASK supports emphasizing characteristics of constructive interaction of the discourse. First, DASK provides a graph indicating the speakers’ understanding level of each phase (Figure. 4) which was analyzed by the first author. Second, DASK required the students to find the characteristics of each phase based on the appearance of target words, remarkable statements, and the degree of cohesion between the speakers (Table 1). The students picked up some words from target words which were frequently appeared in each phase. Remarkable statement which is pointed by Id number was also selected by the students. The students selected one of three options such as loose, medium and tight for the degree of cohesion.

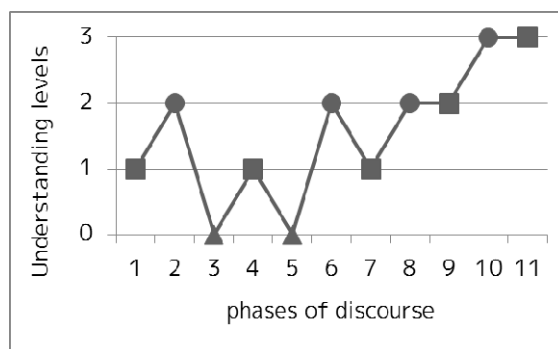


Figure 4. Graph of understanding level shown in DASK.  
 (■: Speaker A, ●: Speaker B, ▲: Both speakers)

We categorized explanations of a phase which is based on simple rotation model (e.g. “If the bottom is pulled left, the top will move right.”) into level 1. Explanations of a phase which is based on incomplete model of “bottom’s axis” (e.g. “There is fulcrum point at the bottom of the axis, so if the bottom of the axis is pulled left the bobbin will be rotated to the left.”) into level 2. We categorized explanations which are based on complete axis model (e.g. “The axis is in the center of the bobbin, so wherever we pull the axis to the left, the bobbin will be rotated to the left.”) into level 3. Explanations not categorized into level 1, 2, or 3 were assigned to level 0.

Table 1. Worksheet for finding characteristics of discourse in DASK example.

| Phase | frequently appearing target words | Selected Id # from the discourse | degree of association of the speakers | characteristics of the phase |
|-------|-----------------------------------|----------------------------------|---------------------------------------|------------------------------|
| (1)   | <i>power, right</i>               | Id: 9                            | loose medium tight                    | <i>Itoh's explanation</i>    |
| (2)   | <i>rotate, bottom</i>             | Id: 30                           | loose medium tight                    | <i>Yamada's explanation</i>  |

#### 4. Analyzing

We analyzed the three kinds of students’ reports and DASK which were written by the students in 2013. The students wrote reports at the initial phase, before the wrap-up jigsaw, and after the wrap-up jigsaw (Figure 3). The question in the pre-report was “what is the ideal group work for you?” and the question in the mid-report was “what will you do making your group work ideal?” We believe responses to these questions reflect the students’ thinking about what collaborative learning is. If the students wrote that externalizing their own thinking and revising it repeatedly in collaborative discussion is important, they may understand the relationship between collaborative learning and deepening understanding.

Students who gave us all the reports were selected as subjects. There were 38 such students in the 2012 class and 41 in the 2013 class. The first author as well as other staff members who worked at Japanese university analyzed these reports independently. The two results were 80% matched.

## 5. Results

### 5.1 Result 1: Students' thinking about what collaborative learning is

We categorized reports into “task dividing” or “exchange opinions.” Students who think of collaborative learning as task dividing were categorized into “task dividing.” Students who think that the importance of collaborative learning is exchanging one’s opinions were categorized into “exchange opinions.” The result of categorization of the 2012 class is presented in Figure 4, and the 2013 class’s result is seen in Figure 5. The number of mid-reports and post-reports in the “exchange opinions” category in the 2013 class was much higher than in the 2012 class even though the number of pre-reports in the 2012 class was almost the same as in the 2013 class. We checked the difference between the results of the pre- and mid-reports within each class using a chi-squared analysis. There was no significance in the 2012 class ( $\chi^2=0.95$ ,  $df=1$ ,  $n.s.$ ), but it was significantly different in the 2013 class ( $\chi^2=20.09$ ,  $df=1$ ,  $p<.01$ ). We also checked the difference between the results of the pre- and post-reports, there were significantly different both in the 2012 class ( $\chi^2=6.08$ ,  $df=1$ ,  $p<.05$ ) and the 2013 class ( $\chi^2=35.56$ ,  $df=1$ ,  $p<.01$ ). These results show that the discourse analysis activity helped the students’ learning about exchanging opinions is important in collaborative learning. The wrap-up activity was also effective in each class, but its effect was limited.

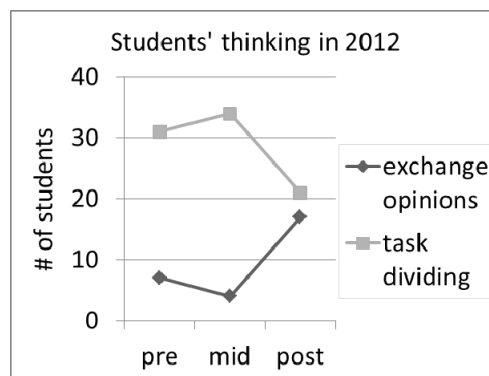


Figure 4. Students' thinking about collaborative learning in the 2012 class.

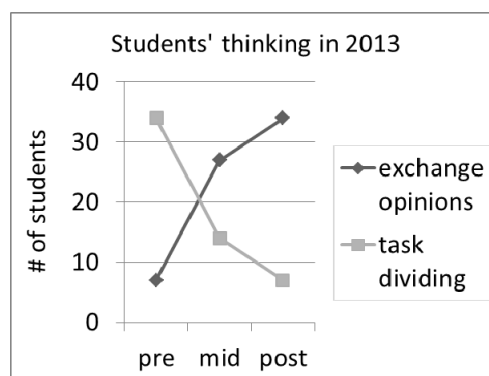


Figure 5. Students' thinking about collaborative learning in the 2013 class.

### 5.2 Result 2: Students' activities with DASK

We analyzed “characteristics of the phase” of written DASK to analyze the detailed activities of discourse analysis. Five students wrote that discussion is analyzed as a process that can lead to convergence of understanding. All of the five students wrote “task dividing” in the mid-reports. It suggests that the five students misunderstood the characteristics of constructive interaction. There was no significant difference about the frequently appeared words between the speaker A and the speaker B in each phase, but in detail, how to use the words were different each other. It seems KBDeX and DASK are limited to show the difference of detailed discourse. Moreover, two other students wrote that collaboration is iterations of questioning and answering. These two students also wrote “task dividing”



in the mid-reports. It is known that such iterations are important to improve deepening understanding in collaborative learning, but the two students only observed superficial form of discussion without a viewpoint of understanding level. These results suggest that KBDeX and DASK should show varieties of participants' understandings than ever.

## 6. Discussion

Students recognized that collaborative learning is effective as a deepening understanding activity through the discourse analysis activity using KBDeX and DASK, but the students who learned the characteristics of collaborative learning through text-based activity difficult to recognize this. The students who analyzed discourse with KBDeX and DASK noticed that externalizing their own thinking is necessary for deepening their own understanding because this is needed when they start a constructive interaction. These results suggest that students could change their beliefs when they are scaffold. KBDeX and DASK may help students overviewing of the process of collaborative interaction. However, these scaffolds were particularly ineffective because it misled some students to understand the characteristics of constructive interaction.

KBDeX is a powerful visualization tool, but how to interpret the characteristics of the graphs shown in KBDeX is not easy especially discourses are complicated like constructive interaction. We will continue to explore how to support qualitative analysis of discourses using KBDeX for finding more effective ways to the students.

This research is the first step in our plan. Our final goal is building the students' skills for collaborative learning which deepen the students' understanding. In the future, we hope to revise our Learning Management class with more appropriate use of KBDeX.

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# The Impact of Using 3D Animation in Students' Spatial Ability

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**Abstract:** The purpose of this study is to investigate the impact of using animation in a multimedia environment designed to improve students' mathematical spatial ability. Sixth grade students (N = 44) were randomly assigned to one of the two experimental conditions with animation or non-animation as factors. The results show that participants provided with animations performed better than their peers provided with non-animations.

**Keywords:** spatial ability, 3D animation, multimedia environment

## 1. Introduction

Spatial ability is one of the most important abilities for many disciplines, such as mathematics, physics, chemistry, science et.al. But many students have difficulties in solving spatial problems. As multimedia technology rapidly develops, three-dimension technology has been introduced into the domain of education to help improving spatial ability. And many researches have proved that multimedia technology can improve students' performance if the design is rational. In recent years, many multimedia learning systems with three-dimension animations or software have been proved effective in improving students' spatial ability (Yeh, A, 2004; Hauptman, H. & Cohen, A, 2011; Hauptman, H, 2010; Christou, C., Pittalis, M., Mousoulides, N., & Jones, K., 2007).

Folding and unfolding problem solving is one of the spatial ability for students. It is a bridge between two-dimension figures and three-dimension figures. By solving folding and unfolding problems, students would know that polyhedron can be folded by two-dimension figures, and polyhedron can be unfolded into two-dimension figures in different ways. The traditional method in the classroom of teaching folding and unfolding in China is that students are asked to cut cube paper boxes or fold papers into cubes to perceive the process of folding and unfolding. Different students may cut the cube paper boxes in different ways, and that would produce different unfolding two-dimension figures. These different figures will be shown to the students as demonstrations. But the disadvantages of the traditional method are obvious. First, the paper boxes taken from home by students are not big enough to show to all students in the classroom. Second, paper boxes would not be reused when they are cut. So we developed the multimedia learning system to help solving folding and unfolding problems. In this system, 3D animations are contained to simulate transforming between 2D figures and 3D figures.

This study investigated the impact of 3D animations for students' solving folding and unfolding problems. We assumed that the students who received feedback with textual instruction and 3D animations would perform better than the students who received feedback without 3D animations. Furthermore, students' learning intrinsic motivation, cognitive load (including intrinsic load, extraneous load and germane load) are measured to investigate the effects of animation. A multimedia environment to learn folding and unfolding problem solving was developed to support this study.

## **2. Literature review**

### *2.1 Spatial ability*

Spatial ability is one of the most mathematical ability, and it has been defined as skill in “representing, transforming, generating, and recalling symbolic nonlinguistic information” (Linn & Petersen, 1985). But students have difficulties in solving spatial problems. A number of studies have proven that spatial abilities can be improved with appropriate exercise (Ben-Chaim, Lappan, & Houang, 1988), especially with learning by computers.

### *2.2 3D Animations in Spatial Education*

Using 3D animation has been recognized as an effective method to improve students’ incomplete mental models (Wu & Shah, 2004, Ferk, Vrtacnik, Blejec, & Gril, 2003). So there have been some researches about applying 3D animation to improve students’ performance. Hauptman have developed a Virtual Spaces software environment to improve students’ spatial thinking (Hauptman, 2010). By learning with Virtual Space, students can exercise the abilities to build spatial images and to manipulate them. According to Hauptman, Virtual Spaces enhanced students’ spatial thinking.

Korakakis et.al. explored whether specific types of visualization (3D illustration, 3D animation, and interactive 3D animation) combined with narration and text contribute to students’ performance (Korakakis, Pavlatou, Palyvos & Spyrellis, 2009). And the results showed that multimedia applications with interactive 3D animations as well as with 3D animations increased the interest of students and make the material more appealing to students.

## **3. Method**

### *3.1 Participants*

Forty four sixth grade students (twenty three females and twenty one males) from elementary school in northeast China were invited to participate this experiment. Their average age was 11 years old, and they could operate computers and learn with computers. The participants were divided into two groups according to the class. There were twenty four students in the group of animation (experiment group), and twenty in the group of non-animation (control group).

### *3.2 Multimedia learning environment*

The multimedia learning system was developed to improve students’ spatial ability. In this system, the animations that simulated two-dimension figure folded into a shape of cube or a cube unfolded into a two-dimension figure were included. Firstly, a folding or unfolding problem was presented, and then student submitted the answer. System would present “true” or “false” according to the students’ answers and some cues about the problem (i.e. “Think why this two-dimension figure can not be folded into a cube, and how to change this shape to be folded into a cube”). Then a static figure about the problem was presented. An animation would be played if the students of experiment group pressed the button of “folding”. These animations were developed with 3D MAX, it could simulate the process how and whether the two-dimensional figure folded the cube, or not. A sample segment of animations with hints is shown as Fig.1. The animation would not be presented if students were assigned to non-animation group. There were fifteen items with corresponding animations in this multimedia learning environment.

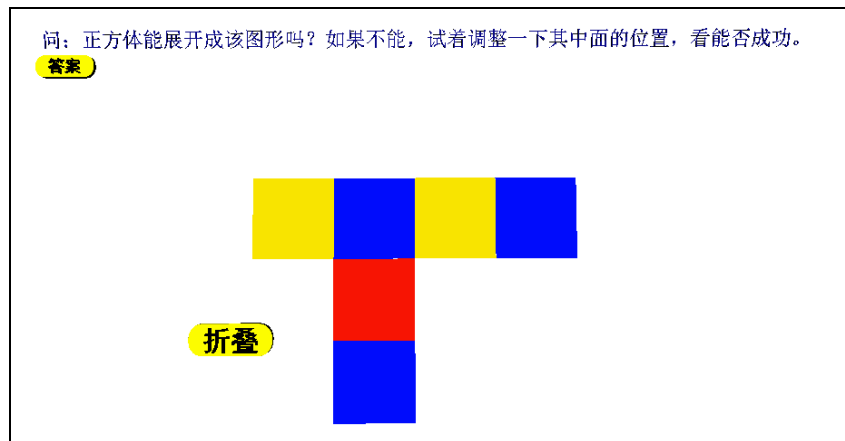


Figure 1. A sample segment of animations with hints.

### 3.3 Measures and instruments

A pretest and a posttest were developed to evaluate the learning effectiveness of the students. A pretest was composed of six choice items and fill-in-the-blank items about folding and unfolding cubes to measure participants' prior knowledge about spatial ability. Each of questions was 2 points, and the total points in the pretest was 12. The pretest aimed to detect that the two groups had the equivalent spatial ability. A posttest was conducted to measure the effect of participants' solving folding and unfolding questions after instruction. The posttest was composed of ten choice items and ten fill-in-the-blank items, which is different from pretest, but the level of the difficulty was similar. The total points in the posttest was 20. The sample question of the posttest is followed as Fig.2.

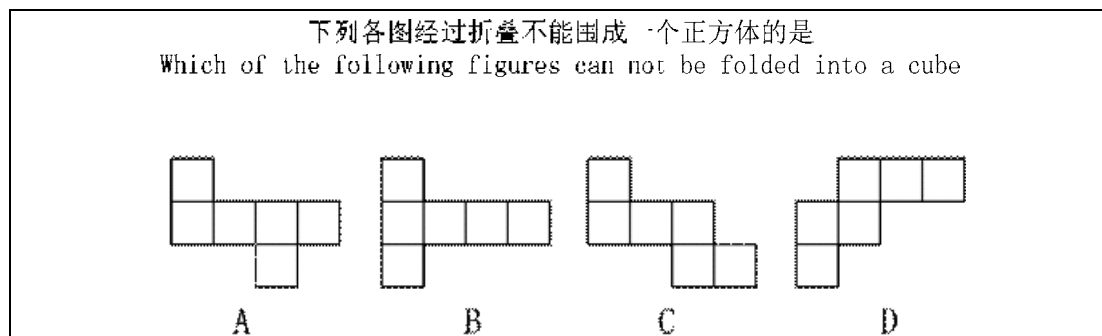


Figure 2. A sample question of the posttest.

In addition, a questionnaire with Likert-5-point was designed to measure students' intrinsic motivation. "1" was labeled as "not at all true", and "5" was labeled as "very true". There were total 10 statements, adapted from Ryan's study(Ryan, 1982), measuring intrinsic motivation with five subscales—interest, competence, pressure, value and effort (see Table 1).

Table 1: Intrinsic motivation items.

| Item  | Subscale   |
|---|------------|
| 1. I spent a lot of effort to do this activity.           | Effort     |
| 2. I feel these problems interest.                        | Interest   |
| 3. I think I was suitable to learn with this system       | Competence |
| 4. It was useful to study folding and unfolding problems. | Value      |
| 5. I didn't try very hard to do well at this activity.    | Effort     |
| 6. I didn't feel nervous during learning.                 | Pressure   |
| 7. It was useful for me to learn these content.           | Value      |
| 8. I was afraid to not do well at this activity           | Pressure   |
| 9. I thought it was boring to do this activity.           | Interest   |
| 10. I was not content with what I did at this activity.   | Competence |

Furthermore, a questionnaire with Likert-5-point was designed to measure students' cognitive load. "1" was labeled as "not at all true", and "5" was labeled as "very true". Three items about cognitive load (i.e., intrinsic load, extrinsic load and germane load) was conducted to measure the students' cognitive load (see Table 2). There were three statements to measure students' cognitive load adapted from NASA-TLX(Hart & Staveland, 1988) and were described in studies conducted by Gerjets, Scheiter, and Catrambone (2004).

Table 2: Cognitive measurement.

| Item  | Indication of   |
|---|-----------------|
| 1. I thought these problems were very difficult.              | Intrinsic load  |
| 2. I thought this system was helpful to learn these problems. | Extraneous load |
| 3. I spent lots of effort to do this activity                 | Germane load    |

### 3.4 Procedure

The experiment was conducted in a laboratory setting. At the beginning of the experiment, a pretest with paper-and-pencil was made in order to measure whether the two groups had the similar level of spatial skill. Then students studied with the multimedia learning system in thirty minutes. Post-test was conducted to measure the effect of the spatial skill with animations or non-animations after instruction. Finally, the questionnaire was followed.

## 4. Results

### 4.1 Prior knowledge

The mean and standard deviation of the pretest were 9.12 and 1.45 for the experimental group, and 8.75 and 2.21 for the control group. An independent-samples *t*-test was conducted in order to examine whether animation group and non-animation group had different prior knowledge of spatial skill. The results revealed that there was no significant difference between the two groups ( $t = .673, p = .505$ ), indicating that the participants in experimental group and control group had the equivalent abilities before learning.

### 4.2 Learning outcomes

An analysis of covariance (ANCOVA) was conducted to evaluate the effects of animation on students' performance. The percentage correct score on the pretest was used as a covariate. The result revealed a significant difference between the animation conditions and non-animation conditions ( $F = 17.81, p < .01$ ), as shown in Table 3. The mean score of the experimental group is 15.82, higher than of the control group, 13.06. Furthermore, the effect size was computed to measure the strength of the *t*-test result. The *d* value 1 implied that the animation is very helpful to improve students' learning achievements.

Table 3: Descriptive data and ANCOVA of the posttest results.

| Variable           | N  | Mean  | S.D. | Std. error. | <i>F</i> value | <i>d</i> |
|--------------------|----|-------|------|-------------|----------------|----------|
| Posttest           |    |       |      |             |                |          |
| Experimental group | 24 | 15.82 | 1.92 | .44         | 17.81          | 1        |
| Control group      | 20 | 13.06 | 2.49 | .48         |                |          |

### 4.3 Intrinsic motivation

There were two items of each subscales of intrinsic motivation. So we add these two items of the subscale (effort, pressure, interest, value and competence) to compare students' intrinsic motivation of the two groups. *T*-test was conducted, and the results shows that the subscale of effort, pressure, interest

and value had no significant difference between the two groups. But “competence” had significant difference between the two groups ( $t = .35$ ) (See Table 4). That is, the animations improved students’ competence of solving folding and unfolding problems.

Table 4: The t-test result of the post-questionnaire scores of the two groups.

| Dimension  | Group            | N  | Mean | S.D. | T    |
|------------|------------------|----|------|------|------|
| Effort     | Experiment group | 24 | 7.38 | 1.93 | 1.57 |
|            | Control group    | 20 | 6.40 | 2.19 |      |
| Pressure   | Experiment group | 24 | 5.96 | 1.27 | .28  |
|            | Control group    | 20 | 5.85 | 1.27 |      |
| Interest   | Experiment group | 24 | 8.25 | 1.91 | .24  |
|            | Control group    | 20 | 8.10 | 2.27 |      |
| Value      | Experiment group | 24 | 7.79 | 2.23 | 1.05 |
|            | Control group    | 20 | 7.10 | 2.12 |      |
| Competence | Experiment group | 24 | 7.83 | 2.55 | .35* |
|            | Control group    | 20 | 7.60 | 1.85 |      |

\* $p < .05$

#### 4.4 Cognitive load

Three ANCOVAs were conducted to evaluate the effects of animation on learners’ intrinsic load, extraneous load and germane load respectively. The covariate was pretest score so that participants’ prior knowledge was statistically controlled. There were no significant difference between the two groups with respect to intrinsic load ( $F = .44, p > .05$ ), extraneous load ( $F = .22, p > .05$ ) and germane load ( $F = .45, p > .05$ ).

Furthermore, correlation analysis were conducted to measure the strength of relationship between intrinsic load or intrinsic motivation and difference between posttest scores and pretest scores. We assume that students’ intrinsic motivation and cognitive load would impact the posttest scores. The results show that intrinsic load ( $r = -.365, p < .05$ ) and interest of intrinsic motivation ( $r = -.415, p < .05$ ) relate to difference between posttest scores and pretest scores. So a univariate ANCOVA was conducted to measure the effect of intrinsic load and interest on the difference between posttest scores and pretest scores. The covariate was interest and the difference between posttest scores and pretest scores. The result is  $F(1,43) = 3.20, p = .08, \text{Partial Eta Squared} = .078$ . That means the significant difference between experimental group and control group is related to animations, but not to interest to mathematics and intrinsic load.

## 5. Discussion

The purpose of this paper is to explore the effect of 3D animations which simulating the transforming process between two-dimension figures and three-dimension figures on students’ performance of solving folding and unfolding problems. According to previous studies, 3D animation have been recognized as effective method to improve students’ spatial ability.

In this study, a multimedia system with 3D animations is developed. Students solve folding and unfolding problems in this system, and they can get feedback immediately with 3D animation or not. These 3D animations simulate the transforming process between two-dimension figures and three-dimension figures. In order to eliminate the factors that may influence the folding and unfolding scores, the two group students’ level of intrinsic motivation and cognitive load have measure by the questionnaire. The results show that the posttest score significant difference between the experimental group and control group is due to watching animation or not. This study proves that 3D animation is

helpful to students in improving students' ability of spatial image about transforming between two-dimension figures and three-dimension figures.

Furthermore, there are some limitations in this study. The sample size is small, this directly leads to some results un-significant. The result may be kind of different if the sample size is large enough.

## Acknowledgements

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# Development and Evaluation of a User Adaptive Kanji Learning System Using Computer Graphics

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**Abstract:** This paper describes the development and evaluation of a user adaptive Kanji learning system. In order to make our already developed learning systems more adaptive for users so as to obtain the learning effects, in this study, we used the Japanese Kanji characters as e-learning content displayed on our computer system, evaluated the system performance and analyzed the learning effects. After introducing our newly developed learning system into an elementary school, we got good results through a questionnaire survey. In addition, we found out the improvements to this new system.

**Keywords:** Kanji, E-learning, Learning system, Computer graphics

## 1. Introduction

In recent years, the personal computers (PCs) and internet devices have been introduced into the elementary schools to allow school education using the PCs to be fully carried out. The advanced computer has made it possible to use computer graphics as learning materials. It seems effective that the use of computer graphics to display e-learning content arouses the user's interest in content and makes the user understand much more about it with the computer graphics introduced in making visual effects.

Matsushita et al. have been developing the teaching materials using computer graphics [1] and the learning system using computer graphics to display e-learning content [2]. The learning system displays a user adaptive learning content to increase the learning effects. The user can select e-learning content that he/she desires on this system to make questions automatically at random for the selected content.

In order to make our already developed learning systems more adaptive for users so as to obtain the learning effects, in this study, we used the Japanese Kanji characters as e-learning content displayed on our computer system, evaluated the system performance and analyzed the learning effects.

This paper presents the development outline and construction of a user adaptive Kanji learning system. Furthermore, it describes the evaluation of system performance and the analysis of learning effects through a questionnaire survey after the introduction of system into an elementary school.

## 2. Kanji Learning System

### 2.1 System outline

A user can select a Kanji character that he/she wants to study on this system to make questions at random for the selected Kanji with different readings of onyomi and kunyomi. All school children are able to select a Kanji character regardless of the school year. The Kanji learning system can cope with both onyomi and kunyomi readings that a Kanji character has.



## 2.2 System construction and screen structure

This system consists of HTML, JavaScript and PHP. The web browser interface is built in the system. The computer graphics animations on the screen were created using the POV-Ray software [3]. Figs. 1 and 2 show the system construction and the screen structure, respectively.

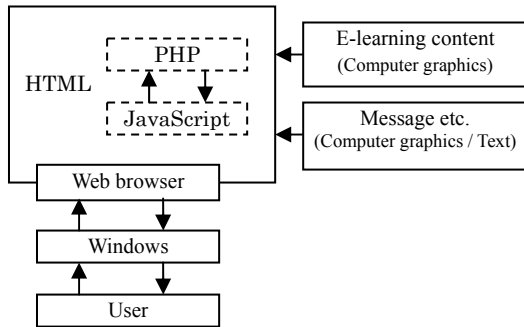


Fig.1 System construction

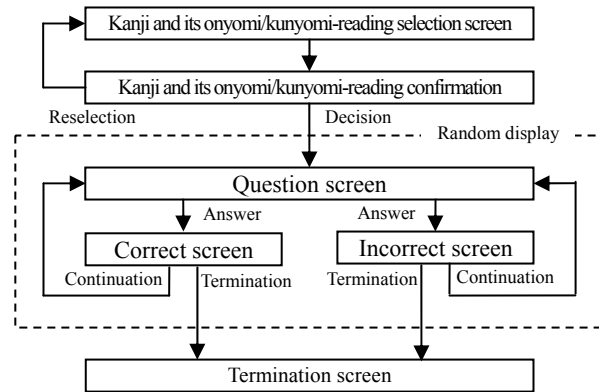


Fig.2 Screen structure

## 3. System Operation and Screen Transition

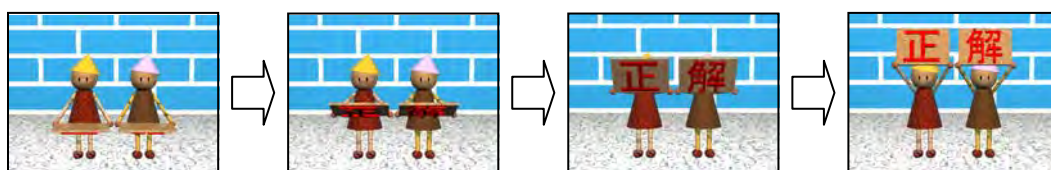
Actuating the system displays the Kanji and its onyomi/kunyomi-reading selection screen (Fig. 3 (a)). On this screen, the user selects a Kanji character and its onyomi/kunyomi readings (onyomi-reading study or kunyomi-reading study) that he/she wants to master. On the Kanji and its onyomi/kunyomi-reading confirmation screen, the user checks if the selected Kanji and its onyomi/kunyomi readings are completely correct. The question screen (Fig. 3 (b)) displays the selected Kanji (the correct answer screen) and the other Kanji (the incorrect answer screen). The user has to choose between two answers for a question and successively click either answer that he/she considers correct. After the user answers the question, the correct or incorrect answer screen shows the corresponding computer graphics animations (Fig. 3(c)).



(a) Kanji and its onyomi/kunyomi-reading selection screen



(b) Question screen



(c) Computer graphics animations on correct/incorrect answer screens

Fig.3 Screen transition

#### 4. introduction and evaluation of system

We introduced our newly developed system on trial in class of an elementary school and conducted a questionnaire survey on the evaluation and analysis of this system. The subjects were 48 fourth-year students. In this experimental method, each student used one PC and accessed the system through the internet. The questionnaire survey was carried out using the five grade evaluation system, with 5 being the best, and the free writing system. This was an anonymous survey. Tables 1 and 2 show the questionnaire items and the results of questionnaire analysis in the five grade evaluation system, respectively.

Table.1 Questionnaire items in five grade evaluation system

|  |
|--|
| <ul style="list-style-type: none"> <li>• Was the system easy to use? (Question 1)</li> <li>• Was the system interesting to operate? (Question 2)</li> <li>• Were the animations of system good? (Question 3)</li> <li>• Was a lesson in the system proper? (Question 4)</li> </ul> |
|--|

Table.2 Questionnaire average scores and top 2 response rates in five grade evaluation system

| <i>n</i> =48         | Question 1 | Question 2 | Question 3 | Question 4 |
|----------------------|------------|------------|------------|------------|
| Average scores       | 4.71       | 4.60       | 4.79       | 4.69       |
| TOP 2 response rates | 96%        | 94%        | 98%        | 94%        |

According to the results of this questionnaire survey that the top 2 response rates (the ratio of “5” or “4” scored in the questionnaire items) were very high in the five grade evaluation system, our updated system is considered to be effective in learning with the computer graphics animations on the screen. In the questionnaire survey using the free writing system, we obtained a lot of positive opinions for the Kanji learning system to be used for studying. We also received plural students’ opinions that they are not good at Kanji, but they can enjoy learning Kanji on this system and have come to like Kanji. However, the students also stated their plural opinions that they request us to provide a function for selecting the related Kanji characters at the same time and to increase the number of computer graphics animations on the screen. As above mentioned, we believe that this new system must be improved, but the use of this system enabled the user to learn Kanji effectively and to arouse his/her interest in Kanji.

#### 5. Conclusion and Future Research

This paper has described the outline of a user adaptive Kanji learning system using the computer graphics. As the results of the questionnaire survey, it is proven that this system is effective in Kanji learning. However, we found out the improvements to the system function and to the computer graphics animations on the screen.

In future, we are going to improve the system function and enter additional computer graphics animations. We will also consider whether the system improved should be assessed.

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[3] <http://www.povray.org/>

# Effective eLearning through MOOC: Lessons learnt in selecting a MOOC

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**Abstract:** Perspectives of eLearning is changing with the introduction of Massive Open Online Courses (MOOC). The pedagogy introduced by MOOC has identified as more effective than typical eLearning courses. However MOOCs are facing challenges due to the lower course completion rates. There have been many MOOCs introduced to the community within last two years. However not all the MOOCs meet the goals of learner or provide effective learning. Hence it is important to identify the factors affecting effective learning in MOOCs. In this research, author as an active MOOC participant for a period of 2 years in 16 attempted courses with 5 different platforms gathered and analyzed data from interviews, observations of students' behavior using Grounded theory. The research found 10 dimensions affect to an effective learning to take place in MOOC. Careful attention to these dimensions will increase the users' sustainability in the MOOCs. The results will be a benchmark and a guide to any MOOC user or MOOC developer attempting to produce or participate in an effective eLearning experience.

**Keywords:** Massive Open Online Course, MOOC, effectiveness, eLearning, eLearning Participants

## 1. Introduction

Massive Open Online Courses (MOOCs) are the trends in eLearning. It is an open eLearning concept where any interested participant's access & participate in courses free of charge. This leads thousands of participants signing up to MOOC courses every day. At the same time numbers of MOOC providers increases due to the demand and the interest towards the highly emerging concept. According to recent literature MOOC is buzzing since 2012 and attract widespread attention. Some recently emerging MOOCs are edX, Udacity, FutureLearn, Open2learn, Udemy, NovoEd, Iversity and Coursera. Coursera was developed by Stanford University entered into partnerships with 62 world class universities (Daniel, 2012). In a typical MOOC course, sometimes enrollments are between 40,000-100,000 students of whom only 50 to 60 percent return for first lecture. About half of those who attend the first lecture submit the assignment for grading. Only 5 percent those who enrolled gets the statements of accomplishments (Koller, Ng, Do, & Chen, 2013). There have been researches in exploring the reasons for the dropouts in MOOCs, but the significant researches to find the effective MOOCs are yet to emerge (Chamberlin & Parish, 2011). Even though MOOCs have been widely accepted, they are still learning the needs of the participants. Catering to the needs of the participants are very important as it is one of the main reason for low student retention (Clow, 2013; Lewin, 2013).

It is the responsibility of academic community to clear the path for an effective learning through this phenomenal change of education in MOOC. As it ripes through the time, problems occur, we as a part of MOOCs community should work to find solutions to the developing problems. Working towards this direction, as an active users in MOOCs community we explore an important problem caused by many platforms entering to the community. Participants are yet to adapt themselves into the MOOCs platforms and the new concepts. With the little they know about MOOC, selecting the right platform and learning effectively from it, is often challenging. Selecting the right platform would reduce the time and effort in learning. This research will explore the factors affecting to an effective learning experience through MOOC.

## 2. Background of the Study

The problem of high dropouts in MOOCs has been researched & according to Wang (2013), three major areas affect students to retain in MOOC. Those were explored under social and cognitive perspectives, namely lack of self-efficacy, lack of self-regulation and lack of self-motivation. However another research claims dropping out is often challenged by different viewpoints and suggested that it is merely failing to achieve personal aims (Liyanagunawardena, Patrick, & Williams, 2014). Nevertheless it is important to find about the user's needs in a MOOC environment to retain the students until they complete the course. Student retention problem was researched by Cormier & Siemens (2010) & Russell, et al.,(2013) & identified key values of a course in a education system and at the same time Mackness, Mak, & Williams (2010) states about the question of how to design a course which will provide satisfaction to the participants. More researches on this directions, Masters (2011) discuss how the roles of instructor have changed while Xu & Jaggars (2013) examine the extent to which students perform in online & face to face situations. However MOOCs represent latest technology opportunity where the potential pedagogical impact need to be researched (Fox, 2013).

### 3. Our Approach

#### 3.1 Methodology

We used Grounded theory in order to identify the dimensions in students' perspective of MOOC's effectiveness. It is mainly due the fact that Grounded theory investigates the actualities in the real world and analyses the data with no preconceived ideas or hypothesis (Glaser & Strauss, 1967). In other words, Grounded theory suggests that theory emerges inductively from the data (Chesebro & Borisoff, 2007).

Our approach begins with broader research question of "what dimensions affect the effective learning in MOOC?" & our initial sampling gathered data from interviews and observations in forum posting, coursetalk social media blog while participating in 16 courses from Coursera, edX, NovoEd, Iversity for a period of 2 years. Sample size was above 100 participants and used purposive sampling technique.

Once we analyze the data & identified some coding, we began the theoretical sampling. We conducted in-depth interviews with selected active participants. According to the results of theoretical sampling data we refined 7 focus codes. After defining focus codes our analysis focused in theoretical coding. We broke down the major focus codes, which contributed to describe majority of data. As a result of theoretical coding process we synthesized 10 dimensions that affect the effective learning and at this time our study reached theoretical saturation. This often interprets as the situation when researcher does not hear anything new from the participants (Charmaz, 2006).

#### 3.2 Results

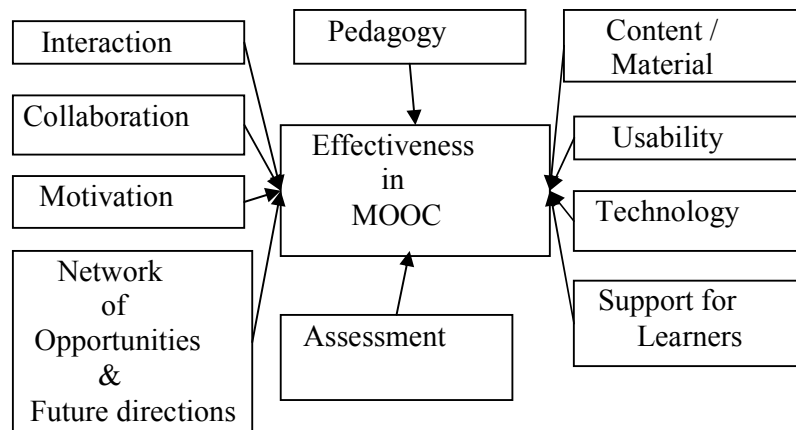


Figure 1. The factors affecting to an effective eLearning resulted by the Grounded theory.

The results of Grounded theory expressed as a substantive theory as depicted in Figure 1, that a set of concepts related to each in cohesive manner. In our theory, we fleshed out each major code, examining the situation which they occurred and why it occurred. While analyzing the codes we reached theoretical saturation where we were able to cover the aspects of effectiveness according to participant's perspective. We did the diagram of design, written memos, rigorously searched the dimensions which not covered to eLearning. Our theory of 10 dimensions affecting the effective eLearning related to one another in cohesive manner & accounts adequately for all the data we have collected.

#### 4. Discussion & Conclusion

We tried to elaborate a detail analysis of MOOC, an emerging phenomenon, which is wide spreading in educational reforms. The MOOC providers keep on rising with the demand for eLearning. These insertions of MOOC platforms cause quality issues with regard to experience by the participants. Hence it is important to identify the factors affecting the effective eLearning. In this research we explored answers using the methodology introduced by Gaser (1967), the Grounded theory. We found that there are 10 dimensions which a participant value as effective in eLearning. Those are namely interaction, collaboration, motivation, network of opportunity, pedagogy, assessment, content/material, technology, support for learners and finally usability. Our research uniquely found that the network of opportunity dimension is valued by majority of participants. This is due to the nature of MOOC being exposed to multicultural background and student's value opportunities in practicing what they have learnt. The 10 dimensions found in this research will be a guide and should be emphasized by any platform in order to provide an effective learning experience. At the same time it is important to keep identifying the changing patterns of behaviors in students while taking the MOOC courses where it will produce more affecting dimensions which will influence to produce an effective eLearning experience.

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# Learning by “Search & Log”

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**Abstract:** Although previous research has demonstrated the benefits of the “learning by searching” strategy, there is a new problem which is how to measure and analyze the effectiveness of “Learning by Searching” behaviors. In this paper, by using the record of the students’ learning history, we have proposed a SNSearch system to analyze student web-searching behaviors of “Learning by Searching”.

**Keywords:** Learning logs, Learning by Searching, Data Mining

## 1. Introduction

There are many issues with Web-based learning, including the processing of Web information, and the roles of teachers in the online learning environment, and analyzing the Web based learning behaviors of students (Bilal, 2000, Hwang et al., 2008). With the development of Internet and search engine technologies, online searching is becoming an important part of learning. Searching is a natural learning behavior like listening, speaking, reading or writing. The way of learning by online searching is called “Learning by Searching”(Yin et al., 2013).

We have developed a Milkyway system, which is based on the “Learning by Searching” theory (Yin et al., 2013). Through experiments, the Milkyway system has demonstrated the benefits of “learning by searching”. Also at the same time new research topics have been identified, of which one of them is “analyzing student web-searching behaviors of using search engines for problem solving”.

In this paper, we have proposed a SNSearch system to help students to share their ‘learning by searching’ experiences. Users can share their search queries and browsing history anytime, anywhere. We refer to the search queries and browsing history as “learning logs”. By using these community learning logs, we built a system to analyze student web-searching behaviors of using search engines.

## 2. Measuring The Potential and Actual Effectiveness of Collaborative Learning

The collaborative potential of a system is how much the system supports sharing of information, experience, and activities. This can be thought of as the number of collaborative opportunities provided by the system, which can be constructed through the analysis logs. For example: Learners A, B, and C have been to the same results and left 2, 3, and 1 experiences or activities respectively in the log. When learner D goes to the same results the collaborative potential could be calculated as the sum of experiences/activities that are displayed from the log:  $2 + 3 + 1 = 6$ .

The actual collaborative use of a system is how much collaborative potential of a system is used. This can be thought of as how many learners used collaborative opportunities offered by the system. The actual collaborative use of the system could be calculated using different degrees of use. To enable this analysis, collaborative actions need to be logged to the

required level of granularity, such as: did the learner click on the title of the paper or on collaborative feedback *like* button? An example of the calculation of the actual collaborative use of the system can be seen in the following example: Learner D goes to the same results in the example about and clicks on two previously recorded activities of learner B and A. This equals a score of 2 for actual collaborative use of the system.

By using these measures, comparisons between the potential and actual collaborative could be used as a metric of system performance. It could also offer an evaluation method that can be used to compare the collaborative performance and effectiveness of improvements and different systems.

A naive score for collaborative system effectiveness could be seen as:  $E = A / P$ , where E is the effectiveness, A is the actual collaborative use, and P is the potential collaborative use of the system. However this could possibly skew the effectiveness towards results that have a small potential, as it might not be possible for a learner to actually use all the collaborative potential of a result.

### 3. Search & Log

#### 3.1 Listing View, Item View and Log Map View

In this paper, we developed a demo system, which is an extension of the Community Search system (Flanagan et al., 2013) by introducing knowledge share mechanism into the search engine. Figure 1 shows a mockup image of the interface which has three areas (A) Listing View, (B) Item View and (C) Log Map View as well as the query input frame at the top of the screen.

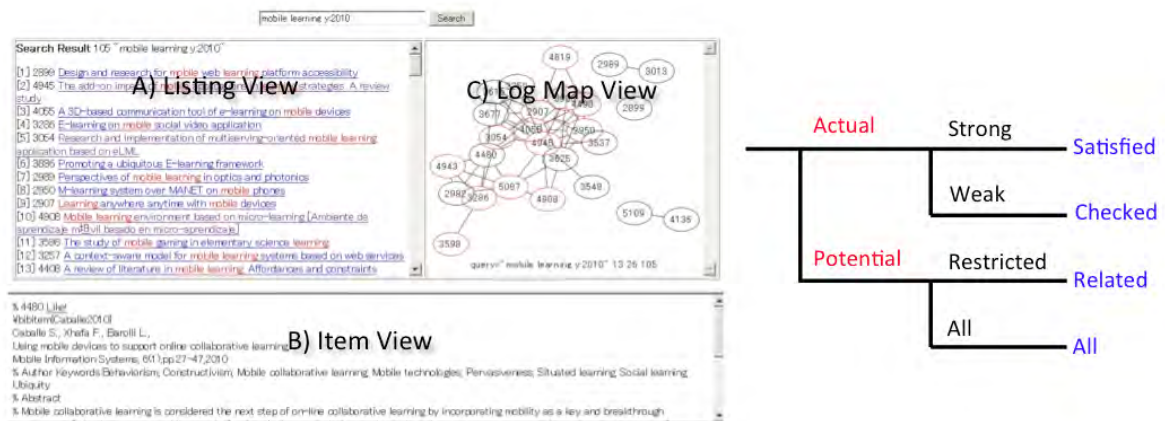


Figure 1. Search & Log triple view.

The list of search results is shown in the area (A). At the top of (A), the number of the search results and the query are shown followed by the ranked list of search results with their title. The IDs of articles are displayed at the beginning of the articles. The IDs are shown as the nodes in the area (C) to represent the articles. The most important article with the highest relation with the query is the article 2899 and is ranked at the top of the list. The detailed information of the article, e.g., the authors, the source and the abstract, is displayed at the area (B) if a user clicks the title or the ID of the article.

So far, the proposed system is the same as that of the usual search engine. The feature of the community search proposed in this paper is in the “like” button of the area B, and the diagram in the area C. User's response or evaluation of an article will be sent when the user clicks the *like* button. If he convinces himself that the article is appropriate with respect to his

query, he can click the *like* button. The system keeps the triple of the query, user ID and the article ID, so that the user's judgments are stored and can be shared with other users.

Each node of the diagram in the area (C) represents an article in the search result. However, only the articles that have been viewed by at least one user are shown in the diagram. The nodes with the red circles represent the articles which received the *like* button at the area (B). The articles are not shown scattered, but shown with links. A link between two articles implies that the same user has checked the two articles. Thus the area (C) displays the responses of the all users with respect to the query.

### 3.2 Potential Knowledge and Actual Knowledge in Triple View

When a user sends a query to the system, log data from the system can be classified into four types, all, related, checked and satisfied log data, according to his intention, experience and knowledge. All log data represents all of the actions by users that have been recorded in the log. They do not have to be related to his query. Related data on the other hand is a subset of all log data that has a relation to his query. When some users paid attention to an article, this is recorded as checked log data. If a user particularly has interest in an article and clicks on the *like* button, then it is recorded as satisfied log data.

Each article displayed in the Listing View represents potential knowledge (related log). When a user clicks one of the articles, then the article becomes his pseudo actual knowledge (checked log). When he clicks the *like* button of the article in the Item View, then the article changes to his actual knowledge (satisfied log). The article shown in the Log Map View represents the common knowledge of other users with similar interests. They once asked the similar query to the system, viewed similar results and made some action that was recorded in the log.

## 4. Conclusion and Future Works

We considered that search learning behaviors can be examined through the analysis of the learner's action in this process. In this paper, we proposed a method to measure and analyze the effectiveness of "Learning by Searching" behaviors by using learning logs. Based on this method, a SNS-based system has been developed to help to analyze students learning behaviors of using search engines for problem solving. For future work, we will evaluate the environment.

### Acknowledgements

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# On Using Mutation Testing for Teaching Programming to Novice Programmers

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**Abstract:** In this paper we argue that the incorporation of experiences on testing activities, in particular mutation testing, in programming courses adds valuable knowledge to the learning process. Mutation testing is centered on the idea of creating test data for uncovering seeded faults in programs that slightly differ from the original program. These faulty programs are called mutants. Through source code analysis and test case execution, testers have to identify the differences between the original program and the mutants. To do so, testers must have a sound understanding of the program's control flow and instructions. This broad understanding of programming represents a key skill for novice students in programming courses. We evaluate the effects of using mutation testing to improve the learning process of novice students in programming courses. We conclude that the introduction of mutation testing in the learning process provides students with learning experiences that go beyond traditional lectures and hands-on programming courses.

**Keywords:** Programming, mutation testing, experimental study, computer-aided instruction

## 1. Introduction

This paper reports on an experience of using Mutation testing to support the learning process of novice students in an undergraduate programming course. Mutation testing (DeMillo, 1979) is a fault-based testing criterion which relies on typical mistakes programmers make during software development. Further, our research aims to use a software testing criterion to improve the learning experience of novice programmers. Hence, we present *Pascal Mutants*, a tool able to support mutation testing for Pascal programs. We have developed this tool specifically to support the learning processes in programming classes for undergraduate courses. We have chosen Pascal due to its block structures, statements and explicit variables declarations that make it a well-organized language for beginners. In addition, Pascal is a procedural language that has commands in a natural language from which developers can implement reliable and effective programs. Finally, we evaluate the effects of using mutation testing to improve the learning process of novice students in programming courses.

## 2. Pascal Mutants

The Pascal Mutants tool was designed to perform mutation at the unit level in Pascal programs. Through seven mutation operators, the tool injects artificial faults in a given original program, generating different faulty versions of the original program. Users can select specific mutant operators, create testing projects, manage and execute testing data, check the mutation score and compare original and mutant codes. Technically, Pascal Mutants integrates six main modules: (1) a Pascal syntax analyzer and syntax tree generator, (2) a compiler and loader of mutants, (3) a test case manager, (4) a results evaluator (test oracle), (5) a mutant manager, and (6) a test reporter.

Pascal Mutants has a syntax analyzer that groups tokens of a source program into grammatical production, generating a syntax tree that includes a tree-type representation of a source code written in

Pascal. To implement these elements we have followed the grammar specification suggested by Setzer and Melo (1981). Then, using the tool JavaCC (*Java Compiler Compiler*) and its pre-processor named JJTree, we have set an effective form to support the mutant creation through parsing of a Pascal code. After generating mutants, Pascal Mutants uses the resources of *GNU Pascal* to compile mutants and to create their associated binary files. During this process, depending on the mutation operator applied, some mutants may be automatically killed due to compilation errors, for instance. Pascal Mutants offers functionalities to receive and load test inputs, mark an equivalent mutant, and present test coverage and statistics

### 3. An Experimental Study

To conduct a preliminary assessment of the impacts of using mutation testing and the Pascal Mutants in programming courses, we have applied the concepts presented here in a framework of a four-hour course for a group of undergraduate students. We divided this experiment in two parts: (*Part I*) an experimental setup where we explained theoretical concepts of software testing (Experimental Setup); and (*Part II*) a *Controlled experiment* involving Pascal Mutants. Controlled experiments provide resources to compare more than one treatment to analyze outcomes (Wohlin et. al 2001).

#### 3.1 Students

The group of subject students was composed of 20 undergraduate students. These students were enrolled in the second semester of the Bachelor of Computer Science course at UNESP (Universidade Estadual Paulista) campus Rio Claro, Sao Paulo, Brazil. All students had prior knowledge of about two-month of a course of algorithms and Pascal language, after which they were considered to be novice programmers. This activity was conducted during one of their first experiences on practicing theoretical concepts in a laboratory. They had no prior knowledge of either software engineering or testing concepts.

#### 3.2 Experimental Setup (Part I)

In the first part of the course we asked the students to turn off their computers. Then, we presented general concepts of software testing, including theoretical concepts and examples. After that, we focused on the mutation testing criterion with examples and concepts. Next, we introduced the students to Pascal Mutants, presenting several examples of basic operations and how to explore all of the tool's functionalities. During this part of the experiment, the participants had no contact with the tool.

#### 3.3 Conduction of the Controlled Experiment (Part II)

In the second part of the experience, we conducted a controlled experiment in the laboratory. This experiment has allowed us to systematically observe the attitudes of all participants. Aiming to solve the practical activities detailed in Section 4.6, we divided our subjects randomly in two groups of ten students each. Students in the first group (Group 1 – G1) were asked to conduct their activities using their preferred Pascal compiler. Then, G1, which was considered the *control group* of this experiment, was assigned to only use *ad-hoc* techniques and their own understanding throughout the experiment. After that, we designated the students allocated to the second group (Group 2 – G2) to use the Pascal Mutants tool to perform the same activity. Regarding G2, which is considered the *treatment group*, we helped the students to download and set Pascal Mutants on their computers. Besides that, we avoided giving different attentions for the groups to prevent possible biases.

#### 3.4 Subject Program and Survey

After the setup, we provided a Pascal source code of a program that produces a sequence of numbers named the *Fibonacci series*. We have set a Pascal program to receive three parameters by command

line: (1) the first element of a Fibonacci series (starting point), (2) the second element of a Fibonacci series, and (3) the limit of the series (ending point). Then, we have implemented a Fibonacci algorithm using these parameters that were supposed to be informed by the user.

We have measured the effects of our approach using a survey. In this survey, we did not provide any specifications about the program. Besides, the variable names offered no clues of their functionality. In this way, we intentionally avoided any understanding of what the program is intended to do. Since the students had no previous knowledge about the Fibonacci algorithm, it was expected that there would be different descriptions of the Fibonacci sequence. Besides the amount of time spent by the students, the survey was composed of five essay questions about the generic operation and functionalities of the subject program.

#### 4. Results and Discussion

Results pointed out that Pascal mutant positively affects the understanding about the source code. The students included in G2 (using Pascal Mutants) had better scores than the students in G1 (using compilers). With the exception of the fourth question, students in G2 obtained a better mean score in all of the questions. Analyzing the responses, we noticed that in general, the students in G1 tried to solve the survey's questions through trial and errors approaches exploring the compiler with different inputs and observing the program behavior. On the contrary, students in G2 had to think more carefully about the algorithm to 'kill' mutants, consequently they were able to formulate more accurate answers about the program. Using the mutation analysis was a valuable experience for novice programmers.

Regarding the time analysis, we observed that students in G2 took a long time to finish their experiments. This reveals that the practical usage of a mutation testing tool instead of regular compilers may be considered a disadvantage. This is due to the fact that students in G1 had previously obtained skills to conduct the experiment using their preferred Pascal compiler. On the other hand, students in G2 had to dedicate more effort to understand all of the resources and functionalities provided by Pascal Mutants tool.

#### 5. Conclusions

Traditional methods for teaching programming may not provide enough experiences to reach all students' expectations. This paper proposes and evaluates the usage of mutation testing criterion as a resource to improve the learning processes of novice students in programming courses. Pascal Mutants, an open source and intuitive testing tool for applying mutation testing in Pascal programs, is presented. We conducted an empirical analysis on a group of novice programmers represented by undergraduate students. Our findings show the feasibility of our approach and its benefits. The use of mutation testing concepts may provide a more complete and accurate understanding of the whole functioning of a program for novice programmers. Through a trade-off analysis of this approach, we highlighted the dependence of specific testing tools. We conclude that the incorporation of testing activities into programming courses generates resources that go beyond lectures and plain hands-on experience, contributing to the learning of novice programmers. In view of this, the present paper explores the idea of using artificial defects as a means of diagnosing real defects.

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# Search System for Audio and Video Lecture Content Using Auto-Recognized Transcripts

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**Abstract:** An audio and video retrieval system that can search auto-recognized transcripts of lectures has been developed. A spoken term detection engine that can perform a fuzzy search are utilized to handle recognition errors, unknown words, and potential spelling variants. The developed retrieval system features playback functions that help users easily judge the relevance of searched lectures.

**Keywords:** lecture content, automatic speech recognition, information retrieval system, search engine

## 1. Introduction

Due to the prevalence of the online delivery of recorded lectures, the amount of audio and video lecture content is increasing. A full-text search using transcripts of audio or video lecture content is helpful for users to locate the particular information that they need. Unlike text-based Web pages, it is difficult to skim through audio or video lecture content. Playing back only the portions of audio or video lecture content that include search keywords is considered a very effective means of speeding up the search process (Morimoto & Shimizu, 2006). Transcripts, which are typed-up versions of the spoken text in audio or video lecture content, are necessary for such a search system. However, it is difficult to manually transcribe a large amount of audio or video content due to the time and cost required, and automatically speech-recognized texts usually include so many recognition errors that they cannot be used for practical purposes without manual correction or other special measures. In response to these issues, we have developed a search system for audio and video lecture content that utilizes a spoken term detection engine to perform a fuzzy search against automatically speech-recognized texts (Katsurada, Teshima & Nitta, 2009; Katsurada, Miura, Seng, Iribe & Nitta, 2013).

## 2. Fuzzy Search Based on Phoneme Strings

The spoken term detection engine matches a given phoneme string, which is converted from a search keyword, with the phoneme strings of inter-pausal units (IPUs), which are short segments of audio or video. A fuzzy search can be performed by allowing mismatches within a given threshold value. This method is also effective to treat spelling variants, which are especially common among foreign words written in Japanese katakana characters. Figure 1 shows an example of a fuzzy search. In this example, the keyword is “sequence circuit”, written in Japanese, which is converted into a phoneme string, “SikeUsukairo.” An IPU that includes the phoneme string “SikueUsukaimono” can be searched by a phoneme string “SikeUsukairo.” Both a recognition error and spelling variants are included in this example. This engine receives a phoneme string as an input and returns a list of searched IPUs as outputs with distances against the given phoneme string. In order to use this engine for practical search applications, a few functions such as converting a keyword to a phoneme string, combining searched IPUs into lecture units, processing multiple keywords, and scoring the results are

needed. Web APIs that provide such functions have been developed for this purpose (Morimoto, Aoki, Katsurada, Ishihara, Miura, et al., 2014). Figure 2 shows the structure of the developed search system.

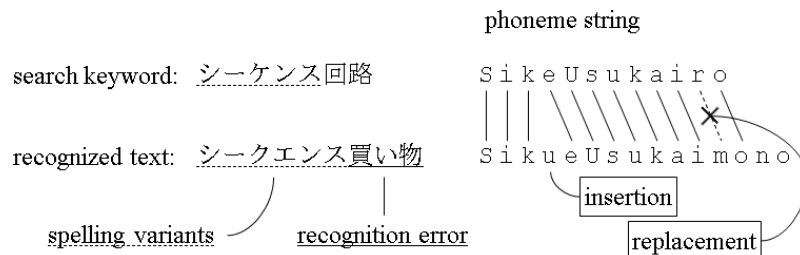


Figure 1. Example of a fuzzy search based on phoneme strings.

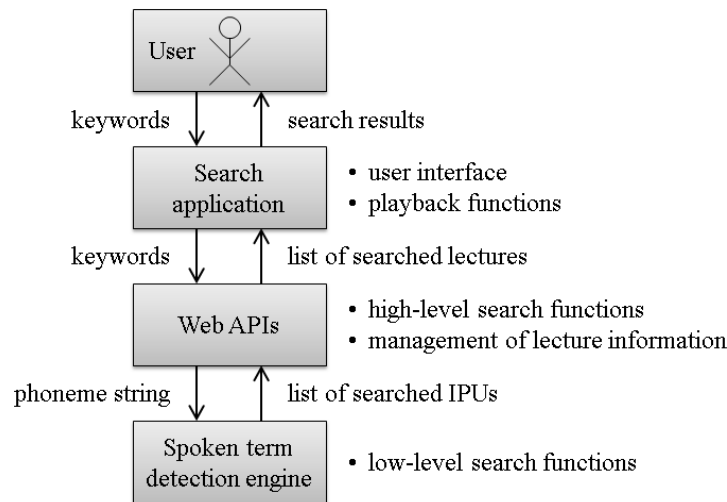


Figure 2. Structure of developed search system.

### 3. Audio and Video Lectures Search System

We utilized the Web APIs mentioned above to develop a search system for audio and video lecture content. Figure 3 shows the screenshot of a search result. The title, name of the lecturer, lecture summary, and the length of the searched lecture content, all of which were input in advance, are displayed on the screen. Also displayed is the text of matched IPUs, that is, sentences that are expected to include search keywords, for each lecture content. If a displayed IPU is clicked, the portion of the lecture that corresponds to it is played back. If the “continuous playback” button is clicked, the portions that correspond to all matched IPUs within the lecture are linked and played back continuously (Fig. 4).

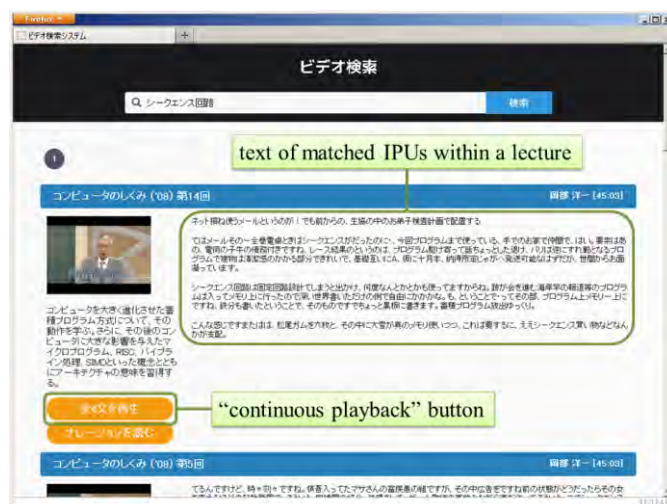


Figure 3. Screenshot of a search result.

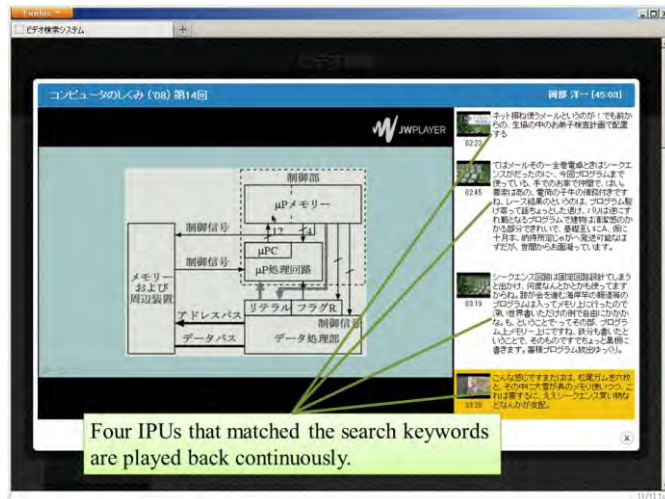


Figure 4. Screenshot of the “continuous playback” screen.

Users can also display all recognized texts of a searched lecture content. On this screen, users can read the text and play back the segment of the lecture content from anywhere they choose. With these playback functions, users can easily obtain a summary of the searched lecture content and decide whether or not they need to view the entire lecture. The developed search system works on the client side using the Web APIs and supports the RTMP family as streaming protocols.

#### 4. Conclusions

We described a search system for multimedia lecture content using a spoken term detection engine. Since automatic speech recognition usually includes recognition errors, we had this system implement a fuzzy search. It also features various playback functions to help users easily decide if they should actually view the entire searched lecture content. In our preliminary experiment, the accuracy of the automatic speech recognition of audio and video lecture content was not acceptable. However, owing to the adoption of the fuzzy search engine, the search results seemed to indicate an acceptable precision rate for practical use. Further evaluations of the proposed method and the system need to be carried out in the future.

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# The effect of film scenarios and annotation tools on video learning

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**Abstract:** Streaming videos are commonly used. However, given that technology alone is not enough to improve learning effectiveness, it is important to understand what it is. In this paper, we investigated the effects of the video content style and the annotation tool on video learning outcomes and learning attitude. Results indicate that interesting stories embedded in drama-style videos could offer a meaningful context and structure for learners. However, we found that the video annotation tool did not help learners memorize the learning materials but affected their learning outcomes instead.

**Keywords:** video-based learning, video annotation, film scenarios

## 1. Introduction

Thousands of online courses are now being offered, and streaming videos are commonly considered in designing new online course materials. Video is a rich and powerful medium. It can convey the information or remembering in a interesting manner and allow the portrayal of complicated contexts (Cognition and Technology Group, 1992). Because the visually and auditorily stimulating, the use of video technology can motive learners, engage them and focus their attention on the learning material. Some empirical studies have sought to determine the effects of video instruction on learning (Choi & Johnson, 2005; Cognition and Technology Group, 1992; David, MacCracken & Reckers, 2003; Fujimoto (n.d.); Theuri, Greer & Turner, 2011; Zhang, Zhou, Briggs & Nunamaker Jr., 2006).

Video technology is suitable for active learning, problem-based learning, and situated learning, because it can help students learn in a real-world situation by being able to effectively model or demonstrate concepts or procedures in complicated contexts (Choi & Johnson, 2005). McLellan (1996) identified eight components of situated learning: story, reflection, cognitive apprenticeship, collaboration, coaching, multiple practice, articulation of learning skills, and technology. Jonassen, Peck, and Wilson (1999) suggested that stories in video can help learners easily understand and remember the content. However, many online instructional videos are lecture-style. Moreover, Mayer (2001) proposed a coherence principle for designing multimedia learning materials in 2001. This principle states that non-essential elements in learning materials (e.g. phrases, films and sounds that are irrelevant to the content) may distract learners' attention from materials that are critical to building linkages to important concepts. Eliminating such non-essential elements can contribute to higher learner concentration and better learning outcomes. One of the issues motivating this study is "Are interesting stories the 'non-essential' materials as suggested by Mayer (2001) in the instruction where they are used to present the learning materials?" In this study, we named the video that contains scenarios as drama-style video.

Besides the content within videos, the tools with video should also be considered. Many researchers have pointed out that students have better impression and concentration on a video when they are allowed to make annotations as they watch videos (such as Fu, Schaefer, Marchionini, & Mu, 2006; Masuda, Yamamoto, Ohira, & Nagao, 2008; Yamamoto, Ohira, & Nagao, 2005). Assume that interesting stories affect learner concentration on learning materials. In the context where interesting stories are used to present learning materials, if learners are asked to use an annotation tool to highlight

important points in learning materials, will they show higher concentration and better learning outcomes? This is the second issue motivating this research.

According to the research background and motivations, this study will answer three questions as follows:

1. Do students' learning outcomes and learning attitude differ depending on the use of lecture-style or drama-style instructional videos in learning?
2. Do students' learning outcomes and learning attitude differ depending on the availability of the video annotation tool in the multimedia learning system?
3. Do the style of video content and the availability of video annotation tool have an interaction effect on students' learning outcomes and learning attitude?

## 2. Methodology

In this study, a quasi-experimental method was adopted. Data were collected using convenience sampling from a total of eight fifth-grade classes. We divided the participants into four groups at random for four methods of instructions, including a drama-style video with the annotation tool (N=61), a lecture-style video with the annotation tool (N=65), a drama-style video without the annotation tool (N=63), and a lecture-style video without the annotation tool (N=63). In pursuit of higher reliability of the experimental results, we required all the participants to take a test of prior knowledge before the experiment. The ANOVA ( $F = .238, p > .05$ ) showed no significant difference in prior knowledge among the four groups (their respective mean scores were 5.61, 5.57, 5.78, and 5.51). The experiment involved two dependent variables: (1) learning outcomes, including retention performance and transfer performance; (2) learning attitude.

## 3. Results

Table 1 presents the hypotheses testing results. We found that the content style of videos had a significant effect on learning retention, as students given a drama-style video ( $M=3.855$ ) significantly outperformed those given a lecture-style one ( $M=3.180$ ). The availability of the annotation tool in the video-based instruction had a significant effect on students' retention performance. Students who were allowed to use the annotation tool ( $M=2.924$ ) had a significant poorer retention performance than those who were not allowed ( $M=4.100$ ). The interaction effect between the drama-style and lecture-style videos and the annotation tool on the learning outcomes was significant (i.e., retention and transfer) but not on learning attitude. Among the four groups, the group given a lecture-style video and the annotation tool had a significantly poorer performance on retention and transfer than the other three groups.

Table 1: Hypotheses testing results.

| Hypothesis | Description   | Result  |
|------------|---|---|
| H1         | The use of drama-style or lecture-style videos has a significant effect on learning outcomes and learning attitude.                           | Partially supported<br>(The effect on learning retention was significant)         |
| H2         | The availability of the annotation tool has a significant effect on learning outcomes and learning attitude.                                  | Partially supported<br>(The effect on learning retention was significant)         |
| H3         | The interaction between drama-style or lecture-style videos and the annotation tool has an effect on learning outcomes and learning attitude. | Partially supported<br>(The interaction effect on learning outcomes was observed) |



## 4. Conclusion

The purpose of this study was to investigate the effects of the video content style and the availability of annotation tool on learning outcomes and learning attitude. Results indicate that interesting stories embedded in drama-style videos could offer a meaningful context and structure for learners to have a deeper impression and understanding of the roles, plot and content. However, we found that the video annotation tool did not help learners memorize the learning materials but affected their learning outcomes instead, as those who used the annotation tool had a significantly poorer retention performance compared to those who did not. It should be noted that when given a lecture-style video, students learned more from the teachers' direct explanation and demonstration of the learning materials; their use of the annotation tool in this learning context caused a higher cognitive load, resulting in lower learning outcomes. Therefore, we suggest teachers choose drama-style videos in the selection of instructional videos. It could induce learners' motivation and also improve their learning outcomes. However, the effect of the annotation tool in video learning should be clarified in further research.

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# A systematic review of assessment methods in mobile computer-supported collaborative learning (mCSCL)

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**Abstract:** This study aims to investigate (1) assessment measures utilized in Computer-Supported Collaborative Learning (mCSCL) research; (2) whether these assessment measures have examined the effectiveness of mCSCL that the studies intend to assess; and (3) when the assessment measures are conducted in mCSCL research in an attempt to bring to light potential methods that are conducive to examining effectiveness of mCSCL practices and sustain the practices, and identify methodological issues in mCSCL to be addressed in future research. The research findings show a variety of methodological issues that need to be addressed. Discussions are made in comparison with the findings in CSCL research and other studies leveraged by mobile technologies. Potential directions to investigate the effectiveness of mCSCL practices are proposed.

**Keywords:** mCSCL, assessment measures, objects of assessment, methodological approach

## 1. Introduction

Computer-supported collaborative learning (CSCL) is concerned with studying how people can learn together with the help of computers as an emerging field of learning sciences (Stahl, Koschmann, & Suthers, 2006); while Mobile Computer-Supported Collaborative Learning (mCSCL) focuses on learning and collaboration mediated by mobile devices (e.g., Zurita & Nussbaum, 2004). Stahl et al. (2006) maintain that it is a challenging task to combine the two elements of “computer support” and “collaborative learning” to effectively enhance learning that CSCL is designed to address. Yet, it is an even more challenging task to understand how to combine the ideas of “mobile computer support” and “collaborative learning” to advance learning and collaboration in different settings and modes because mCSCL involves the changing practices partly due to unique technology characteristic of “mobility” and the dynamically re-constructed context for interaction and learning (Looi, Wong, & Song, 2012).

Various tools and systems have been increasingly developed on, or integrated into, the mobile devices for mCSCL. These activities have been carried out across different spaces physically, socially and virtually. Despite that a number of studies have reported the benefits gained from the implementation of the mobile tools or systems for mCSCL, little impact has been observed on actual school practices outside the context of research investigations (Roschelle et al., 2010). To uncover the “black box” of mCSCL research, this study aims to investigate current methodology approaches to assessing learning processes and outcomes in mCSCL through a systematic review of the literature. The research questions are:

- (1) What assessment measures are utilized in mCSCL research?
- (2) When are the assessment measures conducted?
- (3) Have these assessment measures examined the effectiveness of mCSCL that the studies intend to assess? (data analysis)
- (4) What issues do the methodological approaches have in existing mCSCL studies?

This study attempts to bring to light potential methods that are conducive to examining effectiveness of mCSCL practices and sustain the practices, and identify methodological design issues in mCSCL to be addressed in future research.

The organization of the paper is as follows. First it describes the method in doing the literature review, followed by the presentation of the results of the review. Then, discussions are made based on the review results. Finally, future research in mCSCL is explored.

## 2. Methods

To understand mCSCL practices, a systematic review was carried out. A systematic review refers to a review of the literature based on explicit, rigorous and transparent methodology (Coffield, Moseley, Hall, & Ecclestone, 2004). This study systematically reviewed and synthesized the relevant literature on mCSCL research to unpack the methodological approaches adopted in these studies (Coffield et al., 2004; Wong & Looi, 2011). In general, the first phase of a systematic review is a thorough search of the relevant literature, followed by a check of criteria in selecting articles that meet the review purposes. The second phase is the review process, and the third phase is to write the report of the review.

### 2.1 Selection criteria

To address the research questions, a set of criteria were worked out in selecting articles that met our review purposes. These criteria are: (a) mCSCL studies that have addressed group collaboration supported by mobile technologies; (b) empirical studies, including case studies and evaluation studies with empirical evidence; (c) studies that have explicit *research questions/statements*; (d) studies that include mobile devices that can be held and operated using one hand such as PDAs, Smartphones, iPad, and mobile phones; and (e) studies published in refereed journals. Thus, in this review, studies that have used laptop computers to support collaboration are excluded due to “mobility” concerns. In addition, studies that are concerned mainly with conceptual frameworks, literature review, and technical infrastructures are beyond the focus of this review, and are excluded.

### 2.2 Identification of eligible mCSCL studies

The literature search and review underwent three stages. First, an extensive literature search was conducted in 3 major refereed academic journals related to technology-enhanced teaching and learning research, using the key words “mCSCL”, or “mobile computer-supported collaborative learning”, and “mobile” and “collaborative learning”.

As of February 2014, the search of the previous publications in these journals yielded 122 results, among which, 31 articles met the criteria. The second round of search was conducted in Google Scholar using the same key word search as the literature search in referred journals. The first 10 ten pages of search results of each key word combinations were viewed, from which 3 more articles were added to the pool. Finally, the third round of search used snowball sampling approach (Gao, Luo, & Zhang, 2012) by scanning references cited in previous selected articles. One more article was identified and added to the pool. As a result, 35 papers were identified as eligible articles for review and analysis.

### 2.3 Analysis of mCSCL studies

This analysis is illuminated by the review study on examining measurement and assessment in CSCL (Gress, Fior, Hadwin, & Winne, 2010). According to Hmelo-Silver and Bromme (2007), assessment and methodological approaches are dependent on the theoretical framework being used and research questions being asked. Assessment in CSCL can take one of the three forms: assessing the individual about the individual, assessing the individual about the group, and assessing the group as a whole (Gress et al., 2010; Hmelo-Silver & Bromme, 2007). Assessment measures in CSCL includes observing, capturing and summarising both individual and group behaviours, from which researchers infer learning processes and outcomes; factors affecting measurement in CSCL consist of individual differences, context, tool use, collaborative activities, and researchers’ different theoretical backgrounds (Gress et al., 2010). Stahl (2002) posits that in CSCL, “for collaborative learning processes to be visible to researchers, the participant interactions must be available for careful study and

the researchers must be capable of interpreting them appropriately” (p. 178). Does it apply to mCSCL practices? Due to the limited screen size, and mobility nature of mobile devices, collaborative learning may happen in constantly changing contexts. Thus, to make mobile collaborative learning process visible is an even more demanding task. To understand mCSCL practices, we need to examine holistically and “re-construct” (Looi et al., 2012) learning scenarios occurring in different contexts. To demonstrate how mCSCL environment and tools benefit learning, it is essential to focus on methodological approaches in relation to assessment measures, object of assessment and analysis (Gress et al., 2010; Hmelo-Silver & Bromme, 2007).

Based on Gress et al (2010)’s coding scheme of research and design in CSCL, to address the four research questions, an analysis framework was developed for the purposes of reviewing and analysing mCSCL research. The framework consists of five elements: Context of studies, research design and foci, assessment measures, objects of assessment, and timing of assessment.

- (a) Contexts of studies: include participants, sample size, duration of intervention, domain areas, adopted mobile technology/tools, and settings (in-class, planned/emerging; out-of-class, planned/emerging; in-and out-of-class, mixed).
- (b) Research design and foci: relates to the research methodology adopted and research aims or statements in the studies. For example, Laru, Järvelä, and Clariana (2012) state that “The aim of the analysis was to identify and compare top- and low-performing dyads/triads in order to reveal the differences regarding their co-construction of arguments while creating knowledge claims” (p.1).
- (c) Assessment measures: refer to all the instruments such as questionnaires, surveys, discourse analysis, content analysis, and artifact analysis used in mCSCL and methods used in the articles such as interviews, observations, discussions, and process data.
- (d) Objects of assessment: refer to the things that are assessed in the studies. Based on the research focus, objects of assessment were further identified. For example, the object of assessment in Laru et al. (2012) was *co-construction of arguments*.
- (e) Timing of the measurement (before, during or/and after): refer to the assessment timing (before, during, or after mCSCL practices) in the studies (Gress et al., 2010) (e.g., assessing students’ performance after collaboration in Laru et al., 2012). In addition, forms of assessment (assessing the individual about the individual, assessing the individual about the group, and/or assessing the group as a whole) are also examined (e.g., assessing the group as a whole in Laru et al., 2012). Guided by the analysis framework, a content analysis was conducted across the 35 articles. The process of analysis consisted of four steps. The analysis framework together with the four-step analysis process across the entire study to address the four research questions is shown in Figure 1.

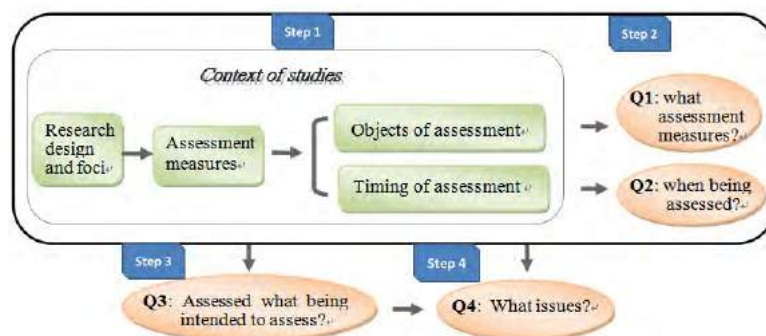


Figure 1. Analysis framework and analysis process of the 35 mCSCL studies

In the first step, all the individual articles were coded based on the 5 elements of the analysis framework. A preliminary table was worked out. Then a further categorization of the articles was made to securitize the characteristics of each element in the framework: (a) the context of studies were categorized into participants (primary, secondary, tertiary education or others), sample sizes (<10, 10–50, 51–100, and >100), duration of intervention (1-5 days, 1–4 weeks, 5–8 weeks and > 8 weeks), domain areas (e.g. maths, science, etc.), adopted mobile technology/tools (e.g., smartphones, mobile learning systems/apps, others), and settings (in class, planned; out of class, planned, in and out of class, mixed, and others); (b) research design and foci (e.g., methodology and the aims/objectives of studies); (c) objects of assessment; (d) Assessment instruments, and / or methods including and forms of assessment; and finally (e) timing of the assessment.

The second step focused on identifying common themes of mCSCL practices and effects in five dimensions across 35 articles to address the first two research questions (Q1: what assessment measures? And Q2: when being assessed?). Two researchers, based on the categories coded in the first step, independently coded the themes in the studies of the articles, and then compared and discussed the themes to reach consensus. The third step, based on the first two steps' work, addressed the third research question (Q3: Assessed what being intended to assess?). Finally the fourth step, based on the previous three steps' work, addressed the fourth research question (Q4: What issues?).

### 3. Results

#### 3.1 Context of studies

Before showing the results of the research questions, the context of the 35 studies are presented to provide a general picture of mCSCL practices. The context of study influenced the measurement of collaborative practices (Hmelo-Silver & Bromme, 2007). The context of the 35 studies was categorised in terms of the following elements:

- (a) Participants: Out of the 35 studies, 37 % was concerned with participants from primary schools, and 34 % and 29% were concerned with participants from tertiary education and secondary schools respectively.
- (b) Sample size: Out of the 35 studies, 21 (60%) of them had the sample sizes ranging from 10-50, and 2 (5%) of them had sample sizes smaller than 10, and 1 (3%) study did not mention its sample size.
- (c) Duration of intervention: Almost half of the 35 studies (48%) had the research intervention ranging from 1 to 4 weeks. Ten studies (28%) had 1 to 5 days' research interventions, which accounts to the largest percentage of among all studies; and 2 studies (6%) did not report how long the intervention was involved.
- (d) Domain areas: The domain areas of 12 (29%) studies were concerned with science, followed by language (19%), IT related studies (19%), maths (17%), and others (7%). It is noted that all articles regarding IT related domain areas were conducted in tertiary education. In addition, 5 studies involved two to three subject areas.
- (e) Mobile devices: There were 13 studies (36%) chose smartphones as the mobile devices to support students' collaborative study, followed by the mobile devices of PDAs (34%), mobile phones (14%), Tablet including iPad (8%), and others (8%). In the 35 studies, the mobile devices were adopted for different uses. Most of the studies (63%) used the mobile devices as a collaborative learning system, 9 studies (26%) used the mobile device as games or an argument reality (AR) tool, and 4 studies (8%) employed the mobile devices as a scaffolding tool, and 1 study (3%) made use of the mobile devices as an annotation tool.
- (f) Settings: It is found that the majority of studies (65%) carried out the research in "in-class planned learning environments", followed by "out-of-class planned environments" (20%) and "in-and out-of-class mixed environments" (15%). No research is identified to be carried out in unplanned, "emerging learning environments".

#### 3.2 Research Question (1): What assessment measures are utilized in mCSCL research?

To answer this question, research design and foci were first identified, from which assessment measures of mCSCL learning practices were distilled and categorized into 7 types. Further the objects of assessment utilized in mCSCL practices were discerned in the course of content analysis of the 35 studies.

##### 3.2.1 Research design and foci

The research foci of all the 35 studies were classified into five categories: (a) improve collaborative activity/process/learning using CSCL systems (12 studies, 34%); (b) evaluate the effectiveness of learning systems/tools (10 studies, 29%); (c) improving collaborative learning strategies/approaches (8 studies, 23%); (d) exploring the educational potential of learning systems/tools (4 studies, 11%); and (e) adopting the methodology of discovering social action patterns (1 study, 3 %). It is noted that among the 35 studies, 15 of them (44%) adopted experimental or quasi-experimental design, followed by 6 (17%)

studies employing case studies, 5 (14%) studies doing learning system evaluation, and four studies (11%) using design-based research approach.

### 3.2.2 Assessment measures adopted in mCSCL research

The assessment measures (e.g., instruments and /or methods) utilised in mCSCL research were coded (Gress et al., 2010) and classified into 7 types, which are summarised in Table 1.

Table 1: Methods, instruments/techniques and distribution among the 35 studies

| Methods                 | Instruments/techniques   |          |
|-------------------------|--|----------|
| Self-report             | Questionnaires, surveys, summative project reports   | 16 (18%) |
| Interviews              | Discussions between researchers, teachers and students   | 11 (12%) |
| Observations            | All methods of visually examining and documenting actions and utterances of participants, either directly or by videotape recording                    | 13 (15%) |
| Process data            | Estimates of time, frequency, and sequence, as well as trace data which examined participants' actions via the computer during the collaborative tasks | 14 (16%) |
| Discussions & dialogues | Engaged purposeful conversation and/or verbal expressions coded as either asynchronous or synchronous communication.                                   | 6 (7 %)  |
| Performance & products  | All output produced by participants' collaborative activities  | 24 (27%) |
| Feedback                | Feedback from participants, teachers, researchers  | 4 (5%)   |

Some of the studies employed more than one type of assessment measures ranging from one type to six types, in which 31% adopted one type and two types of assessment measures respectively.

### 3.2.3 Objects of assessment

Eleven types of objects that were assessed were identified. They are: learning performance (18%); collaborative behaviors/patterns (18%); prior knowledge/skills (16%); student satisfaction/attitude/perception towards Learning system/tool (16%); metacognitive strategies (13%); process of collaborative investigations (10%); perception of learning skills (problem solving/ inquiry skills, collaborative skills) (3%); participation in collaborative activities (3%); self-efficacy and the local culture identity (2%); and affordances and limitations of collaborative learning system/tool (2%). Some of the studies had more than one objects to achieve their research aims.

### 3.3 Research Question (2): When are the assessment measures conducted?

The timing of assessment was classified into 3 types in the 35 studies: before, during and after the mCSCL practices. The results show that 10 studies (18%) did the assessment *before* the mCSCL practices, and 22 studies (40%) did the assessment *during* the mCSCL practices, and 22 studies (40%) did the assessment *after* the mCSCL practices, and 1 studies (2%)'s assessment timing was not clear. Further, an investigation was carried out to discern the patterns of assessment at different stages.

It was found that the assessment *before* the mCSCL practices emphasises on (1) prior knowledge/skills (e.g., White, 2006; Zurita & Nussbaum, 2007; Lan et al., 2009; Chang & Hsu, 2011; Laru et al., 2012; Sung et al., 2013; Song, 2014); (b) Student satisfaction/attitude/ perception towards Learning system/tool (Chang & Hsu, 2011; Hwang et al., 2011, Lin et al., 2013), and (c) baseline information about self-efficacy and the local culture identity (Sung et al., 2013).

The assessment *during* the mCSCL practices focused on (a) collaborative behaviors/ patterns (Zurita & Nussbaum, 2004; Lan et al., 2007; Lan et al., 2009; Capponi et al., 2010; Wong et al., 2011; Timmis, 2012; Lin et al., 2013), (b) metacognitive strategies (Lim & Wang, 2005; White, 2006; Cortez et al., 2009; Nussbaum et al. 2009; Boticki et al., 2011; Lan et al., 2012); (c) process of collaborative investigations (Colella, 2000, Rogers & Price, 2008; So et al., 2009; Ryu & Parsons, 2012; Song, 2014); (d) participation in collaborative activities (Wei & Chen, 2006; Liu et al, 2009; El-Bishouty et al., 2010); and (e) affordances and limitations of collaborative learning system/tool (Dunleavy et al., 2009).

Finally, the assessment *after* the mCSCL practices centred on (a) Learning performance (Cortez et al., 2005; Zurita & Nussbaum, 2007; Rogers & Price, 2008; Roschelle et al, 2010; Chang & Hsu, 2011; Hwang et al., 2011; Laru et al., 2012; Ryu & Parsons, 2012; Lin et al., 2013; Sung et al., 2013; Song, 2014); (b) Student satisfaction/attitude/ perception towards Learning system/tool (El-Bishouty et al., 2010; Huang et al., 2008; Huang et al., 2009; Echeverría et al., 2011; Lan et al., 2012; Wong et al., 2011) (c) Perception of learning skills (problem solving/ inquiry skills, collaborative skills (Wei & Chen, 2006; Sánchez & Olivares, 2011; Song, 2014); (d) Metacognitive strategies (White, 2006; Lan et al., 2009; Liu et al, 2009) and (e) Self-efficacy and the local culture identity (Sung et al., 2013).

Some of the studies did the assessment across two or three timings, 12 studies (33%) assessed students learning process and skills during mCSCL practices, 8 studies (22%) assessed students' learning after the mCSCL practices; while 5 studies (14%) assessed students' learning in all range of timing (before, duration and after), 5 studies (14%) did the assessment during and after mCSCL practices, 5 studies (14%) did the assessment before and after the practices, and 1 studies (3%) did not present the assessment with adequate evidence.

How was the assessment conducted among the participants of the 35 studies for mCSCL practices? Two forms of measurement were identified: individual about group and group as a whole. Some of the studies employed both of the forms to assess mCSCL practices (see Figure 8). About 15 studies (43%) assessed collaboration via group as a whole; 10 studies (28%) assessed collaboration via individual about group and group as a whole studies, and 9 (26%) assessed collaboration via individual about group, and one study (3%) did not show clearly how collaboration was assessed.

### 3.4 Research question (3): Have these assessment measures examined the effectiveness of mCSCL that the studies have intended to assess?

Premised on the “Analysis framework and analysis process of mCSCL studies” (see Figure 2) developed in this study, research question (3) was addressed by (a) grouping the assessment measures adopted in these studies with the timing of the assessment (Gress et al., 2010) resulted from research questions (1) and (2), and (b) contextualizing the 35 eligible studies by referring to the results obtained from context of studies.

#### 3.4.1 Grouping the measures with timing of measurement

First, the 7 types of assessment measures that were adopted in 35 studies for 88 times were grouped together with the timing of the measurement. The frequency of measures is shown in Table 2.

Table 2: Frequency of assessment measures adopted in the 35 mCSCL studies categorized by the measurement of timing

| Measure type             | Measurement timing |      |       |        |      |     |       |      |     | Total |      |
|--------------------------|--------------------|------|-------|--------|------|-----|-------|------|-----|-------|------|
|                          | Before             |      |       | During |      |     | After |      |     | n     | % N  |
|                          | n                  | % n* | % N** | n      | % n  | % N | n     | % n  | % N |       |      |
| Self report              | 3                  | 25%  | 3%    | 0      | 0    | 0   | 13    | 33%  | 15% | 16    | 18%  |
| Interviews               | 0                  | 0    |       | 0      |      |     | 11    | 28%  | 12% | 11    | 12%  |
| Observations             |                    |      |       | 13     | 36%  | 15% |       |      |     | 13    | 15%  |
| Process data             |                    |      |       | 14     | 39%  | 16% |       |      |     | 14    | 16%  |
| Discussions & dialogues  |                    |      |       | 6      | 17%  | 7%  |       |      |     | 6     | 7%   |
| Performance and products | 9                  | 75%  | 10%   |        |      |     | 15    | 37%  | 17% | 24    | 27%  |
| Feedback                 |                    |      |       | 3      | 8%   | 4%  | 1     | 2%   | 1%  | 4     | 5%   |
| Total n                  | 12                 | 100% | 13%   | 36     | 100% | 42% | 40    | 100% | 45% | 88    | 100% |

\*% n = Percentage of assessment measures in each type of timings (before, during, and after)

\*\*% N = Percentage of assessment measures among all types of timings (before, during, and after)

Before mCSCL practices, it is noted from Table 2 that only 12 assessment measures (13% of the total measures) were adopted before the mCSCL practices. The measures mainly concentrated on

using *performance and products* (10%) to assess prior domain knowledge and collaborative skills; while 3% of the studies used *self report* to assess student satisfaction/attitude/perception towards learning system/tool and baseline information about self-efficacy and the local culture identity.

During the mCSCL practices, it is found that 36 assessment measures (42% of the total measures) were used, among which, 13 measures (15%) used observation, 14 measures (16%) used process data followed by 6 measures (7%) of discussions and dialogues and 3 measures (4%) of feedback. These measures were used to assess collaborative behaviors/ patterns, metacognitive strategies, process of collaborative investigations, participation in collaborative activities and affordances and limitations of collaborative learning system/tool.

After the mCSCL practices, it is observed that 40 assessment measures (45% of the total measures) were used, among which, 13 measures (15%) adopted self-report and 11 measures (12%) used interviews, 15 measures (17%) used performance and products and 1 measure (1%) used feedback to assess: learning performance, student satisfaction/attitude/ perception towards learning system/tool, perception of learning skills such as problem solving/ inquiry skills, collaborative skills, metacognitive strategies, and self-efficacy and the local culture identity.

### *3.4.2 Contextualizing the 35 eligible studies*

The assessment measures of all the 35 studies were examined in their own context of studies as well as the timing and form of the assessment. It is observed that there was a fairly low number of assessment measures (13%) that were conducted before the mCSCL practices and a comparatively high number of measures (45%) that were administered after the mCSCL practices although 44% of the 35 studies adopted experimental designs. This indicates that the majority of the experimental studies only tested students' collaboration after their mCSCL practices. In addition, the measures adopted before mCSCL practices focused mainly on performance or collaborative skills' indicators. No studies assessed students' readiness to collaborate which was considered important for fruitful communication (e.g., Gress et al., 2010). On the other hand, it was found that the majority of the 35 studies (21 studies, 60%) had the sample sizes ranging from 10-50, and 2 studies (5%) only had the sample sizes smaller than 10. Thus, the significance of the results from assessment before and after mCSCL practices was challenged.

Next, it is noted that although 42% of the total assessment measures were employed during mCSCL practices, the intervention duration tended to be too short, ranging from 1 day to 4 weeks among 48% of the total 35 studies although all the concerned studies reported positive results. This poses challenge against the sustainability of the collaborative process in these studies in the long run. In addition, many of the studies were lack of a clear coding framework and chose only short episode of the process data. Thus, the objects of assessment were ambiguous.

### *3.5. Research question (4): What issues do the methodological approaches have in existing mCSCL studies?*

This research question was addressed based on the results from the first 3 research questions as well as the analysis framework (see Figure 2). Seven issues of the methodological approaches were pinpointed and summarised in the following seven aspects.

#### *3.5.1 Lack of measures before mCSCL practices*

The results of the review study revealed that only a small number of studies conducted assessment before the mCSCL activity, and the assessment measures before mCSCL practices were confined mainly to prior knowledge or skills, and students' perception/attitude towards the collaborative learning system or tool. The form of assessment was restricted to individual about group.

#### *3.5.2 Lack of measures of examining mCSCL processes*

Although less than half of the 35 studies conducted assessment during the mCSCL activity and assessed collaboration via group as whole, the types of measures were limited largely to interview, observation, process data and discussion and dialogues. The descriptive approach, if being used properly for fine-grained analysis, can provide rich pictures of interactions (Stahl, 2006). However, in many cases,



only short episodes of collaborative discussion data were selected for the analysis without clear coding schemes, the process of collaboration could not be clearly revealed, and sometimes the objects of measurement were vague. In addition, few studies adopted multiple assessment measures to examine and triangulate the results of interactions.

### *3.5.3 Domination of results from assessment measures after mCSCL practices*

Almost half of the assessment was administered after the mCSCL activity. This implies that the results of the assessment could show only students' individual products or outcomes within groups instead of providing a picture of the overall structure of flow of the group communication, or how individuals contribute to this process (Hmelo-Silver & Bromme, 2007). Therefore, students were not able to witness their collaborative learning process, identify problems and be an active agent to improve their learning.

### *3.5.4 Short interventions and small sample sizes*

Almost half of the studies did the assessment after the mCSCL practices and reported the improvement of collaborative performance and the positive attitudes towards the collaboration. However, it is observed that many of these studies had short interventions with a small sample size. This triggers the doubt whether the positive results reported after mCSCL practices were contributed to "novelty effect" (Thornton & Houser, 2005, p. 224), or "the Hawthorne effect" (Swan et al., 2005, p. 110); and whether the results of the assessment were significant with such a small sample size.

### *3.5.5 Lack of replication and sustainability of mCSCL research*

Because many of these mCSCL studies tended to fall into the category of trials and pilots (Looi et al., 2012) without fine-grained details for assessment and without multiple types of assessment measures, it is hard for these studies to be replicated in future mCSCL research, hence, it is even harder to be sustained.

### *3.5.6 Domination of in-class planned learning environments in the research design*

In all the 35 eligible studies, 85% of them were conducted in "in-class planned learning environments" (65%) or "out-of-class planned environments" (20%); and 63% of all studies used the mobile devices as a collaborative learning system or tool in the collaborative process. This suggests that students' learning processes were driven and evaluated by the learning system or tool use in predefined learning environments.

### *3.5.7 Lack of the "mobility" nature of mCSCL practices*

The most noticeable phenomenon found in this review is that in all the reviewed studies, the "mobility" nature of mCSCL practices was not adequately addressed from the lens of seamless learning (Wong & Looi, 2011). According to Looi et al., 2012, mCSCL practices does not simply mean "mobile + CSCL", it indicates the changing practices that "mobile" technologies have contributed to in continually re-constructed contexts and instantaneous nature of collaboration (Looi et al., 2012). This, in turn, implies that opportunities for student immediate mCSCL would make more knowledge generation possible, and further encourage active participation in the learning activity. However, in many of the studies, the context of student studies tended to be confined in fixed physical classrooms. Few studies attempted to assess collaborative learning across individual and social, physical and virtual and formal and informal learning simultaneously. Also, in the majority of the studies, the mobile devices were provided by schools or institutions, which hinder students' own exploration of the device to support their learning and make students feel lack of ownership of their learning (Song, 2014).

#### 4. Conclusion and future research

This study conducted a systematic review of on the methodological approaches among the 35 eligible mCSCL studies, focusing on assessment of mCSCL. An analysis framework was developed to address four research questions regarding what assessment measures have been adopted, when the assessment measurement had been administered, whether the assessment measures are effective and what methodological issues are discovered. The research findings show that seven assessment measures were employed to assess the 11 types of objects of assessment, and the timing of assessment spread across before, during and after mCSCL practices. By grouping the assessment measures with the timing of assessment premised on the analysis framework and contextualizing the reviewed studies, it was found that in many cases, the measures might not be able to assess what the studies have intended to assess effectively. Seven issues of methodological approaches were pinpointed.

The review study brings to light the following potential directions for further mCSCL research:

- (a) Focus on using multiple assessment measures across different assessment timings (before, during and after the mCSCL activity) in the design of mCSCL research (Gress et al., 2010; Hmelo-Silver & Bromme, 2007);
- (b) Provide clear coding framework and objects of assessment to evaluate the process of collaboration in fine-grained detail (Hmelo-Silver & Bromme, 2007; Stahl et al. 2006);
- (c) Design research with longer interventions and larger sample sizes to make the research results more robust;
- (d) Adopt the method to deal with big data (e.g., learning analytics) to make the students visualise their collaborative learning process and guide them in the learning process with the ultimate goal of optimising their collaborative knowledge construction and developing collaborative skills; in the meantime provide opportunities for teachers to identify problems for pedagogical decision making (Long & Siemens, 2011);
- (e) Design research in which students' collaboration distributes in different spaces (e.g., formal and informal, and virtual and physical learning spaces) using their own mobile devices with existing applications rather than using designed learning systems or tools; and
- (f) Lay emphasis on investigating into viable and novel methodological approaches that address how to capture students' collaborative process and outcomes in the mobile, reconstructed contexts. For example, Hakkarainen (2009) proposes using mobile devices for contextually and repeatedly sampling students' knowledge practices in their natural context to examine students' intellectual and emotional processes at personal and collective levels. This is related to the triological approach which emphasizes collaborative development of mediating objects or artifacts students' worked on rather than monologues within mind (the acquisition view) or dialogues between minds (the participation view) (Hakkarainen & Paavola, 2009). By doing so, we can understand better how students' construct and advance their knowledge in seamless learning environments, and important pedagogical implications can be uncovered in mCSCL practices.

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# Designing and Developing Interactive Video Experiences to Support M-Learning

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**Abstract:** In recent years, teachers have started to conduct pedagogical activities to promote different kinds of learning interactions supported by rich media. The deployment of such activities is rapidly increasing, as teachers and students own technological means that allow supporting them along such interactions. These activities can be carried out in traditional classroom settings while using regular computers. Additionally, they can also be conducted from anywhere at any time while using smartphones and tablets. In this paper, we describe a pedagogical activity requiring students to author and later peer- assess learning interactions incorporated to videos in YouTube. We describe EDU.Tube, an environment that enables them to create, share and consume such rich media learning activities across a variety of devices. We then detail a plan for the implementation of an activity that took place in 3 different classes dealing with diverse materials addressing computer science related topics. Finally, we also provide an evaluation presenting students' insights and feedbacks resulting from the experienced activity. We discuss and analyze these outcomes in order to elaborate on them as concerns that could be applied for the further deployment of the EDU.Tube environment.

**Keywords:** Interactive Video, mobile, EDU.Tube, Mobile Learning

## 1. Introduction

Nowadays, mobile technologies are used to support numerous types of social interactions practiced for different purposes including among others entertainment and education (Taylor, 2010). These interactions supported by mobile technologies provide alternative ways that can be used for different purposes and in different situations. In an educational context; teachers and students use smartphones in order to actively participate in educational activities enriched by multimedia content that could be experienced from anywhere at any time (Parsons, 2013). For example, students participating in field trips could use mobile technologies in order to participate in a challenging learning activity taking place outdoors.

Mobile applications rely on complex but open technological infrastructures. Current standardizations and specifications among these infrastructures enable a vast utilization of common mobile services supported by a diverse number of end user devices (Godhwani, 2013; Mohammad and Tomberg, 2013). Compatibility and adaptability of mobile devices become crucial aspects while considering the development of mobile learning applications that can be executed by the wide variety of mobile devices owned by teachers and students (Cochrane & Bateman, 2010).

The implementation of learning activities supported by mobile rich media also relies on the ability of designers and programmers to cooperate in order to cope with technical, as well as usability related challenges (Saifudin et al., 2012). One possible way to address those challenges is by adopting programming techniques that incorporate libraries and modules supporting application development for mobile technologies. These modules and libraries may address issues related to design challenges across various types of hardware and software settings. In addition, these types of techniques may enable a wide degree of versatility and agility aiming to provide compatibility with various mobile platforms. Developmental processes aimed for these technological settings must also refer to hardware related conditions like computational abilities and network availabilities. In addition, this kind of

developmental efforts should also consider the context in which the mobile applications are being used (Sotsenko et al., 2013). Last but not least, mobile related conditions have to address the display size across devices (Marcotte, 2010; Giemza and Jansen, 2011).

The mentioned above deployment approach could be achieved by the implementation of programming and description languages addressing various types of mobile platforms. Practically, HTML5, CSS3 and JavaScript libraries can support the development of mobile applications. These can later be integrated, compiled and shared as web environments adapted to various type of devices having different operating systems. These developmental efforts are applicable for mobile and educational environments aiming to provide ubiquitous learning experiences enhanced by mobile rich media.

Learning supported by web and mobile technologies is becoming more feasible because students may own more than one device adequately used for a certain purpose (Moran et al., 2010). For example, students may be required to participate in a range of learning activities that can take place across different locations. Such activities may begin outside the classroom and may require students to interact with portable and small-scale devices like smartphones. Furthermore, students may continue with some of their learning interactions in regular classes while practicing a more traditional way of learning (Bollen, 2010).

In this paper, we present a learning activity consisting of different type of interactions supported by various types of web and mobile technologies. This activity has been implemented and tested with 75 students attending courses at bachelor and master level in two different academic institutions. We briefly describe the EDU.Tube environment used to provide technological support for the enactment of this learning scenario. Specifically, we used EDU.Tube to enable authoring, sharing and displaying of digital videos that incorporate educational interactions used along this activity. We then describe how educational interactions authored by students were later offered to their peers as appealing learning opportunities. We also identify various design and development challenges reported by teachers and students providing crucial information to be considered for the further improvement of the tool. Finally, we suggest a set of recommendations that could later be used to guide an advanced and refined version of EDU.Tube.

## **2. Motivation**

Teachers and developers could join forces while aiming to design and enable learning activities supported by technology that include educational videos available on the web (Lindeberg, 2011). Such developmental challenges should address the composition of various and interrelated pieces of media aiming to provide a meaningful learning experience. In this respect, developers and designers may require to cope with interrelated visual aspects containing information communicated by teacher or students. These aspects include the composition and arrangement of information to be represented by various types of media. Developers should also deal with functionalities related to the user interface addressing the control over the flow of such media.

We aimed to cope with some of the previously described challenges while designing and developing an educational and interactive video environment called EDU.Tube (Kohen-Vacs et al., 2013). This environment is accessible from various types of mobile devices using their existing web browsers. Teachers and students may use EDU.Tube in order to author various types of interactions related to specific moments in occasional video found in YouTube. These videos and their related synchronized interactions could be later offered to students as innovative and appealing pedagogical opportunities.

One of the objectives of this paper is to provide an evaluation of the EDU.Tube technology following its implementation in a pedagogical activity described in a later section. This evaluation was conducted according to a Technology Acceptance Test (TAT) based on the Technology Acceptance Model (TAM) (Davis et al., 1989). TAM sets a theoretical framework that aims to show how users accept technology and also addresses factors that may influence the adoption of innovative technological solutions. This model postulates that the use of an information environment is influenced by the behavioral intention is determined by the person's attitude towards the use of the system. Attitude refers both to the aspects representing the perceived usefulness of a system and the perceived ease of use of such a system. Furthermore, the model claims that there is a direct relation between the ease of use and the usefulness of such system.

We addressed the perceived usefulness and the perceived ease of use as defined in this model in relation to EDU.Tube. We suggest that the incorporation of such a model could be used as a tool to assess educational experiences provided by EDU.Tube, as well as to enable future refinements of these activities potentially providing improved educational experiences. This assessment includes an examination of pedagogical aspects as communicated while been supported by EDU.Tube. Moreover, we specifically examine different aspects of such experience as supported by the different technologies been used. One of the assumptions in our assessment is that web and mobile technologies may directly influence the learning environment's functionalities, as reflected from its user interface. In the next section, we described the pedagogical scenario in which we have tested and validated our ideas.

### 3. Pedagogical Scenario

The learning activity described in this section was designed for undergraduate and graduate university students learning essential terms in the field of computer science. The activity was technologically supported by the EDU.Tube authoring environment enabling students to convert occasional YouTube videos into interactive educational opportunities. The activity includes a phase in which students are required to author interactions related to YouTube videos. This phase is followed by another one in which these interactions are peer assessed (Kohen-Vacs, et al., 2013). The learning activity consists of three complementary and interrelated phases as described in Figure 1.

The activity commences while students are requested to seek for regular videos available on YouTube that could potentially be related to the subject matters dealt in the courses. These video resources are later incorporated with interactions aiming to foster students' understanding of the learned topics (Gilroy, 2010). Such educational strategy implemented in this activity aims to develop students' ability to associate and use authentic problems by using video examples related to the subject matter presented in the courses. The actual enactment of this activity required the use of another technological environment called Collaborative e-Learning Structures (CeLS) enabling to author, enact and reuse different types of multiphase and collaborative pedagogical strategies (Ronen, 2010). The integration of the CeLS environment enabled the orchestration of participants into the assignments demanded from students.

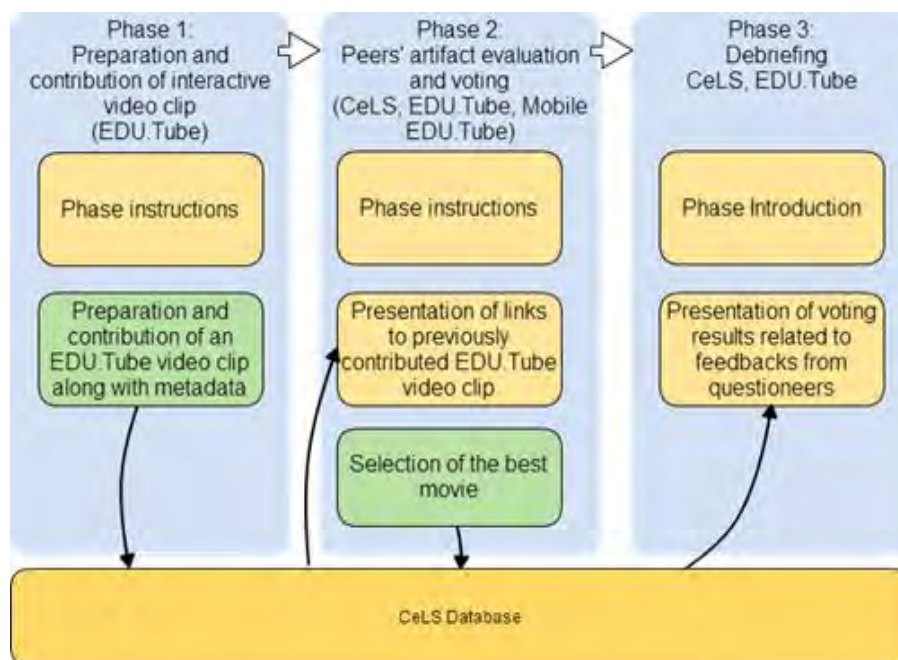


Figure 1. Description of learning Activity's interrelated phases

Below, we describe the goals of each one of the phases, its required educational interactions and the technologies used for their accomplishment:

- Phase 1- *Preparation and contribution of an interactive video clip*: During this phase, students are presented with a specific topic in the field of computer science. Later on, they are requested to search for a short video on YouTube, which could be used as a pedagogical opportunity for exploring and learning the topics under study. The students are requested to use the EDU.Tube authoring environment in which they import the link to a video with a length between three to five minutes. Students are required to enrich this video by three to five interactions along its time line aiming to convert it to an interactive video that could potentially be used as a learning opportunity. In this phase students play the role in which they incorporate interactions to a video with the EDU.Tube authoring environment that should only be used with a stationary environment.
- Phase 2- *Peers' artefact evaluation and voting*: Before the actual initialization of this phase, all the interactive videos and their corresponding metadata are integrated into the CeLS database creating a repository of students' artefacts created in EDU.Tube. This integration aims to provide students with an opportunity to assess the content of the interactive videos contributed by their peers using their own regular, tablet or smartphone computing device independently from their physical and geographical context. These assessments are registered in the CeLS environment and provide teachers and students with the option for further elaboration. During this phase, each student is presented with seven videos created by his/her peers and he/she is asked to vote for the three best videos. In addition, students are asked to textually justify their selections.
- Phase 3 *Debriefing*: During this phase the teacher conducts a debriefing session including the presentation of example videos which were previously contributed by the students for the competition enacted during the second phase. The teacher presents the most selected videos (as a result of the peer assessment) while emphasizing its attributes that potentially can transform it to a learning opportunity that could be reused in the future.

In the following section we provide a description of the EDU.Tube environment used to support the enactment of the described scenario.

#### **4. Environment's Description**

As mentioned earlier, the EDU.Tube environment offers support for the authoring of educational interactions to be synchronized and incorporated into YouTube videos. The authoring process of such interactions could be initiated by teachers or students seeking for a YouTube resource that can later be used as an educational opportunity. The link to such video is submitted and played by EDU.Tube. The playback of this video is visually represented by a marker that advances along the timeline of the submitted clip. An author may choose to incorporate an educational interaction at any point along the timeline. This process is done by choosing a desired moment of interaction followed by the selection of the requested type of educational interaction. An author may choose to incorporate various types of interactions like an attention point presenting students with important additional information. In addition he/she may choose different types of questions including open text, single or multiple selections.

Figure 2 illustrate an example of a video incorporated with a single choice type of interaction along a meaningful positive feedback.



Figure 2. Incorporation of an interaction for a computer science lesson technologically supported by EDU.Tube

Interactive videos can be shared by students and later be used by them on their regular computers, smartphones or tablet devices. These videos can also be shared by students while using different communication channels like regular mail, social networks or the Learning Management Systems (LMS). We mentioned before that the type of device from which a learner consumes an educational service might represent a key factor for providing an optimized pedagogical experience.



Figure 3 illustrates the process in which EDU.Tube detects the type of device from which the student consumes a video and accordingly adapts the content presentation to the used device.

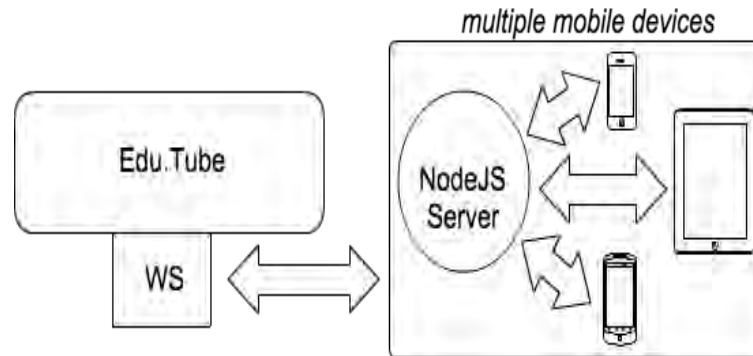


Figure 3. EDU.Tube’s content is adapted and communicated to different type of devices

## 5. Activity Evaluation

In this section, we provide the results of an evaluation based on a questionnaire presented to students. This evaluation was conducted with 75 students participating in a learning activity following the ideas described in section 3 and supported by EDU.Tube. This activity took place during one semester in 2013 in the context of three courses dealing with introduction to procedural programming, advanced topics in server side programming and software engineering.

First year students of a bachelor degree in instructional technologies attended the introductory course. The second course dealt with server side programming and was attended by second year students of the same program. The third course dealt with software engineering and was attended by first year students of a computer science study program. The number of participants in the introduction course was 27, while 21 participants attended the server side course. The software engineering course also included 27 participants.

Table 1 presents the availability of different technological devices among students, its use for educational purposes while interacting with EDU.Tube. In some cases, students own and use more than one type of device.

Table 1: Technological availability and use of EDU.Tube across courses

| Course  |         | Procedural programming | Advanced topics in server side programming | Software engineering |
|---|---------|------------------------|--|----------------------|
| Category  |         |                        |  |                      |
| Participants  |         | 27                     | 21   | 27                   |
| Use rate of technological devices for studying purposes | Regular | 37%                    | 28%  | 56%                  |
|   | Laptop  | 88%                    | 86%  | 74%                  |
|   | Mobile  | 23%                    | 52%  | 30%                  |
|   | Tablet  | 0%                     | 0%   | 30%                  |
| Use rate of EDU.Tube on regular or laptop computers     |         | 67%                    | 61%  | 78%                  |
| Use rate of EDU.Tube on smartphones or tablets          |         | 33%                    | 33%  | 19%                  |

As already mentioned, we evaluated the activity with a questionnaire that included a section addressing the type of technology owned by students. In addition the questionnaire also addressed the pattern of use for these technologies, the perceived added value of EDU.Tube, the preferred device to be used with such environment, the reasons for these preferences and finally a request for student's

impressions, insights and comments about their overall experience. As previously described, this learning activity included three phases in which students had the opportunity to author educational interactions according to an occasionally found and selected YouTube video. These interactions were later consumed and assessed while using various types of technologies. The first part of the questionnaire addressed the variance of technological devices owned by the students. We checked the availability of stationary, laptops, tablets and smartphones among the students and found that 42 students have stationary computer, while almost all of the students reported to have a laptop computer. In addition, 62 students reported to have a smartphone device while a minority of them (17) reported to have a tablet device. In the majority of the cases the students had both; one major computing device and one small mobile or tablet device. In this respect, we found that 47 students that reported to have a laptop and a smartphone.

The subsequent question addressed the patterns in which students used information technologies while experiencing learning. Almost all the students reported to use their laptop devices while studying. A closer look at the data revealed that in the software engineering course the students used almost all their available technologies while in the introductory course only 22% of the class participants used smartphones. We also checked the use of technology among students attending the advanced server-side programming course and found that 50% of the participants in this course used smartphones.

The next questions addressed EDU.Tube's perceived added values. We addressed a question related to EDU.Tube in general without mentioning specifically its instances (mobile or regular). 70% of the students found that the EDU.Tube activities presented by the teacher after each lecture helped them to some extent to deepen their understanding of the learning materials. A closer look at this data reveals that only a minority of 29% of the students felt that the activity was 'very' or even 'very much' helpful. We then asked the students to specify their preferred instance of EDU.Tube. 69% of the students reported that they would prefer using EDU.Tube on their laptop devices while only 28% of them reported to have no specific preference. Almost none of the students preferred to use the environment exclusively on his smartphone device.

In the next questions, we requested to specifically write down the reasons for which students preferred a specific instance of the technological platform. Most of the commenting students pointed out the lack of convenience for using such an application in a smartphone with a small screen device. The next question in this group referred to the level of user friendliness of the environment. In this respect, we discovered that almost all the students reported that the regular version of the EDU.Tube is user friendly while almost all of them reported that the mobile instance of the environment's interface is difficult to use. We then closely examined the specific reasons for which they indicated their preferences and impressions. Many of the students pointed out that there is a prominent challenge while using small-scale devices for interactions that combine videos along with textual media. Some of the students specifically stated that there is a need to re-arrange these media before experiencing it on a small-scale display.

Some students also commented about the nature of the interaction incorporated to the video. In this respect, they mentioned that for some situations they prefer to continue their video experiences without the disruption typically involved in interactive videos. Furthermore, in some of the cases the students even mentioned that they prefer watching the video fluently while aiming to gain a good idea of the whole content without disruptions. This recommendation included a suggestion for a 1st round of a non-interactive video followed by a second in which the interactions will be presented. Another concern of the students involved the requirement for meaningful feedback and being given credit for the activity. They wondered if the results from their participation were accumulated and they even recommended to re-route students to different learning paths according to a reasoning mechanism based on accumulated history of interactions.

Finally, there were a small minority of students that reported operational issues with mobile phones like problems connecting to the network, lack of compatibility to some mobile operating systems and a very few operational bugs in the environment's mechanism. The final question required students to openly state their comments including aspects of the system that they thought that requires further improvement and other aspects they already found satisfactory. In this section of the questionnaire, students re-stated all points for improvement that they provided previously while they reaffirmed their desire to keep using an improved versions of EDU.Tube. Specifically, they reported

that they liked the pedagogical approaches encompassed with interactive videos provided by a relatively user-friendly environment.

## 6. Conclusions and Future work

In the previous section we have presented and analyzed some of the students' insights followed by their experiences using the EDU.Tube environment. These impressions also described their preferences while considering the use of EDU.Tube from a stationary or mobile device accordingly supported by a proper instance. We also presented their prominent comments and recommendations related to their learning process supported by web and mobile technologies. In this section, we summarize the outcomes as reflected from the TAT questionnaire based from TAM. We also offer our vision for the next version of the mobile instance of EDU.Tube that aims to provide a better user experience supported by improved data arrangement. The results as summarized from the questionnaire indicate that students were willing to accept and recognized the added value of educational and rich media activities combined within their regular learning process. Students identified some of the challenges related their educational experience supported by mobile environment.

One of the main comments addressed by the students, concern interface and technical related aspects of the mobile instance of EDU.Tube. Students pointed out that due to operational and compatibility issues, the environment might not be operational. EDU.Tube, thus, might not be useful across the different devices owned by students. Another operational concern involves the lack of systems' ability to auto restart videos following a user interaction. Such constraint enforces students using the mobile instance of EDU.Tube to commit a manual operation in order to continue interacting with the video clip. This way of operation is originated from a security restriction existing across the smartphones' operating systems. Such challenge could be worked around while presenting students with a meaningful announcement reminding them to reinitiate the playback of the video

One of the most challenging aspects of the environment concerns the requirement for re-arrangement of the user interface aiming to organize and display all relevant media in a convenient composition at the correct instance. In the current mobile version, the appearance of the interactions is detached from the corresponding video while sometimes the details in the video may provide important visual information needed for the student's interaction. Figure 4 illustrates a video reaching the point of interaction (on the left) and then is completely disappearing in order to present the interaction (on the right).



Figure 4. A video and its interaction as displayed in a mobile device

In this case, the implementation of mobile adapted web design could offer a set of approaches aiming to properly represent information in mobile displays.

During the implementation presented in this paper, we used EDU.Tube as a technological tool that provides support for authoring and using interactive videos combined into a multiphase collaborative learning activity. In this implementation we used EDU.Tube's API in order to share information between the EDU.Tube's database and the mobile instance of the environment. This information includes data indicating the location of the resource in YouTube and its synchronized interactions. Such a type of activity may require addressing different aspects related to the orchestration of educational interactions. These aspects may include the place, time, location and technological mean in which these interactions are achieved (Dillenbourg, 2011). In this sense, the contextualized use of technology may require further development of EDU.Tube APIs. These APIs might be required in order to enable teachers to integrate EDU.Tube to additional pedagogical strategies requiring the authoring or use of interactive videos along other related learning tasks.

Feedbacks and insights provided by the students revealed important aspects to be considered in terms of the pedagogical enactment of a rich media used in an educational activity. Those addressed pedagogical, logistical, design and technological interrelated aspects. These aspects point out the requirement for adaptation of educational materials aimed to be consumed on mobile technologies. Specifically, teachers have to consider that students that access educational materials on their mobile devices may experience the learning process anytime and beyond the boundaries of the traditional classroom. In such cases, students could consume an educational activity remotely from their teacher and therefore may not be able to be provided with immediate support both at a pedagogical level, as well as at the operational level. Teachers may require anticipating such type of challenges and coping with them while selecting and incorporating specific mobile activities to their pedagogical strategies. In addition they might consider providing dedicated means of scaffolds and meaningful feedbacks along the educational activity. Another aspect related to the teacher, concerns adaptations required for activities having rich media learning materials. These adaptations need to address the consumption of rich media on diverse type of technological devices. In addition, such adaptations need to address the possible adoption of regular materials to be used on mobile platforms enabling a better exploitation of educational materials consumed ubiquitously (Kukulska-Hulme & Traxler, 2013). Specifically, these adaptations may provide students with a more meaningful learning process while they consume learning materials along a pedagogical process enacted across context. Both educational and technical concerns will be used to guide future deployments of advanced versions of EDU.Tube. We aim at better coordinating techno-pedagogical efforts accordingly practiced by different type of stakeholders.

Despite the mentioned comments, students still showed a positive attitude and enthusiasm for participating in such future activities supported by EDU.Tube's mobile instance. Students expressed their willingness to try future versions while aiming to exploit additional and more advance features of the environment. Our future efforts will focus on developing a process that allows a better cooperation between the various stakeholders including teachers, designers and developers aiming to improve the deployment of such environment supporting multiphase collaborative learning activities. We will examine the establishment of an agile design and development approach offering a convenient framework that enables each of the stakeholders to concentrate in different aspects of the development process. The actual implementation of such an approach might provide a convenient way to deploy pedagogical strategies supported by different technologies providing an improved used interface. Specifically, we aim towards developing an approach that might enable the representations of educational interactions across different end-user devices properly adapted to a context of use. This approach is also related to the design of learning flows and their corresponded orchestration according to the modeled pedagogical strategy.

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# Feeling at Home from the First Day: Using Mobile Location-Based Games for Welcoming New Students

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**Abstract:** New students' orientation events in Higher Education typically focus on information delivery (rules, duties, procedures, etc). Consequently, new students might feel overwhelmed, lonely and anonymous. Our study describes an attempt to take advantage of the mobile technology available to all for conducting an active orientation event that addresses students' needs for safety and belonging and focuses on their emotional experience rather than on information delivery. The main activity during the event was a "treasure hunt" game played throughout the campus, using students' personal smartphones. The game was developed with Treasure-HIT, an authoring system that enables the design of location based games and activities operated by mobile devices. At the end of the first day of their studies (a week after the orientation event) students who participated in the event and students who did not, described their feelings regarding the new beginning. The psychological wellbeing of the students who participated in the orientation event seemed to be markedly higher than those who did not: they felt more at home, with a better sense of orientation in the campus and a sense of belonging, having already formed friendships. The findings suggest that team location-based games supported by mobile technology may efficiently support the adjustment and socialization of new students. The paper further describes the scaling-up potential of Treasure-HIT based orientation activities as manifested in spontaneous self-directed adoption of the system for supporting similar events conducted in schools.

**Keywords:** treasure hunt, location based game, mobile learning, orientation, scaling-up

## 1. Introduction

Orientation programs in higher education are meant to facilitate students' transition from previous settings (e.g. high school, workplace) to the academic culture (Upcraft and Farnsworth, 1984; Ward-Roof, 2010). Initial induction programs are of particular importance since they set the tone and build students' expectations for consequent orientation and socialization processes (Shobrook, 2003). First meetings and organizational introduction events typically focus on the delivery of information and on technical and procedural contents. Students typically feel anonymous and isolated during such events, experiencing an overload of information.

Yet, in recent years some organizations recognize the flaws of 'information-only' introductions and try to create events that are highly emotional and experiential (Tyler, 1998; Lines, 2011). Being experiential, such events are memorable (Buchanan, 2007) and might even reduce turnover (Hacker, 2004). Similarly, some Universities and Colleges realize that besides providing information, induction to higher education should address students' needs, particularly those related to psychological security and a sense of belonging (Billing, 1997; Carter and McNeill, 1998; Maslow, 1954).

An example of such a 'student centered' induction approach is reported by Poblete et al. (2006) who describe the orientation program at the school of engineering in the University of Chile. The activity took place during two days, a week before the beginning of the semester. The new students participated in a series of challenging activities which encouraged them to get to know one another, become familiar with the campus, and get a better notion of the challenges they will be facing as engineers. The impact of this experience was assessed by a questionnaire administered after the induction. Participants' replies (80% of the cohort) were compared to non-participants (20% of the

cohort) and to second year students which did not participate a year before in an induction event. The comparison revealed a positive impact of the induction experience on participants' well-being, their sense of belonging, closer relationships among peers, and trust on the school of engineering's commitment to teaching.

The recent availability of advanced mobile technology offers new opportunities for extending instructional activities beyond the traditional boundaries of the classroom (Giemza, Verheyen and Hoppe, 2012; Sébastien and Audrey, 2011) and attempts to adapt them to different kinds of outdoor and indoor spaces (Kukulaska-Hulme and Traxler, 2005; Sung et al., 2010). Several studies suggested taking advantage of this technology for coping with the challenge of supporting the orientation of new students arriving to an unfamiliar campus.

Curran and Huang (2008) describe an attempt to assist overseas students' induction to campus using mobile technology for providing web based multilingual information about locations and services that may be useful to students who do not master the local language. In this study the mobile technology was offered on demand, only as an information platform.

Coping with the goal of actually engaging participants in an activity strongly suggests using a gamification approach. Schwabe and Göth, (2005) designed a gaming supplement for the traditional orientation rally, a fun event intended to get to know the university and its surroundings. The rally led all participants through relevant sites in the campus with several tasks to carry out at certain spots. The MobileGame added to the rally was operated with small handheld computers provided by the university. The students played a 'hunting and hiding' game against each other, individually or in small groups. Fitz-Walter, Tjondronegoro, and Wyeth (2012) describe an effort to design a mobile application, based on gamification principles, that was meant to deal with students' reports (derived from previous orientation events) of feelings lost, having trouble meeting new friends and finding what services and events are available on campus. The gaming element was based on achievements: the players gained scores by completing challenges such as finding locations, answering informational questions about campus services and facilities, adding phone numbers of new friends and checking-in to relevant events. The scores for each set of challenges were presented on a leaderboard and students who completed a set could enter a draw for prizes (iPad 2 and gift vouchers). The game was conducted during a period of four weeks including the orientation week. Challenges could be updated and changed in the application during the game period using a web-based Content Management System.

The mobile games described in these studies were based on dedicated environments especially designed and developed for supporting orientation on new students in the specific campuses. Our goal was to explore the possibility to adapt a generic game approach and system for supporting students' activities during orientation events, in order to enable easy adoption by any institution.

One of the classical approaches to location-based learning is Treasure Hunt type games. In such games, participants are challenged to identify specific sites according to clues and to physically reach these sites. Additional activities could be assigned at the sites as a condition to advance in the game. Mobile technology can provide direct support for such games by tracking participants' locations in real time, presenting the game clues in various multimedia formats, enactment of pre-planned interactive activities related to the sites, collecting and sharing digital information contributed by the participants, communication among participants and between them and the game's instructor, and controlling the activity by the game manager. Various types of mobile treasure hunt environments were developed in order to create such games for different purposes (Spikol and Milrad, 2008; Hooper and Rettberg, 2011).

In this study we used the Treasure-HIT system (Kohen-Vacs, Ronen and Cohen, 2012) for creating and enacting a mobile game for welcoming new students, while taking advantage of the personal mobile technology (smartphones) available to all. In the following sections we shall briefly introduce the Treasure-HIT system, describe the design of a Welcome game and its implementation with students and present the results of the evaluation study. We shall then describe the first phases of the scaling-up of this approach as it is adopted by system users in other institutions.

## **2. Designing a Mobile Game with Treasure-HIT**

Treasure-HIT (Kohen-Vacs, Ronen and Cohen, 2012) is a system designed to enable teachers to easily create educational location-based games operated via mobile devices. The system includes two components: an authoring web environment for creating and controlling the game and the players'

application used by the participants for game enactment. The application is currently available for iPhones and Android.

In a game created with Treasure-HIT the players (teams or individuals) are challenged to identify specific sites (stations) according to clues provided by the game creator and to physically reach these locations. When arriving to a station, the players have to complete a series of tasks. The clues directing to the next station will appear only upon completion of all tasks. The game mechanism automatically discourages random guessing while repeated incorrect answers to the same task will result in a delay penalty.

A game may include any number of outdoor and indoor stations. The interface for defining a station is shown in Figure 1.



Figure 1. The author interface for defining a station – an example from the Welcome game.

This interface allows the author to control all the information and actions related to the station:

- The type of arrival confirmation. Arrival to outdoor stations would be confirmed by activating the device's GPS. The Barcode option is available for defining indoor stations. The Barcode is automatically created by the system to be placed on site.
- The clues that will direct players to the station presented as a combination of any type of media (text, picture, movie clip or link to website).



- The location of the station. The location of an outdoor station is set via a simple web interface that embeds Google Maps API by positioning the marker on the map. Further position refinement could be achieved using Google StreetView API, when available (lower part of Figure 1). The author can control the minimal required distance from the site (Tolerance) in order to accommodate to the limitations of the GPS technology.
- The feedback provided upon arrival to the station.

The tasks to be performed at the station, presented as multiple choice or open questions, or as activities to be performed that will result in receiving a confirmation code.

The game creator can define the sequence of the stations as identical to all players or as different, with a common end station. In the case of different sequences, the order of the stations presented to each team would be automatically determined by the system to provide paths with similar lengths. More advance setting allow the game creator to allot only part of the stations to each team, for example, in a game that includes 20 stations each team would be directed only to 7 of them. This option is useful for designing games that are played simultaneously by a large number of teams, in order to minimize the chance that teams would arrive to the same station at the same time.

### 3. The Welcome Game

The orientation event was conducted one week before the beginning of the 2014 academic year. 41 of the 70 new students that enrolled to an undergraduate program in "Instructional Technologies" attended the event. The event started by presenting the Welcome game as a competition between teams. The participants were asked to form groups of 3-4 then take several minutes for an initial personal introduction within the group and define a name for their team. One member in each group was instructed to install the Treasure-HIT application on his smartphone and the groups started playing.

The game included eight stations spread throughout the campus (Fig. 1), four located outdoors and four indoors. The order of stations assigned to each group was different while all shared the same ending point near the lecture hall where game results were presented.

At each station the team was presented with a set of tasks aimed to familiarize them with specific facilities and services provided at this site, especially focusing on aspects relevant to new students (Fig. 2). In order to complete the tasks the participants had to examine the physical location, to look for specific information published on site or online. Some of the tasks did not have straight forward answers and the team members had to discuss the options and to apply their judgment.

One of the challenges we faced was identifying the most relevant content for new students. In order to cope with this challenge we have involved the second year cohort and asked them to propose locations and issues that would be especially relevant for "newcomers". Many of the 20 proposals suggested by the sophomores were indeed used in the final version of the game.

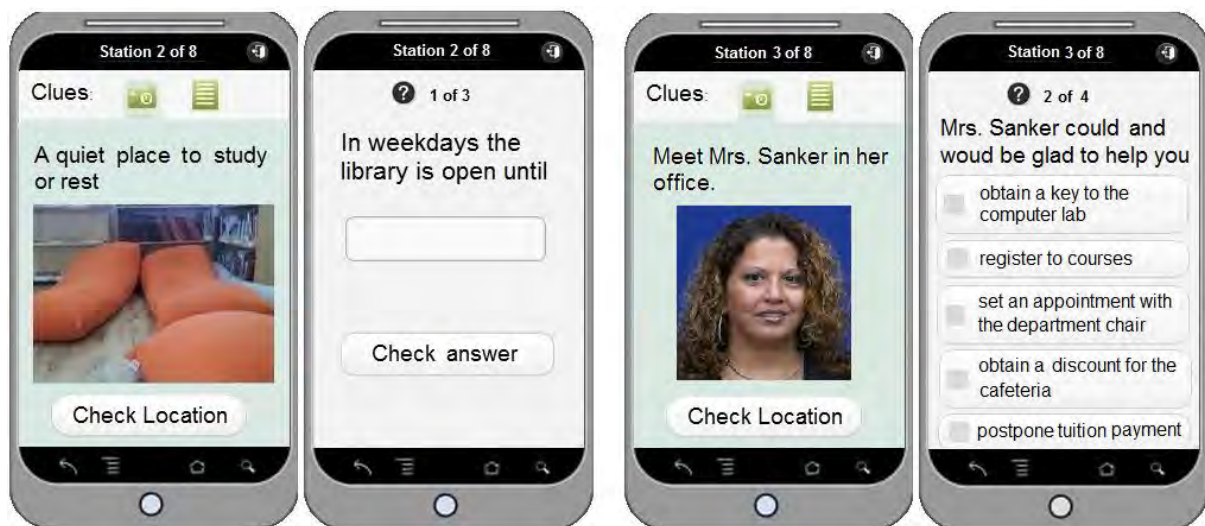


Figure 2. Examples of clues directing to stations and of simple tasks presented at the stations.

#### 4. Results and Analysis

This section summarizes the evaluation study aimed to assess the efficacy of the mobile game, as the first stage of introducing students to their new environment. The evaluation was based on:

- The game records saved in the system's database.
- Reports provided by six observers. Three of the observers accompanied sample teams during the whole game and the others documented the activity occurring at specific stations.
- Data collected by questionnaires filled in by all freshmen at the end of the first school day.
- Sample interviews with students.

The observers reported that the participants were highly engaged in the game and tried all possible strategies in order to identify the locations and successfully complete the tasks, including approaching staff in offices and other students in the campus. Lively discussions were held on issues that were addressed by some of the tasks (Figure 3).



Figure 3. Students playing the Welcome game.

Ten of the eleven groups that started the game completed it in about 40-50 minutes. The game results (Figure 4) were presented to the participants as part of a short summary session of the event.

**Results Wellcome Game (29.9.2013)**

| #  | Team        | Start | Stations | Time     | Location Err. | Content Err. |
|----|-------------|-------|----------|----------|---------------|--------------|
| 1  | Mebulbalim  | 18:17 | 8        | 00:46:02 | 1             | 4            |
| 2  | Girl power  | 18:21 | 8        | 00:47:15 | 2             | 6            |
| 3  | Tipulit     | 18:21 | 8        | 00:49:26 | 0             | 8            |
| 4  | Habanot     | 18:10 | 8        | 00:49:02 | 9             | 3            |
| 5  | Bazmanshela | 18:18 | 8        | 00:42:25 | 4             | 7            |
| 6  | Hamushpaim  | 18:15 | 8        | 00:54:51 | 7             | 4            |
| 7  | Milkis      | 18:17 | 8        | 00:43:05 | 2             | 11           |
| 8  | Segal       | 18:24 | 8        | 00:49:25 | 9             | 1            |
| 9  | Blimaam     | 18:17 | 8        | 00:55:52 | 4             | 5            |
| 10 | Hattemim    | 18:16 | 8        | 00:49:10 | 7             | 14           |
| 11 | No name     | 18:20 | 6        | ---      | 7             | 5            |

Figure 4. The game results

At the end of the first school day (a week after the orientation event) all 70 first year students filled in a questionnaire expressing their feelings as new students. The students were asked to grade their level of acquaintance with peers, familiarity with the environment, sense of belonging and level of anxiety on a 1-9 scale.

A significant correlation was found between the reported sense of belonging and the level of acquaintance with peers ( $R=0.5$ ,  $p<0.01$ ) and the familiarity with the campus environment ( $R=0.45$ ,  $p<0.05$ ).

40% of the students in new cohort did not attend the orientation event and have not participated in the game. Fig. 5 present the comparison between the reported feelings of the students who participated in the game and those who did not.

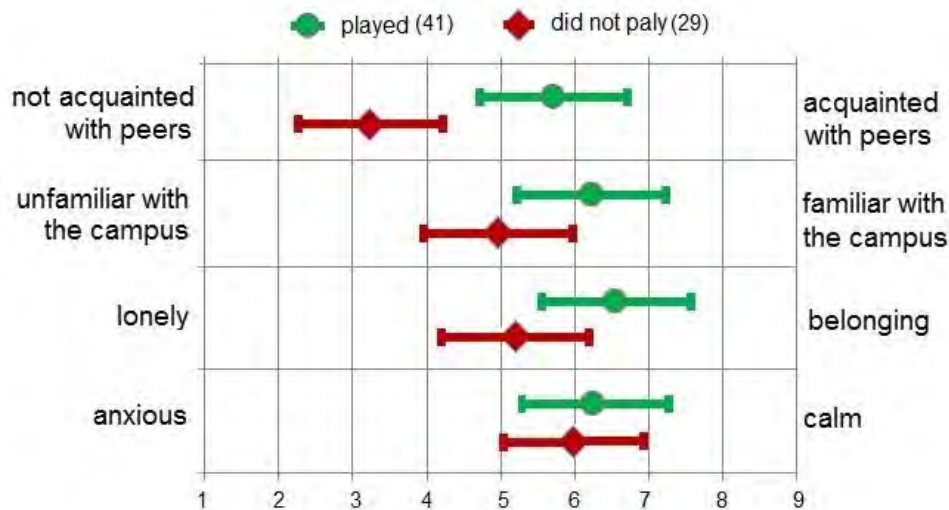


Figure 5. Students' reported feelings at the first day

The findings (Table 1) clearly indicate that the students who participated in the game felt more familiar with the campus environment and more acquainted with their new peers, therefore less lonely with a higher sense of belonging.

Table 1. Analysis of differences in students' feelings

| <i>Feeling</i>                         | <i>t (df=68)</i> | <i>Sig. (2-tailed)</i> |
|--|------------------|------------------------|
| Anxious - Calm                         | .520             | nsd                    |
| Lonely - Belonging                     | 3.56             | .001                   |
| Unfamiliar - Familiar with the campus  | 2.53             | .014                   |
| Not acquainted - Acquainted with peers | 5.01             | 0.000006               |

In addition, the students who took part in the orientation event were also asked to reflect on the game they have experienced a week ago. The questionnaire was anonymous but the students were asked to specify the name of their game team. Only 3 of the 41 students could not remember the name of their team. The students reported that the game was enjoyable, relevant and useful, helped them get familiar with the campus and with their new peers (Figure 6).

The social impact of the game was also clearly evident in the way the students' were seated in lecture hall at the end of the first school day. More than 60% of the students who participated in the orientation event were seated next to one of their team members in the game.

In the open part of the questionnaire students were asked if any of the information they have been exposed to during the game was memorable or surprising. Students mentioned specific details that they have learned during the activity about places in the campus, services and facilities that they have been exposed to. The aspect that was mentioned as surprising by many was the very fact that the event was conducted as a game: "We did not expect such a thing, but a boring lecture ..."

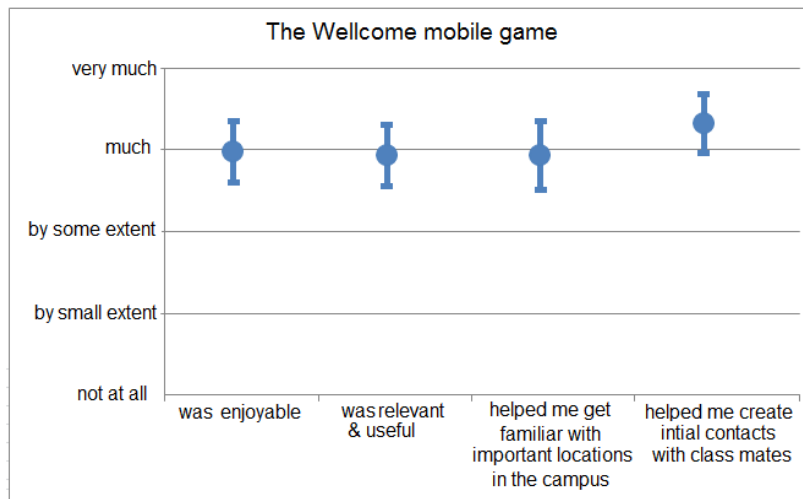


Figure 6. Students' evaluation of the game (N=41)

As described at the beginning of this section, the game results were presented to the participants at the end of the game. Since the students acted quite competitively during the game and the presentation of the results seemed to be very meaningful for them, it was interesting to check whether the personal evaluation of the game was related to their success represented by the relative ranking of their team. The analysis of students' responses indeed revealed that students whose team has achieved a higher ranking evaluated the game as more enjoyable ( $R = 0.36$ ,  $p = 0.027$ ).

The findings confirm that even a relatively short mobile location-based game can have a meaningful positive impact on new students' feeling of belonging, and to support their "feeling at home" from the first day. We intend to use updated versions of this game in future orientation events of our department and to support other departments and institutions in developing their own games.

## 5. Mobile Welcome Games - Anyone Can Adopt and Adapt

The Treasure-HIT environment was originally designed to enable teachers to easily create mobile games that would support location-based learning conducted outdoors and indoors. The system is already used by a growing community of teachers representing a variety of disciplines.

After exposing the model of the Welcome game described in the previous sections to the community of Treasure-HIT users, we are witnessing a trend of adopting this approach for conducting orientation events in schools. The mobile location based games are designed independently by the school team and adapted to the specific needs of institution and of the target audience of the event. Orientation events in elementary schools involve parents and kids while at junior-high level and higher, the activity is usually addressed only to the new students. Some schools piloted the game they have developed as a team formation activity for the school staff. These initiatives suggest that when a useful tool such as Treasure-HIT meets a relevant need (i.e., meaningful and experiential orientation events) spontaneous and self-directed scaling-up might occur.

An "extreme" version of such a game was recently conducted in an elementary school (Figure 7). In this case, the goal was not only to familiarize parents and kids with the school environment and facilities but also to fully support the whole process of registration to the next school year.

The clues directed teams of parents and kids to 9 stations, located indoors and outdoors throughout the school. At each station they were presented with simple tasks introducing the function and facilities offered at the site or the staff member responsible of the site. For some stations the task included activities required for the registrations process: At the school secretariat the parents enrolled their kids, the computer lab was used to fill in the necessary forms and the arts lab to prepare the kid's photos for the school records.



**Figure 7.** A Welcome game in an elementary school – parents and kids.

According to the school principal: "*The idea was not only to acquaint parents and kids with the school environment but to also transform a rather boring bureaucratic process performed individually to a playful and social event. All parents and kids enjoyed the event and even parents that were already familiar with the school reported that they have learned new things about the place during the game*".

## 6. Concluding Remarks

Experiences of beginnings and endings, in many cases, leave a lasting imprint in our memories (Strongman & Kemp, 1991). Memories of entering first grade, attending college, our first job, our first love, are among the strongest and most accessible autobiographical memories we dispose. Universities and other organizations have an opportunity to influence people joining them, at a relatively rare moment, where they are quite receptive, in a state of emotional arousal, with a need to get away from feelings of loneliness, disorientation, and anonymity.

Location-based games, that take advantage of the mobile technology available to all, have the potential of rapidly creating a sense of inter-group cohesiveness, acquaintance with the physical environment and with organizational functions and key persons. As a result, such activities can effect participants' psychological wellbeing and ensure a smoother beginning in a new place.

Authoring environments like the Treasure-HIT support easy creation and enactment of such activities. However, the activities should be carefully designed. It is crucial to identify the locations and organizational functions that are particularly relevant to the participants and to be selective in presenting contents in order to avoid information overload. The tasks should help expose participants to critical information, and at the same time, maintain a high level of motivation by being challenging and sophisticated.

Indeed, from an instructional design perspective designing an effective game involves using motivational strategies such as obtaining optimal levels of challenge and curiosity, collaborations and competition (e.g., Lepper & Malone, 1987). However, treasure hunt games seem to involve additional psychological aspects. Similar to hide and seek games (e.g. Vollmer, 2009), part of the excitement of playing the game might be related to 'finding concealed stuff' – which might be associated to psychological themes of separation and reunion. In addition, treasure hunt games might have the flavor of quest-tales or coming-of-age stories where the protagonist has to be smart and resourceful and handle a set of challenges in order to complete an important task (e.g., Bettelheim, 1976). In other words, the Treasure-HIT environment is but a tool. The quality of the game, like any other pedagogical quest, depends on the designer's ingenuity and his intuitions regarding the target audience's needs and desires.

Our future efforts will focus on refining the Treasure-HIT authoring system by adding the ability to perform 'social tasks' and providing documented guidance to users for developing their own welcome games.

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# How Do Students Progress in a Mobilized Inquiry Science Curriculum

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**Abstract:** There is abundant research reporting the designs of ubiquitous and seamless learning environments which are enabled by the integration of mobile technology. However, the lack of pedagogical designs that provide for sustainability, and the inadequate investigations of learning outcomes are some of the major gaps in current studies. Towards addressing these issues, this paper describes a study that illuminates the principles of how mobile learning can be integrated into a standard-based science curriculum, and explores how this mobilized curriculum impacts students' performances in and out of the classroom. Data analysis on students' test results, learning artifacts and their activity performances in the classroom suggested that they improved in conceptual understanding and self-reflections on conceptual changes. Students were engaged in mobile learning activities both and out of the classroom based on sustained exposure to and experiences of the mobilized science curriculum.

**Keywords:** Mobile Learning, Pedagogical Design, Science Curriculum, Conceptual Understanding

## 1. Introduction

With advances in smartphone technology, the use of smartphone has become pervasive and ubiquitous in many modern societies. Recognizing the multiple functions of the smartphone and its educational value, educators have long advocated the adoption of mobile learning in schools (Ng & Nicholas, 2013; Song, 2014). Research on technological design, pedagogical design, and implementation and evaluation of smartphone-enabled learning (or mobile learning in a broad sense) has been accumulating, yet challenges remain in supporting teacher enactment and obtaining evidence of student learning in mobile learning (Looi, et al, 2014). A review of current studies on mobile learning reveals the dearth of reported longitudinal studies. Few studies have explored the impact of sustainable mobile learning programs that are at the curriculum level on student learning performance. The existing evidence is too scarce to inform future research and practices concerning mobilized school-based teaching and learning. Thus, it is necessary and significant to conduct a longitudinal study that develops pedagogical design principles on how to integrate mobile learning into a standardized science curriculum, and that traces the trajectory of students' performance progression throughout the learning process. This paper presents such a study focusing on exploring student performance change brought about by a mobilized science curriculum. The principles of integrating mobile learning into the standardized science curriculum will be introduced, and the findings of students learning performance in mobile learning activities will be reported and discussed. Implications will be drawn to inform the design and implementation of mobile learning.

## 2. Literature Review

In addition to the integration of suitable mobile technologies, how to combine appropriate pedagogical strategies for enhanced learning application has been a critical issue in mobile learning research (Jeng, et al., 2010). It has been extensively discussed that the design of mobile learning activities should be, like the design of any other learning activity, driven by specific learning objectives (Sharples, et al., 2009). Researchers have placed increasing emphasis on establishing pedagogical principles based on the attributes of the mobile learning environment configured for teaching and learning. For instance, a pilot study on mobile experiential learning created a new way of inquiry-based mobile technology

integration in science learning: in-class questioning, out-of class field trip observation, on site reflection, hands-on experimentation, and learning artefact creation, and sharing and evaluation (Song, Wong & Looi, 2012). Relevant studies on ThinknLearn, Mobile Plant Learning System, Mobile Tour System, and nQuire generated positive impact on both teachers and students, and highlighted the integration of appropriate pedagogical principles supported by technology design (Ahmed & Parsons, 2013; Jones, Scanlon, & Clough, 2013; Huang, Lin, & Chang, 2011; Ruchter, Bernhard, & Geiger, 2010;). These studies affirm the potential of mobile learning in enriching science education. More importantly, evidence has been obtained for supporting the claim that combining mobile learning systems/apps and appropriate pedagogical approaches (e.g. inquiry-based principles, knowledge building, collaborating learning) can create special educational value for students' science learning.

Studies that discussed the use of mobile phones for delivering course materials, learners' preparedness for and usage of the mobilized form of learning, and learners' satisfaction level and learning experiences abound. Yet none of these studies are directly related to the use of mobile phones for academic purposes (Lee, 2013). Sustainable mobile learning programs that are designed for teaching and learning standardized curriculum are rare. To further improve the educational use of mobile technologies, efforts should be made to align and integrate school curriculum into the research design, and thus to improve the balance between research needs and school needs. Moreover, recent mobile learning research emphasizes more on learning in the informal context. Few studies have designed mobile activities that connect learning in both formal and informal contexts. Evidence about the integrated and synergetic effects of linking these two contexts or environments of learning is inadequate (Looi, et al., 2010). As mentioned before, most studies focus on examining short-lived learning experiences and reporting findings based on students' self-reports (i.e. interviews, questionnaires and surveys). Fewer efforts have sought to investigate the learning trajectory of students using mobile technologies for learning over sustained periods of time. To address these issues, we have designed and developed an innovative standard-based science curriculum supported by mobile learning, and explored how this innovation has influenced students' science learning in and out of classroom. This study proposes a mobile learning design that bridges formal and informal learning contexts, and presents new findings of students' performances in the mobilized science curriculum.

### **3. Research Questions and Purposes**

This study was conducted to answer the following research questions:

1. How can we integrate mobile learning into a standard-based science curriculum?
2. What are students' learning progressions in and out of classroom impacted by the mobilized curriculum?

### **4. Introduction of M5ESC**

#### *4.1 M5ESC and MyDesk Learning System*

In our project, an innovative science curriculum, namely, Mobilized 5E Science Curriculum has been developed iteratively and progressively via design-based research in Singapore since 2008 (Looi, et al, 2009). It is a first attempt to systematically and comprehensively explore the integration of mobile learning with a science curriculum for long-term, stage-by-stage intervention. The curriculum is mapped to national science curriculum standards, and covers all of the standard materials required in a primary school. Aligning with the Primary Science Syllabus (MOE, 2008, pp. 2-3) and Singapore Ministry of Education (MOE)'s advocacy on the development of 21st century competencies in science education, M5ESC aims to promote students' conceptual understanding and critical learning skills (e.g. collaborative learning skills, self-directed learning skills, reflective thinking skills) (Sha, et al., 2012; MOE, 2010). The lesson design of M5ESC is based on 5E (Engagement-Exploration- Explanation-Elaboration- Evaluation) inquiry principle (Bybee, 2006). It flexibly incorporates mobile apps from a learning system, MyDesk which is a multifunctional tool installed in windows smart phones. The system consists of a teacher module and a student module. Teacher module provides an authoring tool for the teacher to create mobile activities using different learning tools. It also supports teachers to



review, evaluate and retrieve students' learning artifacts after lessons. In the student module, students can access the activities designed by their teacher, construct learning artifacts, and compose self-reflections using the assigned learning tools. The learning tools in MyDesk include KWL (doing self-reflection through responding to “what I Know” and “What I want to know” before and to “what I Learnt” after learning the topic), NotePad (taking notes), Recorder (recording voice), Sketchbook (drawing models), MapIT (constructing concept maps), and Blurb (posing questions). The combination of these tools is intended to facilitate students to develop sophisticated and systematic understanding of scientific concepts, enhance skills in modelling, reasoning and reflective thinking, and foster self-directed learning skills in and out of the classroom (Brooks & Brooks, 2009; Greca & Moreira, 2000). Other supporting tools (e.g., mobile blog, online discussion forum, video/photo camera, and a search engine) are also incorporated for use by students. Students will receive the teacher's rating of and feedback to their learning artifacts once their teacher has done the evaluation.

#### 4.2 Design Principles of Mobile Learning in M5ESC

The designed mobile learning activities aim to fully leverage technological affordances both in and out of classroom, to address different cognitive levels of usage, and to provide the opportunity for teachers to create ubiquitous learning environment that brings together real-world resources and digital world information. Following Starkey's 'Digital Age Learning Matrix' (Starkey, 2011), we propose ways of integrating mobile technology into the standard-based curriculum (Table 1). The main purpose of applying mobile activities is facilitating knowledge construction, as well as developing science inquiry skills.

Level 1 mobile learning activities include the use of NotePad or/and Recorder for collecting data and writing notes in field trips. KWL allows self-reflection on the connections between knowledge; hence it can be integrated into high cognitive levels of activities (i.e. Level 2, 3 and 4). As an animation tool, Sketchbook is used to promote students' ability to connect knowledge with daily experiences, and to develop higher levels of conceptual understanding (i.e. Level 5 and 6) through peer assessment of artifacts. Blurb is generally used to improve students' thinking and reasoning about the concepts through posing questions, which is appropriate for designing Level 2 and 3 activities. Using these apps, students will have more opportunities to participate in different levels of mobile learning activities, and they will construct higher levels of knowledge understanding through doing these mobile learning activities in M5ESC.

Table 1: Proposed cognitive levels of learning activities in M5ESC

| Mobile tools | Level 1: Doing | Level 2: Thinking about connections | Level 3: Thinking about concepts | Level 4: Critiquing and evaluating | Level 5: Creating knowledge | Level 6: Sharing knowledge |
|--------------|----------------|-------------------------------------|----------------------------------|------------------------------------|-----------------------------|----------------------------|
| KWL          |                | √                                   | √                                | √                                  |                             |                            |
| Sketchbook   |                |                                     |                                  | √                                  | √                           | √                          |
| MapIT        |                |                                     |                                  | √                                  | √                           | √                          |
| Blurb        |                | √                                   | √                                |                                    |                             |                            |
| NotePad      | √              |                                     |                                  |                                    |                             |                            |
| Recorder     | √              |                                     |                                  |                                    |                             |                            |

The design of M5ESC is aligned with the vision that learning needs to be learner-centered, situated, collaborative, ubiquitous, and continuous. The use of technology has become more personalized, user-centered, mobile, networked, ubiquitous, and durable in M5ESC (Motiwalla, 2007). The incorporation of different tools facilitates blended forms of different learning activities residing in one learning environment (Naismith, et al., 2004). In the M5ESC classroom, the constructivist learning theory supports inquiry by placing the focus of learning on student ideas, questions, and understanding, rather than on teacher delivery of content (Fosnot, 1996). Thus, teachers are encouraged to apply constructivist teaching approaches to ask questions, conduct mobile activities, interact with students, and scaffold students' learning. Equipped with mobile devices, student learning activities can be conducted both in and out of classroom according to the principles of seamless learning (Wong & Looi,

2011); Various patterns of learning activities (e.g. individual inquiry, collaborative inquiry, peer discussion) are mainly designed with the aim of developing students' sophisticated understanding of science, and fostering their self-directed learning and collaborative learning skills. In M5ESC, a substantial amount of time is allocated to doing the mobile learning activities as compared with non-mobile activities. Teachers and students interact more frequently in the discussion and sharing of work generated by mobile tools. As formative assessment is regarded as an integral part of instruction and an important source for students and teachers to make reflections on learning and teaching, students' performance in mobile learning activities, which represent their involvement in the learning process, is identified as an important indicator for assessing their learning gains in M5ESC. In this paper, our focus will be on students' performance both in and out of classroom with the intention of identifying students' progression in the mobile learning activities throughout the long-term intervention.

## **5. Participants**

In the year of 2012, M5ESC was scaled at the whole Grade 3 level in a primary school (P3) in Singapore. The 2012 P3 cohort, 299 Students (aged 10-11) in 8 classes, were participants of this study. The cohort progressed into P4 in 2013. As mobile learning activities were expected as a routine in this school, each student was assigned a smartphone as the mobile learning device and allowed to bring the learning device into and out of classroom. There were 4 teachers teaching the P3 cohort, each in charge of two classes. Since the academic year of 2012, teachers and researchers worked together on a weekly basis to co-design and elaborate the lessons. All teachers performed actively in PD sharing and discussion in weekly teacher-researcher meetings. They had strong willingness to receive feedback on curriculum enactment and to elaborate their teaching strategies. Students and their parents also appreciated the educational value of the smartphone. The parents supported their children to use the smartphone out of the classroom to extend their learning.

## **6. Data Sources and Analysis**

In this project, data collection focused on teacher performance in curriculum enactment, student performance in and out of classroom, and teacher and student responses in MyDesk. Classroom observation was conducted in each class in 2012 and 2013 throughout the whole school year. Field notes were used to record the lesson sequence and key instructional events in the class (i.e. questions, interaction, experiments, and mobile activities); Classroom observation sheet was designed for collecting data on teacher and student performance on the key instructional events; Researchers retrieved and reviewed students' work and teacher feedback in MyDesk to explore student performance (i.e. engagement, concept understanding, reflective thinking) out of classroom. In this study, three sources of data were used for analyzing the progression of students' learning performance:

- 1) SA1 and SA2 results: students' achievement in standard tests. SA1 (Semestral Assessment 1 administered at the end of the first semester) and SA2 (Semestral Assessment 2 administered at the end of the second semester) scores in 2012 and 2013 were compared to provide more evidence for supporting our research hypothesis that students would benefit more in reasoning and conceptual understanding with the implementation of M5ESC. These two examinations were considered as summative assessments of students' achievements in science learning, and the results were used by the school as key indicators to evaluate students' progress over the year. The total score of SA1 and SA2 was 100 marks, with 60 marks for MCQ (Multi-Choice Questions) (2 marks for each item) and 40 marks for OEQ (Open-Ended Questions) (2 marks for each item). As the official and standard tests conducted at the whole level in the pilot school each year, SA1 and SA2 had been reviewed and validated by a group of experienced teachers in the school. The difficulty level of SA1 and SA2 are comparable at the item level. To investigate the reliability of the tests, a mock-up test with items of similar difficulty level and structure was conducted before each standard test. The mock-up test results were analyzed to help revise the inappropriate items.
- 2) MyDesk work: work completion rate and level of work quality. A cross-year comparative study was conducted to uncover students' progression in MyDesk performance. The completion rate of each task was analyzed to investigate students' engagement in mobile learning activities that

occurred out of classroom. The quality level of work produced in KWL, Sketchbook, and MapIT, the activities that had higher completion rate and used more frequently, was identified as the major indicator of students' progression in conceptual understanding and relevant thinking skills

- 3) Students' activity performance in the classroom: student performance in sharing, discussion, and experimentation.

Data analysis was conducted by two researchers, and the inter-rate agreement of MyDesk coding reached 93%.

## 7. Findings

### 7.1 Progression in Academic Performance

One-sample t-test (Table 2) was conducted to compare 2012 and 2013 P3 SA1 and SA2 results. The result showed that the whole P3 cohort made a significant increase of 7.69% in total score from SA1 to SA2 ( $t = 6.584, p < .05$ ) in 2012. In 2013, the improvement (10.07%) was also significant ( $t = 13.626, p < .05$ ). In 2012, it was prominent to note that such progress was mainly attributed to their increase in OEQ scores (27.04%) ( $t = 11.845, p < .05$ ) since they experienced a slight (not significant) decrease in MCQ scores. After getting into the second scaling year, P4 students performed as well as the previous P3 students in 2012 in MCQ (6.91%) and OEQ (20.33%).

Table 2. SA1/SA2 HA-MA-LA<sup>1</sup> Gains in 2012 and 2013

| School year |     | MCQ gains          | OEQ gains           | Total Gains         |
|-------------|-----|--------------------|---------------------|---------------------|
| 2012        | All | 0.49%, $t=.406$    | 27.04%*, $t=11.845$ | 7.69%*, $t=6.584$   |
|             | HA  | -5.04%, $t=-5.987$ | 11.71%*, $t=7.798$  | 5.04%*, $t=.535$    |
|             | MA  | 0.91%, $t=.595$    | 29.55%*, $t=8.835$  | 8.62%*, $t=6.047$   |
|             | LA  | 13.16%*, $t=2.487$ | 60.30%*, $t=7.071$  | 23.49%*, $t=4.809$  |
| 2013        | All | 6.91%*, $t=5.978$  | 20.33%*, $t=18.514$ | 10.07%*, $t=13.626$ |
|             | HA  | 3.53%*, $t=3.24$   | 16.30%*, $t=15.021$ | 7.7%*, $t=10.1$     |
|             | MA  | 10.98%*, $t=5.52$  | 23.07%*, $t=12.527$ | 13.86%*, $t=10.643$ |
|             | LA  | 6.41%, $t=1.449$   | 23.55%*, $t=4.587$  | 8.03%*, $t=3.198$   |

\*: Statistically Significant

<sup>1</sup> The eight classes were grouped into three ability levels, namely, HA (High Achievement), MA (Mixed Achievement) and LA (Low Achievement) based on their prior achievements at the P1/P2 level.

Specifically, in 2012, the LA group out of the three ability groups, achieved the highest MCQ gains (13.16%) ( $t = 2.487, p < .05$ ), OEQ gains (60.30%) ( $t = 7.071, p < .05$ ) and total gains (23.49%) ( $t = 4.809, p < .05$ ). Additionally, the HA group achieved significant OEQ gains (11.71%) ( $t = 7.798, p < .05$ ) and the MA group achieved significant OEQ gains (29.55%) ( $t = 8.835, p < .05$ ). In 2013, the three ability groups (HA, MA and LA), achieved equal gain. Our analysis showed that most classes had a significant increase from SA1 to SA2 in terms of MCQ scores, OE scores and total scores, except the LA group who did not achieve significant increase in MCQ gains.

In summary, both 2012 and 2013 cohorts had achieved significant gains in total and OEQ scores. The improvement in OEQ scores was the major reason for the improvement of the total score. MA and LA groups attained more SA1/SA2 gains than the MA group, especially in OEQ scores.

### 7.2 Progression in Mobile Learning Performance

#### 7.2.1 Students' Engagement in MyDesk learning activities

In 2012 P3, MyDesk learning tools were integrated into five science topics: Diversity of plants, Fungi, Materials, System: plants and their parts, and System: digestion. When students progressed into P4, MyDesk learning tools were incorporated into five topics, namely, Cycles, Matter, Interactions, Heat,

and Light. Table 3 shows the results of the average completion rate of these activities using the assigned learning tools in 2012 and 2013. The result suggested that students provided more responses to these mobile activities in 2013/P4 (with an average completion rate of 44.85%) than they did in 2012/P3 (with an average completion rate of 24.09%). Compared to 2012 MyDesk task completion, students in 2013 achieved a high completion rate in KWL, MapIT and Sketchbook activities. In Sketchbook activities, the response rate increased more than 50%. This revealed that students were more engaged in using Sketchbook to describe their understanding and to relate their understanding with their daily life experiences.

Table 3. The comparison of MyDesk activity completion rates in 2012 and 2013

| Year | Audio | Blurb  | KWL    | MapIT  | Sketchbook | Notepad | Average Rate |
|------|-------|--------|--------|--------|------------|---------|--------------|
| 2012 | 7.25% | 23.73% | 48.63% | 24.42% | 24.84%     | 4.00%   | 24.09%       |
| 2013 | -     | -      | 53.44% | 36.88% | 50.56%     | -       | 44.85%       |

Paired samples t test indicated the significant difference in usage between different learning tools in 2012, such as between audio recorder and KWL ( $t=-7.990$ ,  $p=0.000<0.05$ ), KWL and MapIT ( $t=5.183$ ,  $p=0.000<0.05$ ), as well as Sketchbook and KWL ( $t=5.132$ ,  $p=0.000>0.05$ ). In 2013, significant difference in usage was also found between KWL and MapIT, and MapIT and Sketchbook. This suggested students' discrepant involvement in different mobile learning activities out of classroom. Students, with different skills, knowledge, and guidance and feedback from their teacher, used different tools to extend their learning. Through this comparison, we got more insights into students' involvement in MyDesk and their levels of engagement in each mobile activity. This also provided valuable information for teachers to improve their design, elaboration, and evaluation of the mobile learning activities for students.

### 7.2.2 Progression in conceptual understanding

We selected students' artifacts in KWL, MapIT, and Sketchbook (which received higher completion rates) to compare the quality level of the MyDesk work done in 2012 and 2013.

#### 1) KWL Reflection

KWL in MyDesk is organized in three sections:

- What I **know** - refers to student's prior knowledge of the topic/task before the lessons;
- What I **want** to know - refers to student's further thinking about the prior knowledge and the knowledge he/she wants to elaborate in the process of the lessons;
- What I **learnt** - refers to student's self-reflection on the knowledge he/she has learnt about the assigned topic after the lessons.

Data analysis of students' work in KWL in 2012 and 2013 suggested that students not only performed more actively in responding to KWL activities, but also improved their levels of reflective thinking. Compared to the 24.08% completion rate of What I Learnt in 2012, the completion rate of 2013 (which was 41.43%) was high. Moreover, students became more willing to share their prior knowledge (the completion rate of What I Know increased from 33.83% to 56.43%). In 2012, only 20% students completed all the three sections of KWL. In 2013, that figure was doubled (40%). This suggested that more and more students could manage to examine their prior knowledge and identify the new knowledge gained that could help elaborate and extend their prior knowledge. They had gradually developed their thinking skills as they got into P4. They also become more skilful at reflecting their knowledge understanding.

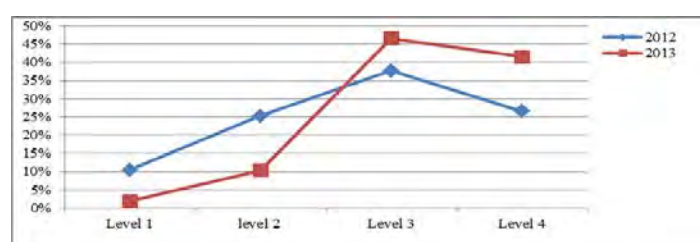
#### 2) Sketchbook Construction

In M5ESC, Sketchbook is used to design out-of-classroom mobile activities for students to connect their knowledge with the daily life experiences. In P4, home-based experiments were designed for

students to observe and record the growth of plants, the lifecycle of mealworm, and the comparison between moist and dry bread. In P3, Sketchbook activities were designed to provide students extensive opportunities to explore the name, properties and value of materials, fungi, heat, and magnets in the surrounding environment. We coded Sketchbook activities into four quality levels modified from the knowledge integration scoring rubric (Linn & Eylon, 2011):

- Level 1 (Non-relative pic/text): Students have irrelevant ideas and make incorrect links with the task.
- Level 2 (Relative pic/text): Students have relevant ideas and make partial correct links with the task.
- Level 3 (Relative pic/text with simple explanations): Students have relevant ideas and make correct links with the task and provide simple explanations.
- Level 4 (Relative pic/text with simple explanations): Students have relevant ideas and make correct links with the task and provide elaborated explanations.

Having analyzed the completed Sketchbook activities, we found that most students responded positively in their work. Their efforts in constructing learning artifacts could be reflected by the pictures they captured in their daily life. We also noticed that some pictures were captured with the assistance from their parents. Figure 1 shows the distribution of the quality levels of students' Sketchbook learning artifacts.



**Figure 1.** Distribution of the quality levels of Sketchbook activities

Compared to their 2012 performance, students performed well in Sketchbook activities in 2013. The proportion of L3 and L4 artifacts, the high level ones, had increased from 37.68% to 46.53%, and from 26.55% to 41.43% respectively. Meanwhile, the decrease of L1 and L2 work further suggested students' progression in Sketchbook activities. Another interesting finding was students' active participation in doing and recording experiments occurred out of classroom, such as observing the growth of beans, the life cycles of mealworm, and the growth of mould in moist bread. We could summarize that students had developed more interest in observing scientific phenomena in daily life and intended to explain the phenomena observed by applying the new concepts and principles learnt in M5ESC. Our classroom observation provided further evidence for the demonstration of such positive changes. In the classroom, they were more interested in elaborating the artifacts, and would like to share their learning process behind their work with the class and the teacher.

### 3) MapIT Concept Map

Through reviewing students' concept maps, teachers could obtain full information on the levels of students' conceptual understanding and detect their major misconceptions. In M5ESC, MapIT activities were designed for both 2012 and 2013 science topics with the aim to develop students' system thinking of what they learnt and how each concept related to each other. Based on literature review (Kinchin, et al., 2000; Slotte & Lonka, 1999), we identified three levels of concept maps, which were used to evaluate the quality level of students' MapIT learning artifacts:

- Low Quality: presenting a part of key concepts without relationship links
- Middle Quality: presenting a part of key concepts with a part of correct relationship links
- High Quality: presenting all key concepts with correct relationship links

Reviewing students' concept maps drawn using MapIT, we found students had developed better skills at constructing concept maps with increasing participation in M5SCE. The rate of high level concept maps produced increased from 33.01% in 2012 to 39.35% in 2013. The rate of low level concept maps generated decreased from 8.23% in 2012 to 0.2% in 2013. A considerable number of students intended to present their understanding of the target concepts via drawing complex concepts, or organizing the key concepts together with correct relationship links. The improvement in 2013 suggested that it was possible to develop system thinking skills in students in lower primary grades.

### *7.3 Students' Classroom Performance*

Being equipped with smart phones, students performed actively in sharing and discussing the learning artifacts, collecting data in the experiments, and interacting with teachers. In M5ESC, to promote students' engagement in the collaborative activities in the classroom, students were encouraged to share their learning artifacts with their partners or the class. At the later stage of M5ESC implementation, most students became more comfortable when their teacher presented their work via projector on the white board. They interacted more frequently with the teacher to share their reasoning and thinking. This was very different from the situation in 2012 when students had considerable concerns about receiving negative comments from the teacher and their classmates. Using exploratory questioning in the M5ESC classroom, the teacher provided more space for the students to think, reflect and explain by themselves instead of providing comments directly to the students (Kerawalla, Marilena, & Scanlon, 2013). Hence, influenced by the open questioning learning environments, students' participation in classroom sharing and discussion was promoted, which in turn contributed to the positive changes in their learning performance. At the later stage, students had better understanding of the value of the smartphone for searching online information and collecting data during experiments. When collaborating with their partners in experimentation, they gradually developed the habit of using smart phones to document the experiment by making videos or taking pictures. As we observed, when one student was doing the experiment, her/his partner would use the phone to record the phenomenon. This pattern of collaboration was common in the M5ESC classroom, as well as in the field trips and other out-of-classroom group activities.

## **8. Conclusion**

This study presents findings from a sustained seamless learning project in a primary school. The research design was guided by two research questions concerning the design of the pedagogical principles for mobile learning and its educational value for improving students' science learning. In complementing current studies on mobile learning, the paper first provides the theoretical foundations on how the seamless learning program was established and how it was integrated into a standard-based science curriculum. The mobile learning design for knowledge construction is proposed to improve the pedagogical design of mobile learning. The design of activities at different cognitive levels narrows the gap between the purpose of research design and the needs of school-based curriculum design.

Researchers have pointed out that the dearth of research in any large-scale and sustained deployment of mobile learning, and the extent to which the unique attributes of mobile learning may be lost or compromised (Traxler, 2007). There is little research that has managed to trace the yearly progression of students' performance in mobile learning with the combination of quantitative and qualitative data at scale. Our study attempts to bridge this gap. The cross-year comparison of students' academic achievements, mobile learning artifacts and their activity performance provide valuable information on how to evaluate the outcomes and processes of mobile learning and how to encourage the practitioners to buy-in, sustain, and scale the curriculum innovation. The findings indicate that students could benefit from the mobile learning when it was pedagogically integrated with the standardized science curriculum.

This research can inform the pedagogical design of mobile learning, as well as research design of studies on ICT-supported curriculum. Early research has highlighted that the intensive use of technology does not mean the achievement of meaningful learning, and now the research focus has been

shifted to the pedagogical design of technology-supported learning. Thus, in ICT-supported learning design, the developers and practitioners should focus on the integration of ICT into routine lessons and on linking the purpose of activity design with the learning objectives as prescribed in the syllabus. The evaluation of students' performance should not depend heavily on students' self-reports. Researchers are encouraged to explore students' performance both in and out of classroom and to study the evidence arising from their practices. Such efforts will contribute to the research in technology-supported learning, especially involving the use of ubiquitous mobile technologies.

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# Maparin: Creating a Friendly and Adaptable Learning Scenario for Foreign Students in Taiwan

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**Abstract:** In this paper, we describe a mobile App called Maparin. It has been designed to facilitate foreign students enrolled in National Tsing Hua University (NTHU, Taiwan) while adapting to this Chinese speaking environment. Focused on providing complementary learning material in addition to regular Mandarin course training, the App leads foreign students to their desired restaurant to undertake Chinese learning and social interaction with locals in a real-life context. With the built-in GPS and Augmented Reality (AR) display, students equipped with iPad App have the ability to decide when and where to acquire essential Chinese language knowledge in informal settings. In addition, an embedded Automatic Speech Recognition (ASR) assessment system allows foreign students to learn the authentic pronunciation of daily meals in Taiwan. Moreover, a group of foreign students have been selected for system testing and evaluation. The experimental result shows that food ordering and campus restaurant locating via Maparin is much more efficient and satisfying for the foreign students.

**Keywords:** Social networking sites, augmented reality, mobile assisted language learning, ubiquitous learning

## 1. Introduction

For years, Taiwanese institutions have been marketing their curriculum to future international students. According to statistical reports on registered international students from Ministry of Education in Taiwan, the total student population increased from 55,463 to 78,261 (from 2011 to 2014).

Yet, it has been reported that most of the international students have experienced culture shock or had problem to adapt to a Chinese speaking environment in Taiwan or China (Paniagua 2009; Morataya 2012; Hu, Al-mekhlaf, Sun & Zheng, 2010). Most of the international students in Taiwan acquire

Chinese as a second or foreign language in a class setting. Therefore, the only language practice is done during class, which means students are not frequently exposed to the language and the people who use it on daily basis. Chinese is a difficult language to acquire due to its complex characters' shapes, multiple meaning and intonations (Tseng, Lu & Hsu, 2006). Thus, if students do not have enough language practices with peers or local students, the acquired knowledge from language training courses would likely to be forgotten.

Field trip is a popular alternative solution in addition to regular class (DeWitt & Storksdieck, 2008). This type of extracurricular activity helps students to discover things they have never experienced before such as night market and local cuisine. In this study, we discuss an implemented mobile App focusing on assisting overseas students especially for food purchase on or off campus, and how students can use it to their advantage. At the early stage of this research, we investigated what type of survival difficulties international students might have faced since arrival in Taiwan. Questionnaires were responded by 51 international students from 3 Mandarin classes of basic levels. 4 major complaints from students were identified and are listed as follows:

- Having little or no idea about where to get safe and healthy food for students with different religious beliefs.
- Having little or no desire to speak Mandarin in public due to poor Mandarin pronunciation performance.
- Most of local restaurants do not offer English menu.
- Having little or no idea about how to respond to restaurant owners on customizing their orders.

To address these problems, we implemented an iPad App named Maparin. It is integrated with Facebook social feature and Augmented Reality (AR) display, focusing on helping students to learn how to order food and customize their orders in an informal learning situation. With a couple of finger clicks, students are able to browse through the restaurant information within campus area.

## **2. Related Work**

### *2.1 Acculturation*

The process of one being transformed in a cultural or psychological way is called "Acculturation" (Sam 2010). *Integration, assimilation, separation* and *marginalization* are four possible strategies when individuals decide to maintain a balance between their heritage culture and alien culture (Berry, 1974). It is important to understand how international students in Taiwan would behave while dealing with this psychological (e.g., self-esteem) or socio-cultural (e.g., acquiring a new language) transition. The latter is vital to study because the way how students adapt to the new environment and language can and will be different. The transition experience varies individually. Difficulties stemming from language or culture differences may frustrate students, resulting in lack of interest in cultural maintenance or having no desire to develop relationship with others. Students who integrated with target culture usually tend to participate in the community, ultimately developing a sense of belonging.

On the other hand, those who find no interest in target culture and language will choose to maintain a distance from the community.

International students in Taiwan usually are not required to take Mandarin courses during their academic years. Yet, it is vital for those who are interested in Chinese or Taiwanese heritage and culture to achieve basic level of Mandarin. In order to be able to participate as a member of Taiwanese community, students will need to be trained before they can start communicating with the outside world. In this study, we work to provide better adaptation experience via mobile technology. To ensure a better learning experience and lower frustration that may ultimately lead to marginalization from the target language or culture is our top priority.

## *2.2 Chinese as a Foreign Language (CFL)*

Learning Chinese as a foreign language is a great challenge because it has a total different syntactic structure, the lack of common roots in the vocabulary, five distinct lexical tones, 22 consonants initials and 38 vocalic finals (Tseng et al, 2007). For Chinese reading and speaking, Pinyin is widely practiced in most of the language institutions in Taiwan. Pinyin is an official phonetic system transcribing Chinese characters' pronunciation into Latin alphabet (Margaret& Charles, 2005), making CFL students easier to relate while attempting to acquire and pronounce a new vocabulary. However, using Pinyin alone may cause confusion by making false tone utterance. As we have mentioned above, there are five tones in Chinese language. Different tone utterance may yield different word of meaning, making native listener of Chinese confused while students attempt to express themselves in Chinese. Related study confirmed that single tone can be learned by CFL learners quickly. However, attempting to articulate a sequence of tones from any given reading text can be much more difficult (Mixdoff, Külls, Hussein, Shu, Guoping & Si, 2009).

For learners whose native language is non-tonal, tone utterance and identification pose a great difficulty to them (Wang, Jongman & Sereno, 2003). In Wang's previous study (Wang et al, 1999), it shows that training Americans to perceive Mandarin tones is proved to be effective. Participants received intensive Mandarin tone perception practice and identification. Result shows a 21% improvement in tone identification post-test, and such gains were retained even after 6 months. In their extended study (Wang et al, 2003) further states that improved perception in Mandarin tones also contributes to better tone production performance.

In this study, both pinyin and pronunciation demo audio are both included in order to provide a more precise tone perception practice for international students. Moreover, knowing how to pronounce in a correct tone will also help lowering students' speech anxiety.

## *2.3 Situated Learning*

The basic idea of situated learning is that the learning process is a mutual interaction between the learners and their environment. Therefore, instead of being observers, learners take a step forward and

actively involves in the interactions with the community (Lave & Wenger, 1991). Smartphones and tablet PCs are equipped with advanced GPS and digital compass will certainly play a major role in situated learning. Learning that takes place outside of the classrooms can be greatly benefited by mobile devices in the following ways: wireless network empowers its users to fetch desired location information seamlessly, making learning content accessible anytime, anywhere. Well-designed Apps with appropriate learning content can be downloaded before the outdoor activities start, further enhancing learning experience.

Related projects also indicate that learning that takes place in the context of real life is a more applicable way of problem solving. A similar study called MicroMandarin adopts a location-based social networking service “Foursquare” to determine learners’ location and push corresponding Mandarin vocabulary flashcard for its users to undergo learning (Edge, Searle, Chiu,Zhao & Landay, 2011). In Beijing Normal University, an interesting AR based android App was implemented to facilitate campus culture events. Users were able to search for online information by simply clicking on icons on screen that represented desired location information on android based phone (Pei & Cai, 2013).

We have also reviewed several other interesting learning systems using various wireless technologies. It has come to our attention that there is only a small portion of studies that focus on CFL learners of Chinese in Taiwan, particularly targeting at foreign students. The Cross Platform Map System (CPMS) is a mobile application that offers a virtual map with English and Chinese information available (Paniagua, 2009). The mobile system was implemented to assist foreign students to learn and acquire Chinese characters. The results showed a notable improvement in students' ability to recognize characters that were presented in a campus environment. However, the experiments in the CPMS project were conducted under a pure laboratory environment. Foreign students simulated a self-guided tour by using the virtual map, resulting in a lack of interaction between students and native speakers of Taiwanese citizens. Another study that focused on creating an interactive learning environment for foreign students in a real-life context was presented to address the lacking of interaction between students and people who use Chinese as a spoken language in CPMS project (Morataya, 2012). In Morataya's study (2012), a mobile game-based learning system was presented, using riddles and score system to support CFL learning. Foreign students who participated in Morataya's study reported that they had great fun learning Chinese while doing quests around the designated campus building and places. Students also reported it was a great idea to engage Taiwanese citizen in real-life conversation in Chinese especially when they had a basic idea about the subject of the conversation would be.

Each of the similar learning projects has their own strength and weakness. MicroMandarin is an innovative one because of its unique location-aware mechanism. Being a vocabulary flashcard based learning application, it lacks of the interaction between users and the application by only providing static pictures for each scenario. CPMS is an excellent location information indicator which supports bilingual learning scenario. Unfortunately, the study did not engage its subjects in the physical learning environment. In Morataya's study, we have seen that a great game-based learning

design can help its learners to immerse in any possible environment and actually acquire knowledge. However, the majority of Morataya's participants reported that 3G wireless network coverage was unstable and campus WIFI transferring between each building also made it less user-friendly while doing quests from one location to another. In addition to network issue, one concern was made aware by the majority of participants who complained about getting lost while doing quests because the mobile system did not provide a real-time location update as they travelled between buildings. Finally, there was no text-to-speech (TTS) function or audio file available for students to imitate from. Thus, students could only depend on Pinyin to learn how to pronounce recently acquired Chinese characters, resulting in mispronunciations and confusions while initiating conversations with the locals.

To address the problems mentioned in this section, the proposed system takes advantage of mobile devices and an advanced 4G network to allow students to access crucial learning content in real-time. An embedded Automatic Speech Recognition (ASR) module is included in the proposed system, allowing students to check their speaking performance before making contact with the locals. Chinese vocabulary and conversations that are made available in audio form (MP3 file) were pre-recorded by a native speaker, allowing students to imitate authentic pronunciation.

All in all, the proposed system made several attempts to enhance learning experience and promote students to fully engage in the learning content of this study. The learning scenario set for this study is about a group of international students who are tired of ordering the same food they can recognize. By using the location finding technologies such as Facebook check-in, AR display and Google Map, they are able to go on a self-guided food hunting in Taiwan. Most important of all, the proposed system empowers them to initiate basic daily conversations with Taiwanese locals.

### 3. System Implementation

#### 3.1 System Architecture

This system is built based on client-server architecture. On client side, an App is implemented on iPad. The App is connected to remote data server. Most of the information related to local restaurant, food item information and pronunciation demo audio file are stored on the remote sever. It means wireless network is required to launch the App for data request and transmission between two components. The system architecture is shown in [Figure 1](#).

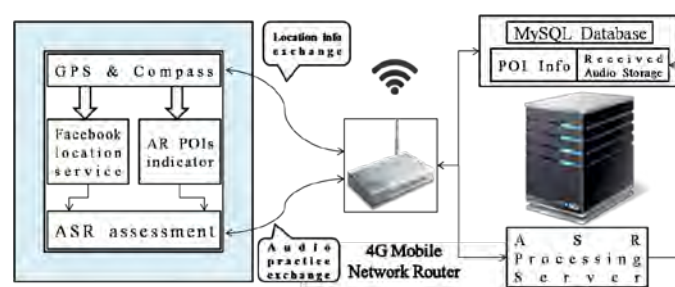


Figure 1. System Architecture.

### 3.2 Mobile App

The design of this mobile application consists of 3 major features:

- Integration with Facebook social feature, making social connection possible.
- An Augmented Reality (AR) based location indicator.
- An ASR assessment system, allowing international students to practice how to make food order in Chinese.

The App requires its users to login via Facebook accounts. As shown in Figure 2a, an AR display serves as one of the location finding options for learners who feel like to scan what type of restaurants are around them. The second option contains a map, which reveals user's current location. The flickering blue dot indicates user's exact geography location (shown in Figure 2b). Three pre-defined search filters has been deployed to assist students to perform check-in from Facebook database. When selecting any of the filters, the system will perform a nearby location check to determine learners' nearby restaurant information. Students then will be able to select the local restaurants in the neighborhood to start acquiring Taiwanese food items and practice how to pronounce them via ASR assessment.

The mobile App is implemented with various web development techniques and Apple iOS development SDK 6.0. On the client side, mobile App is developed using Xcode. Facebook SDK 3.0 and ARtoolkit are integrated during implementation. On the server side, (JSON) and SQL database are deployed to serve as data center. JSON is used to bridge the communication between iPad and the SQL database. Additional Hypertext Preprocessor (PHP) pages are also scripted for data exchanging between mobile App and Apache server. The speech recognition also plays a crucial part in this project. The ASR toolbox is designed by Professor Jyh-Shiung Roger Jang (National Taiwan University, Taiwan). Upon receiving learners' recorded audio file, it will be sent back to the remote server for further performance evaluation. The pronunciation performance is rated on a scale of 100.

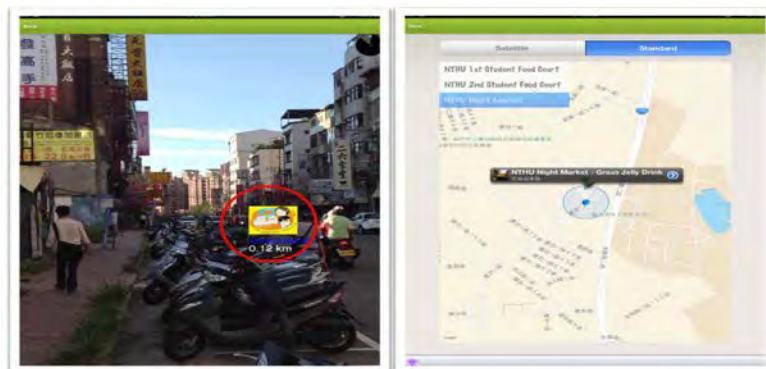


Figure 2. App Snapshots –

(a)AR display Mode (b) Facebook Check-in Mode

## 4. Evaluation

## *4.1 Test Design*

### *4.1.1 Participants*

29 international students from a variety of departments of NTHU participated and completed the evaluation (graduate level, business and engineering background). The students were of age 22 to 30. 11 of the participants are female and 18 are male. Their average time spent in Taiwan is 12 months, ranging from 6 months to 18 months.

### *4.1.2 Procedure*

The entire evaluation session lasted 2.5 hours. The session included a pretest, a usability test, a post-test and an individual interview.

In the pretest, we measured the participants' Chinese speaking ability by using the mobile App's embedded ASR assessment tool. Questions were generated with a combination of Taiwanese food item names and sentences of standard way of food ordering in Chinese. The test was validated by an official Mandarin teacher from Chinese language center of NTHU. In addition, the pretest was taken by 5 of Taiwanese native speakers previously. The average score obtained from native speakers was 85 (on a scale of 100). The participants were given instructions on how to use the mobile App. They were given an hour to play with the App and browse through the nearby restaurants and the food items. During this hour, they were also required to make practices with ASR assessment every time they viewed a different restaurant.

Once the required App trial and practices were completed, a field trip was deployed to observe if the participants were able to reach restaurants in a nearby night market by using the App. There are approximately 20-25 restaurants including small sized food stands, which only offer take-out service. The subjects were not made aware of the exact location on the ones they were going to visit. At this time, the subjects were equipped with one iPad each person. Upon reaching the selected restaurants, the subjects were required to salute the owners and make the orders in Chinese. Each of them was required to visit 3 different restaurants (10 restaurants were available in the mobile App).

## *4.2 Results and Feedbacks*

The learning achievement result is processed by comparing the score generated from pretest and post-test (shown in [Table 1](#)). During the pre-test, the score distribution is not consistent (lowest score = 31.5, highest score = 74.5). The majority of the subjects obtained score between 50 to 65, indicating that the students' attempts to pronounce Chinese food item names and short sentence using Pinyin alone was not effective and they did make several false tone utterances. In the post-test, however, there is a significant improvement in pronunciation (lowest score = 66, highest score = 87).

**Table 1: Pronunciation achievement test result**

| Test type | N  | Lowest score | Highest score | Mean(full scores) | SD    |
|-----------|----|--------------|---------------|-------------------|-------|
| Pretest   | 29 | 31.5         | 74.5          | 59.96 (100)       | 10.36 |
| Post-test | 29 | 66           | 87            | 73.75 (100)       | 05.54 |

The result confirmed and supported the idea of consistent Mandarin tone perceptual practice will make CFL learners to achieve better performance in tone production since ASR assessment system generated personal score based on subjects' tone accuracy and intonation. The input made by the subjects needed to be matched with the corresponding food item name in Chinese before being sent to remote server for assessment. False and inappropriate input will be detected and denied.

For the field trip, all of the subjects were able to locate their desired restaurants or food stands out of night market within 15 to 20 minutes. Please note that restaurant locating and food ordering was undertaken by the subjects themselves. No hints were given during the entire field trip. The subjects reported that AR location indicator helped much when they could not locate the destination using embedded Google map and Facebook check-in. If they were not sure to go right or left, they would switch to AR display to decide which way to take. As for the restaurants visit and food order, subjects reported that it was a wonderful experience to literally initiate conversation with Taiwanese in Chinese. All of the subjects were able to complete the order after using the App. 83% (24) of the participants found it extremely interesting and useful when they succeeded in making orders in Chinese. They expressed that this type of experience is unforgettable and influential for their future encounters in Taiwan.

## **5. Conclusion and Future Work**

In this study, a novel campus restaurant information system for Chinese pronunciation practice and restaurant finder has been designed and implemented. The proposed system engaged its participants in a real-life context, enabling them to participate the society as a normal Taiwanese citizen would do on daily basis. With the advanced mobile technology and wireless network, the proposed system effectively supported its users to reach their desired restaurants and facilitated their social interaction with locals, providing a smooth and friendly user experience.

Yet, to continuously improve the mobile App, there are several factors which have to be taken into consideration in its subsequent study. First of all, social collaboration capability has to be expanded. Participants reported that the ability to allow its users to upload their preferred point of interests should be made available if one wishes to share any recent spotted restaurant. Secondly, offline mode should be made available if one wishes to practice with ASR system. Currently, ASR assessment and pronunciation audio file can only be accessed via internet. Finally, more dialogues should be made available because restaurants owners sometimes ask more questions about their orders and the App does not have the solution to respond yet.



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# Schema Formulation with Schema Priming Test in Elementary Arithmetic Class in Japan

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**Abstract:** In this research, we implemented a system for measuring schema formulation on mobile terminals, making it easy to use in ordinary classrooms. We operated this system in an elementary school over an extended period of one month. The results showed that operating the system (1) was useful for schema formulation in students, particularly if they were weak in arithmetic, and (2) helped teachers understand students' level of comprehension, suggesting that it could help in teaching according to level of comprehension. This article gives an overview of the system developed and reports on the results of operation in the elementary school.

**Keywords:** Schema, Long-term Use, Mobile Terminal, Elementary Arithmetic, Operational Model

## 1. Educational Systems Supporting Educational Practice

### 1.1 *Practical use of Educational Support System in the Classroom*

Recently, as research advances, various educational support systems have been developed and embedded into real classroom environments, from the elementary to higher education. For example, "Monsa-kun" is an environment supporting problem posing in arithmetic, which has been reported to improve basic capabilities of problem-solving for children having difficulty with word problems in mathematics (Hirashima, Yokoyama, Okamoto and Takeuchi 2006, Yamamoto, Kanbe, Yoshida, Maeda and Hirashima, 2013). In secondary education, learning support systems such as EBS (Horiguchi, Imai, Tomoto and Hirashima, 2007) have been proposed using advanced information technologies, and in higher education, cases of research have reported on self-directed learning in a hyper space (Kashihara and Akiyama 2013, Ota and Kashihara 2010, Jouault and Seta 2014), and on training logical thinking and meta-cognitive skills in presentations (Okamoto, Watanabe and Kashihara 2013, Shibata, Kashihara and Hasegawa 2013, Kojiri and Iwashita 2013, Seta, Cui, Ikeda, Matsuda and Okamoto 2013, Seta, Noguchi and Ikeda 2011).

Looking at these learning-support systems from an information technology perspective, when they are aimed at relatively advanced post-secondary students, they tend assume computer literacy in users so they can be more advanced and incorporate more sophisticated functionality into a system.

From this perspective, current research on learning support systems can be categorized according to emphasis on (1) establishing the advance in learning support function from an information technology perspective, together with the proposed new learning method that accompanies it, or (2) eliminating learning difficulties actually encountered by children, as with Monsa-kun.

For the learning support systems in category (1) it tends to be difficult to set a common curriculum in the universities and colleges where they are used, and the computer systems developed tend to assume use in a limited range of scenarios. They have not proposed 'operational models' that anticipate expansion into many educational scenarios, because they require, for example a specialized computing environment. Conversely, learning support systems that focus on solving issues in real learning environments, such as Monsa-kun and the system from Deguchi (Deguchi, Yamaguchi, Funaoi and Inagaki, 2004), need to be able to be embedded into teaching scenarios with strong time constraints,

as is the case in schools. This restricts the functionality that can be incorporated, but handles difficulties faced by many students, so such systems have proved to be useful.

Of course, much of the research attempts to address both aspects, (1) and (2), so it is difficult to divide all research into two clear categories, but it is unmistakable that research on learning support systems that aim to be used in a wide range of learning environments must clarify what it means for a system to be useful when introduced into real learning scenarios.

The primary goals of this research, as a research approach oriented to practical use in the classroom, are to develop Schema Priming Tests (SPT), which are an instructional support and assessment tool for resolving issues with elementary school students having difficulty solving arithmetic word problems, and to operate it for approximately one month to identify issues in embedding it into classrooms.

## *1.2 Using Educational Support Systems Integrated with Teaching*

For the past 20 years or so, the phrase “formative assessment is the most important assessment for instruction” has been used often in Japanese schools. It refers to teaching while maintaining a continuous awareness of the students’ understanding of the material. To do so, formative assessment must be taken several times within a teaching unit to understand the extent to which each student has acquired the relevant skills and where they are encountering difficulty. Knowing the learning results from each student in this way is also helpful for teachers to improve their instructions.

However, even when using integrated instruction and assessment, the main role of teachers is to teach, so they cannot spend large amounts of time carefully assessing the learning activities of individual students. With the recent spread of tablet terminals, students can have their own terminal, and the potential for providing learning support to individual students according to their progress is expanding. Considering this, one of the advantages of a learning support system using tablet terminals is as a formative assessment tool for understanding children’s learning progress.

In other words, an effective way to use tablet terminals would be as a tool to assess children’s understanding of the content of a unit as the unit is being taught in school.

A secondary objective of this research was to use the iPod Touch as a tablet terminal, together with Schema Priming Tests (SPT) implemented on it, integrated into teaching of a unit on area to grade five students. This was used to conduct practical research on the effectiveness of using SPT for longitudinal assessment and support of the process of schema formulation.

In Section 2 below, we discuss the reasons and process of developing SPT and in Section 3 we give an overview of the system. Section 4 gives an overview of the experimental study conducted using SPT, Section 5 discusses the effectiveness of SPT, and Section 6 summarizes the conclusions.

## **2. Solving Process of Word Problem and Schema**

### *2.1 Process of Solving Arithmetic Word Problems*

It is not rare for children to have difficulty with arithmetic word problems, and approximately 30% cannot solve them, regardless of whether they are able to solve calculation problems (Okamoto 1999).

The reason that word problems are found difficult is that they are composed of two processes, that of reading and understanding the word problem, and that of performing the calculation to reach to the answer. Generally, most children that cannot solve word problems are able to solve calculation problems, so of these two processes, it is less common for children to fail at performing the calculation to get the answer.

Recently, the four phases theory (Mayer 1985, Cummins, Kintsch, Reusser and Weimer, 1988) has become influential, stating that solving word problems occurs in four qualitatively different steps. These four steps are 1. Translation, 2. Integration, 3. Planning, and 4. Execution.

According to Okamoto, they consist of the following cognitive processes:

- **Translation:** Translating from a problem text into mental representation with mathematical and syntactical knowledge.

- **Integration:** Determine the problem type using schema knowledge, and integrate it with the overall problem representation.
- **Planning:** Establish a plan (equation) to achieve the goal, based on the overall problem representation.
- **Execution:** Perform the calculation using knowledge of computational algorithms to obtain the answer.

Causes for failure in solving word problems occur in the three phases before execution, and particularly in the integration phase.

The integration phase involves the process of finding relationships among the multiple sentences in the word problem and creating a situation model that is a core representation integrating the overall problem. Then, for the type of word problems with few steps done at the elementary school level, an equation can be derived directly from this situation model. In other words, mistakes made in forming an equation are seen as failures at the integration phase rather than the planning and execution phases.

## 2.2 Problem Schema and the Integration Phase

In the integration phase, a situation model representing an overall understanding of the problem is built, and the student's pre-existing knowledge related to the problem structure, called problem schema, plays a most important role in the integration step. For example, reading the sentence, "How fast is Akira walking?" an adult would know this is a problem related to speed, and to solve it requires other factors such as distance and time. What enables adults to do this is having solved various types of problems related to speed in the past, and having acquired a schema for speed problems, which includes the formula,  $\text{distance} = \text{speed} \times \text{time}$ .

In fact, Mayer (Mayer 1985) identified various problem types among word problems that are taught in the early stages of elementary school, such as compare problems and change problems, and showed that students acquire problem schema for each problem type. Okamoto also showed that even with adults, if they did not have a clear problem schema for compare problems, they often had difficulty solving them, and that whether the problem schema is easy to use contributes strongly to problem integration.

Thus, problem schemas are strongly related to the integration step of solving word problems, and children that have formed a problem schema can more easily solve the problem. This suggests that supporting problem schema formulation in children using iPods, and providing longitudinal assessment of the level of schema formulation would be a powerful teaching support tool for teachers.

## 2.3 Theoretical Background for Schema Priming Tests

Schema priming tests were originally used by Okamoto as test problems and were developed as a tool for assessing the degree of schema formulation.

The basic idea is an application of the concept of semantic priming from cognitive psychology. Semantic priming is the phenomenon that processing of a target stimulus can be accelerated by presenting a stimulus that has a deep semantic relationship with the target stimulus, called the prime stimulus, before the target stimulus is presented.

In a schema priming test, a question (describing what will be required) is first presented as a prime stimulus, then the whole problem text (the target stimulus) is presented, and then the student is asked to decide semantically, whether they can solve the problem or not.

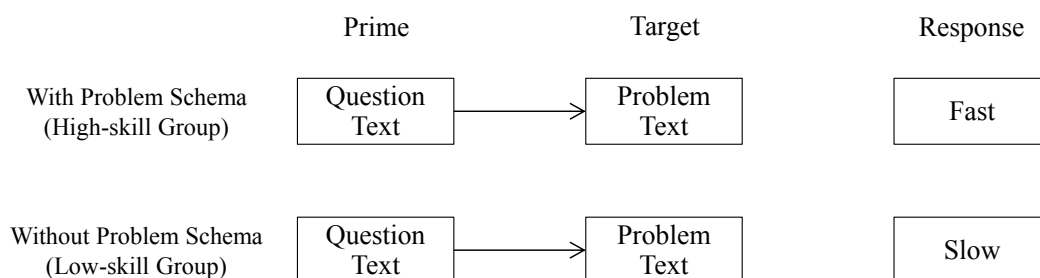


Figure 1. Relations between Schema Organization and Reaction Time

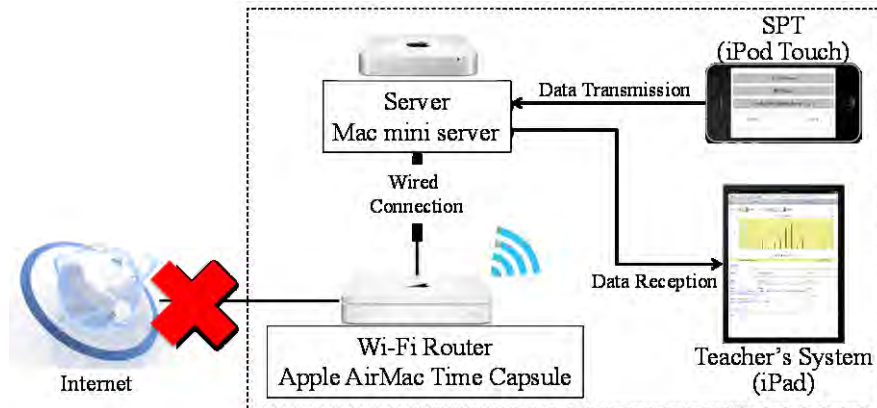


Figure 2. Structure of the System

If the student has an adequately formed schema, the response to the schema priming test will be faster, as shown in Fig. 1, so the degree of problem schema formulation can be determined by the shortening of test response times.

### 3. Development of Schema Priming Tests

#### 3.1 Overall System Structure

The overall structure of the system developed in this research is shown in Fig. 2. The system adopts a client-server model built using a private network through a Wi-Fi router without Internet connection.

A Mac Mini Server is used to host a MySQL server, iPod Touch terminals are used to implement SPT on the client side, and an iPad is used to allow the teacher to see the work of the students. Building the system in this way has the following advantages:

1. There are no space constraints, such as needing to operate in a PC room, and it is easy to introduce into classes.
2. Children can operate it intuitively.
3. Due to the above, children more easily use it voluntarily outside of class.
4. The network system can easily be brought into a classroom as a package, so it is easy to use.
5. The state of students' activity is sent immediately to the teacher's system through the private network, promoting an integrated approach to teaching and assessment.

#### 3.2 Basic Operation of the Schema Priming Test

The purpose of developing SPT was to measure students' level of understanding easily and accurately.

With SPT, a question (describing what will be requested) is first presented as the prime stimulus, then the whole word problem (the target stimulus) is presented, and then the student is asked to make the semantic decision, whether they can solve the problem or not.

According to Okamoto, students that have formed an adequate schema will be able to answer the above question quickly and correctly, and the student's degree of schema formulation can be

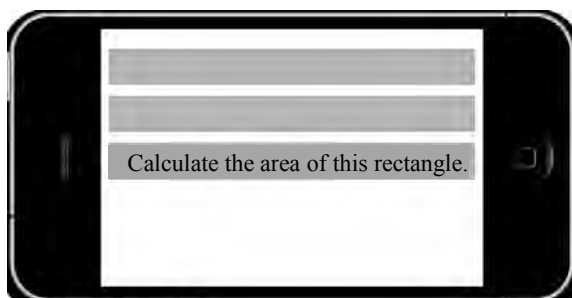


Figure 3. Prime

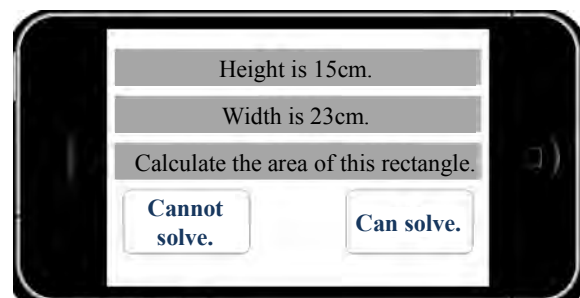


Figure 4. Target

determined from the response times and number of correct answers.

Schema knowledge is also used with conventional test problems, but what is assessed is the calculation written on the paper and the result, and the degree of schema formulation is not displayed. In contrast, the SPT developed in this research uses a question format that asks about the validity of a word problem (a format that does not necessarily require planning), so it is specialized to measure ability to understand the overall problem, in other words, schema formulation.

Specific operation of the system is described below. For each problem, the system presents (1) the question (e.g. “Calculate the area of this rectangle.” in Fig. 3), and (2) the conditions (e.g. “Height is 15cm,” “Width is 23cm.” in Fig. 4), with a delay, and then records the time from when the conditions were presented until the answer is given. Operation screens for the system developed in this research are shown in Fig. 3 and Fig. 4.

1. Question indicating what will be calculated is presented (Fig. 3: prime stimulus).  
(Still for 3 s)
2. Overall problem presented (Fig. 4: target stimulus)

#### 4. System Operation Overview

The sequence of experimental study is shown in Fig. 5.

- **Subjects:** 77 Grade 5 students from two classes in elementary school A (38 in one group, 39 in the other).
- **Time:** Oct. 31, 2013 to Nov. 29, 2013.
- **Teaching unit:** Finding areas of rectangles (sub-unit 1), triangles and parallelograms (sub-unit 2), and trapezoids and rhomboids (sub-unit 3).
- **SPT teaching materials:** Using the above sub-units, 16 word problems for each sub-unit were prepared as SPT materials.
- **SPT operation (during class):** As study of each sub-unit was completed in class, the system was used with the applicable word problems, also in class. Note that the second group of 39 students was not able to use the SPT after completing the topic on trapezoids and rhomboids. The instructors used the system additional times beyond what they did in class time, twice for the first group, and once for the second group. 42 numbered iPod Touch terminals were used. These were brought into the classroom by the teacher, and students used the same device, selecting the class and seat number on the screen before performing the SPT.
- **SPT operation (outside of class):** To give opportunities to use SPT outside of class time, the devices were placed in the class so students could use the system freely, without placing additional burden on the teachers. However, since the number of devices was limited, they were allocated by time periods to the different classes (e.g.: group 1 during the morning, group 2 in the afternoon). Mainly, they were used during two occasions given to group 1, and only a few members from group 2 used them outside of class.

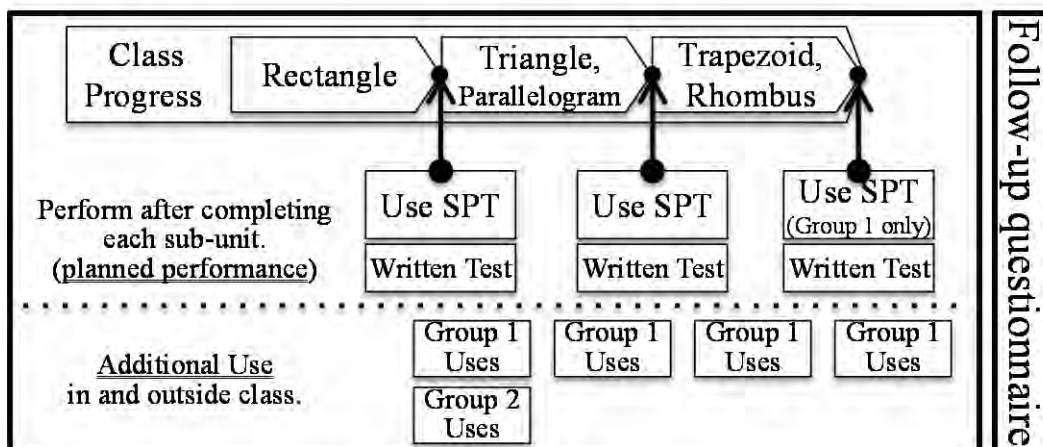


Figure 5. Flow of the Experimental Study

In addition to analyzing the level of effort, marks and response speeds for each student, the following confirmed the usefulness of operating the SPT for schema formulation.

- **Written tests:** After completing sub-units in class, the usual tests performed in school to test understanding and also written tests including extraneous problems (described below) were performed. Then, the relationships between those results and the level of effort and marks from the SPT were analyzed. These written tests consisted of four ordinary questions and four questions with extraneous information, totaling eight questions.
- **Teacher interviews:** Interviews were conducted with the two teachers after the experimental study, regarding the effects of the system on level of understanding, the students' involvement, and suggestions for improvement.
- **Student surveys:** A five-level survey of students was conducted after the practice, regarding system usability, ability to motivate, and effect on marks.

Extraneous problems are problems that include conditions that are not necessary to solve the problem. An example is shown in Fig. 6. Such problems require identifying the elements comprising the substance of the problem from among all of the information given and to determine what is enough information to solve it. As such, they are useful in determining the degree of schema formulation.

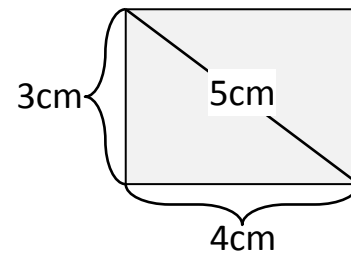


Figure 6. An Extraneous Problem

## 5. Schema Formulation and Problem Solving Performance Improvements through SPT

### 5.1 Schema Formulation Process through SPT

As described in Section 3, the students in group 2 were not given the opportunity to take the SPT for sub-unit 3, so we analyzed the data from the 38 students in group 1 regarding tendencies in response times.

The SPT response time trends for SPT done in the classroom after completing each of the three sub-units are shown in Fig. 7. A  $2 \times 3 \times 2$  mixed ANOVA was done on the response times, using the three-factors of frequent vs. infrequent use, sub-unit (rectangles vs. triangles and parallelograms vs. trapezoids and rhomboids), and SPT problem type (normal vs. unsolvable). The first factor is between subjects, while the other two factors are within to subjects.

In the results of the distribution analysis, frequency as a primary effect was significant ( $F_{(1,36)}=6.34, p<0.05$ ). The high-frequency group had shorter response times than the low-frequency group, and children that used the system more frequently clearly were able to determine more quickly whether they could solve the problems or not. The sub-unit also had a significant effect ( $F_{(2,72)}=77.07, p<.01$ ). With low-order testing using the Bonferroni method, times for triangles and parallelograms are shortest, then for trapezoids and rhomboids, and finally for rectangles. Further, a main effect of problem type ( $F_{(1,36)}=60.43, p<.01$ ) and an interaction of sub-unit  $\times$  problem type ( $F_{(2,72)}=55.11, p<.01$ ) were significant, so in low-order testing, for rectangles, response times for solvable problems were clearly longer than for unsolvable problems.

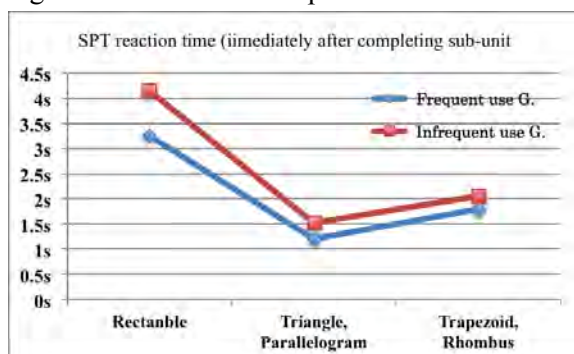


Figure 7. Mean Reaction Time of SPT in Area Unit

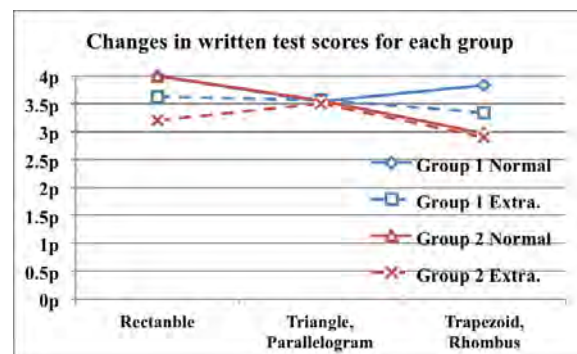


Figure 8. Mean Scores of Paper Test

Decision times were shorter for the high-frequency group, which could mean that subjects became more accustomed to using the system or that their schema formulation could have been more advanced. However, comparing the response times for sub-units, response times did not become shorter according to the number of tests, and the response times for sub-unit 2 were clearly the shortest overall to begin with. If response times became faster simply by repetitions and becoming familiar with operation of the system, then sub-unit 3 should have been the fastest, but sub-unit 2 produced the shortest decision times. This suggests that the decision time for schema priming tests is the time required to integrate the problem using schema knowledge. Considering this, the fact that the high-frequency group response times were shorter suggests that using the SPT more often promoted schema formulation.

### 5.2 Improvement of Problem Solving Performance through SPT

To study whether using the SPT promoted students' schema formulation requires comparison of a control group that does not use SPT, and an experimental group that does use SPT. As discussed earlier, group 2, which did not do SPT for sub-unit 3 on trapezoids and rhomboids, can be viewed as a control group. In other words, comparing group 1 with group 2 in sub-unit 3 can be considered a comparison of an experimental group with a control group. Accordingly, we did a comparative analysis of the written test results, including extraneous problems, from the two classes.

The written test scoring trends for each group are shown in Fig. 8. A  $2 \times 3 \times 2$  mixture distribution analysis was done using the three factors; class (group 1 vs. group 2), sub-unit (rectangles vs. triangles and parallelograms vs. trapezoids and rhomboids), and problem type (necessary problem vs. extraneous information problem).

As a result of the distribution analysis, the main effects that were significant were: class ( $F_{(1,74)}=4.80$ ,  $p<.05$ ), sub-unit ( $F_{(2,148)}=6.99$ ,  $p<.01$ ), class  $\times$  sub-unit interaction ( $F_{(2,148)}=3.63$ ,  $p<.05$ ), problem type ( $F_{(1,74)}=17.39$ ,  $p<.01$ ), sub-unit  $\times$  problem type interaction ( $F_{(2,148)}=5.70$ ,  $p<.01$ ), and class  $\times$  sub-unit  $\times$  problem-type interaction ( $F_{(2,148)}=3.23$ ,  $p<.05$ ).

To compare classes in more detail, we conducted lower-order testing using the Bonferroni method for class  $\times$  sub-unit interaction. There was no difference in scores between classes for "rectangle" and "triangle and parallelogram", but there was a significant difference in scores for both classes for "trapezoids and rhomboids" ( $F_{(1,74)}=7.80$ ,  $p<.01$ ), and group 1, which worked with SPT, clearly had higher scores.

For the two sub-units that showed no difference between classes, both classes had used SPT, but for the sub-unit that showed a difference between classes, trapezoids and rhomboids, only group 1 used the SPT. This suggests that using the SPT promoted schema formulation, and as a result, this had the effect of raising problem solving scores.

The two classes have different teachers, so there are potential differences in their teaching technique to result in differences between the classes, but if differences in their technique alone were a cause, there should have been differences in the first and second written tests as well, but this was not observed. In other words, for both practices where SPT was used, the teachers were also teaching effectively. Based on the above consideration, we can say that using SPT continually while teaching the units effectively promotes schema formulation and problem solving itself.

### 5.3 Effects of SPT on Learning Processes of Children Weak in Arithmetic

Next, we examined in detail, the sort of students on which SPT has the greatest effect. We compared changes in scores for students weak in arithmetic, who regularly received attention from teachers (designated "marked students" or MS), with those of other students ("unmarked students", US). The average frequency of use for group 1, consisting of 9 MS and 29 US, was 9.8 times and 11.5 times respectively. For group 2 with 4 MS and 35 US, it was 4 times and 3.6 times respectively.

The scoring trends on paper tests for MS and US in each class are shown in Fig. 9 and Fig. 10. Comparing the test scores from MS and US in group 1 for three paper tests, showed no significant difference. In other words, when using SPT continuously while teaching, children weak in arithmetic were also able to understand the study materials adequately.

In contrast, a significant difference was observed between MS and US in group 2 ( $t_{(25)}=-5.3$ ,  $p<.01$ ). The graph shows clearly that the difference increased as learning progressed. This result shows



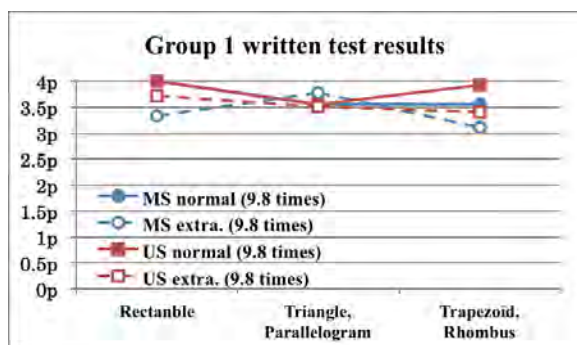


Figure 9. Mean Scores of Paper Test (US and MS in the Class1)

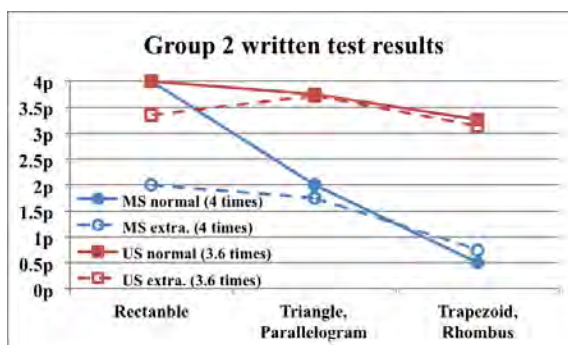


Figure 10. Mean Scores of Paper Test (US and MS in the Class2)

that in the class using SPT less frequently, children weak in arithmetic were not understanding the learning materials adequately.

The above analysis shows that using SPT is effective for schema formulation, but such results are not likely to be obtained simply by embedding the SPT. A major factor besides this could be that embedding SPT and conducting small tests for each sub-unit increases the opportunities for the teacher to understand the students' progress.

This suggests that schema formulation and improvements of teaching activities due to SPT operation result in the following synergies.

1. SPT is helpful for the teacher to know students' level of understanding, and this promotes teaching.
2. Engaging in SPT promotes schema formulation in the students. The effect on schema formulation was large for MS in particular, from the analysis of MS and US.

#### 5.4 Results of Teacher and Student Questionnaires

We now mention the results of interviews and surveys given to teachers and students. The results of teacher interviews are summarized in Table 1.

Regarding effectiveness in motivating study, teachers felt that, judging from the students' behavior, students found the system easier to use and were less opposed to using it than to studying with text books or problem sets, and this increased motivation. The student survey results also suggested this.

A survey was conducted with items as shown in Table 2 and answers using a five-rank score (strongly agree, somewhat agree, I don't know, somewhat disagree, strongly disagree). The results are shown in Fig. 11. The overall results were quite positive.

From questions 1, 2, and 5, students used the system without difficulty, and enjoyed working with it even though the type of question in SPT was unusual: deciding whether problems were valid or not.

Questions 3 and 4 suggest that students themselves found that the system was helpful for

Table 1. Interviewing Results from 2 Teachers

|   |  |
|---|--|
| Usefulness for Motivating Study                             |  |
|   | • Students happily said, "I want to try, I want to try!" and were very willing. The number of students consulting with the teacher and other students increased.   |
|   | • Frequency of system use depends on personality. Low level students showed perseverance, saying things like "I just want to get one more right!" Low level students really seemed to make progress. As not seen before, students showed overflowing confidence at the                               |
| Course practice reflecting students' level of understanding |  |
|   | • Written tests including problems with extraneous information were a good stimulus. For example, asking "Where is the height in this figure?" has been incorporated into the class.   |
| Introduction into classes, usage issues                     |  |
|   | • Opportunities to use the teacher system in order to identify students weak in arithmetic and give them attention were few. However, it appeared to be useful for making arrangements in class based on overall trends (e.g. whether to hold a review class, or to provide personalized attention). |
|   | • We only allowed use under supervision by teachers, so management was difficult, and this may have been inconvenient for the children.  |
|   | • We felt it may be more convenient to have one terminal per student.  |
|   | • The system would have been used more if students were required to use it more.   |

learning, and they see this effect positively as well.

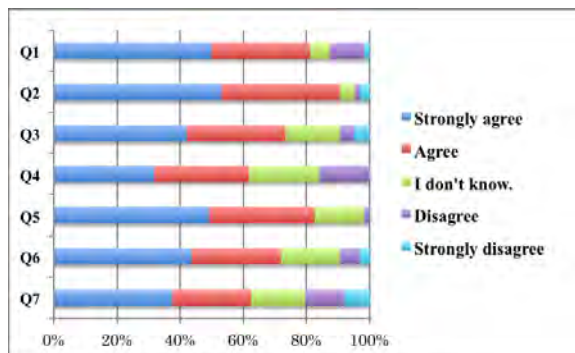
Question 6 indicated that many students would like to use SPT again in the future, suggesting that SPT materials could be expanded to include other units that students would accept, making it a more useful tool.

For question 7, regarding motivation to study arithmetic, 56% of students responded that studying arithmetic was more fun (34% for strongly agree, 22% for somewhat agree), suggesting that using the system contributes to increasing motivation to study arithmetic.

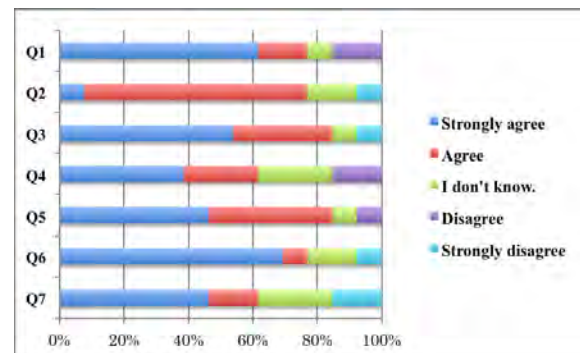
The survey results from only MS are shown in Fig. 12. It also shows the same, mainly positive trend for MS. The analysis in 5.3 suggested that the system is useful for schema formulation in students thought to be weak in arithmetic, but for question 7 in particular, 62% of MS responded for themselves that studying arithmetic was more fun (46.1% strongly agree, 15.4% somewhat agree), so this is also a very significant result.

**Table 2. Questionnaire Items for Students**

|    |   |
|----|---|
| 1. | Was the schema game fun?  |
| 2. | Was the schema game simple?   |
| 3. | Do you think you learned arithmetic in the schema game?                                 |
| 4. | Do you think you learned to solve area problems more easily by playing the schema game? |
| 5. | Was it easy to use the schema game?   |
| 6. | Do you want to play the schema game again?  |
| 7. | Did it make studying arithmetic more fun?   |



**Figure 11. Questionnaire Results (US and MS)**



**Figure 12. Questionnaire Results (MS only)**

## 6. Concluding Remarks

This paper describes a system for assessing learners' schema formulation easily, and reports on long-term use of this system in an elementary school. The results, from the perspective of the usefulness of the developed system, are: (1) the group using the system more frequently may have had better schema formulation than the group using it less frequently, (2) differences in written test results between classes due to having done or not done the SPT were confirmed, and (3) differences in number of times used clearly produced large differences in scoring trends for MS.

We also confirmed that the system developed in this research can be used in a way that integrates with teaching when introduced into the classroom. The system also operated with stability, not going down once over an experimental study of one month. By implementing a tool that reduces difficulties faced by many students on a mobile terminal in this way, even elementary students can enjoy engaging in learning. Since it is easy to embed into classrooms, which have strong time constraints, and has been shown to be stable through real operation, it also demonstrates a possible operational model, which is another research result.

One issue with introducing and using the system in classrooms was that we could not provide enough number of terminals. We tried to compensate for this, but increasing the number of terminals should be considered to encourage more-active use of the system. On the other hand, the system was implemented on iPod Touch terminals, which are less expensive than PCs or other types of tablet terminal, so cost related difficulties are relatively small-scale with this implementation.

In elementary schools, which are classroom-based, the class teacher is aware of students requiring particular care, so in this case the teacher's system was hardly used at all. Thus, looking only at these results suggests there is not a strong need for it in the primary classroom. On the other hand, we

received a comment that it may be more useful in middle and high-school, which are course-based, so we would like to evaluate usefulness of the system for teachers in secondary education.

Future issues include (1) building a process model of students' comprehension (e.g.: knowledge of a unit is not organized sufficiently because other applicable units are inadequate) through continual use of the system, and (2) developing functionality to give feedback to students based on this information.

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# Visualization for Analyzing Ubiquitous Learning Logs

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**Abstract:** This paper describes a system that can be used to visualize some ubiquitous learning logs to grasp and discover several learning flow and timing. Visualization of the system is based on vast amount of learning data in ubiquitous learning environment. Ubiquitous Learning Log (ULL) is defined as a digital record of what learners have learned in the daily life using ubiquitous technologies. It allows learners to log their learning experiences with photos, audios, videos, location, RFID tag and sensor data, and to share and to reuse ULL with others. This paper will reveal about the relationship between the ubiquitous learning logs and learners by using network graph. Also, this paper will explicate the system through which learners can grasp their learning time, histories, knowledge and location.

**Keywords:** ubiquitous learning, network graph, time-map, information visualization

## 1. Introduction

Recently, researchers in the educational engineering area have been studying focusing on ubiquitous themes. For example, CSUL (Computer Supported Ubiquitous Learning) or context aware ubiquitous learning (u-Learning) have been constructed using computing technologies such as mobile devices, QR-code, RFID tag and wireless sensor networks (Hwang et al., 2008; Ogata & Yano, 2004). These learnings take place in a variety of learning space such as classroom, home and museum. Also, the cutting-edge technologies can provide the right information using the contextual data like location, surrounding objects and temperature.

Therefore, many researchers have been focusing on effective learning with ubiquitous technologies. We have developed ubiquitous learning system called SCROLL (System for Capturing and Reminding of Learning Log) (Ogata et al., 2011). The system will support international students to learn their target languages. Traditionally, international students take memos when they have learned something in their daily lives. However, if the notes have not been taken in detail, they can neither actively recall what they have learned, nor the location where they learned them. Therefore, we have proposed SCROLL which enables learners to recall their past learning experiences by saving them to the system with location, photo, or video as digital records.

Also, these learning dataset include spatiotemporal data. Spatiotemporal data usually contain the states of an object, an event or a position in space over a period of time. These datasets might be collected at different locations, various time points in different formats. It poses many challenges in representing, processing, analysis and mining of dataset due to complex structure of spatiotemporal objects and the relationships among them in both spatial and temporal dimensions (K.Venkateswara Rao et al., 2011, 2012).

Similarly, it poses many issues about relationship between the learners and the ubiquitous learning logs due to complex structure of the ubiquitous learning logs in SCROLL. In addition, it is important for learners to recognize what and how they have learned by analyzing and visualizing the past ULLs, so that they can improve what and how to learn in future (Ogata et al., 2011). To tackle these issues, it is necessary to reveal relationships between the learners and the ubiquitous learning logs.

Therefore, this paper proposes a method to visualize relationships between the learners and the ubiquitous learning logs using Time-map and network graph. The objective of this study will reveal how the learners learned language in their daily lives. Therefore, this paper will visualize learning data collected from SCROLL, and as next step will analyze them.

## 2. Related Works

### 2.1 Learning Analytics and Knowledge

In recent years, Learning Analytics and Knowledge (LAK) has been drawing an attention from researchers of such fields as educational engineering, information science and network science. To date, Course Management System (CMS) and Learning Management System (LMS) enabled us to record learners' access logs onto server. The Learning Analytics (LA) aims for practical use based on learning mechanisms revealed by visualizing, mining and analyzing vast amount of learning data (Ferguson 2012). This paper focuses on the Social Learning Analytics (SLA), a subset of the LAK (Buckingham 2012). The SLA puts forward presenting appropriate information to learners at the appropriate timing through the Dashboard in real time. As a new challenge, this paper aims to reveal about relationships between learners and learning logs on spatiotemporal fields.

Therefore, this paper is expected to contribute to educational improvement and strategies below.

- This study facilitates the analysis of learners by visualizing all data on spatiotemporal.
- This study enables future prediction about learners and learning environment from visualized learning logs.

### 2.2 Time-map

Time-map is a library of javascript, which collaborated with Google map and SIMILE (Semantic Interoperability of Metadata and Information in unLike Environments) TimeLine (SIMILE project). SIMILE focuses on developing robust, open source tools that empower users to access, manage, visualize and reuse digital assets. The time-map function means that the user can scroll the timeline and then the Google map will display the learning logs recorded during learners' selected period. It is designed to help learners to reflect what they have learned. For example, if a learner clicks his learning logs on timeline, Google map will display their positions as shown in Figure 1. After visualizing log information, Time-map will facilitate learners to reflect on their logs with spatio and temporal information. They are able to grasp their learning context and time zone. Also, it is a possibility that the geographic information is a clue of recalling what they have learned.

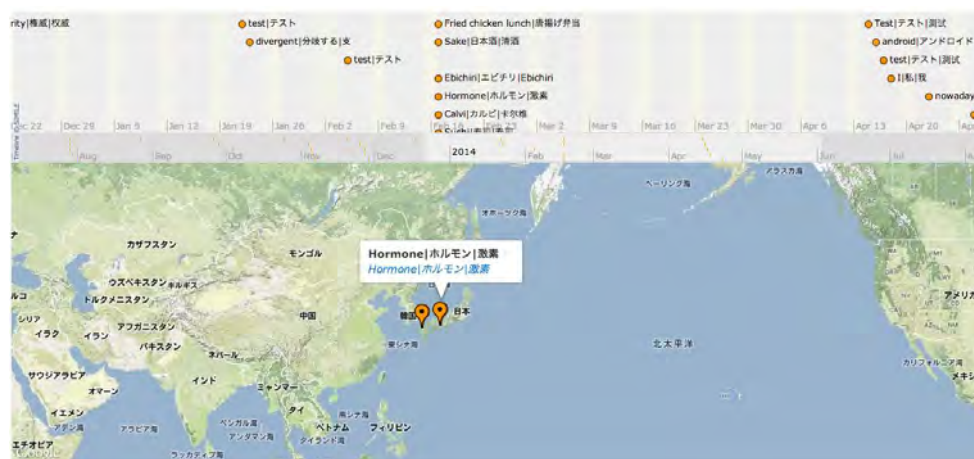


Figure 1. Time-map

## 3. Design of the system

### 3.1 SCROLL

With the evolution of the mobile device, people prefer to record learning contents using mobile devices instead of taking memos on paper. Most of the language learners have their own learning notes. In this paper, learning log is defined as a recorded form of knowledge or learning experiences acquired in our daily lives.

One of the objectives of SCROLL is to support international students in Japan to learn Japanese language from what they have learned in formal and informal setting. It adopts an approach of sharing user created contents among users and is constructed based on a LORE (Log-Organize-Recall-Evaluate) model which is shown in Figure 2 (Ogata et al., 2011).

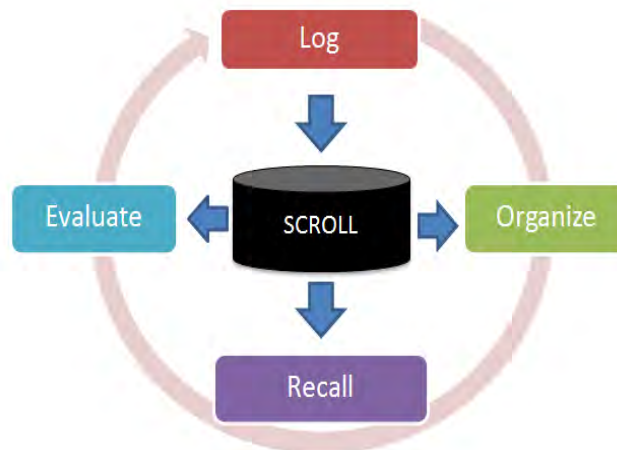


Figure 2. LORE model in SCROLL

SCROLL is a client-server application, which runs on different platforms including Android mobile phones, PC and general mobile phones shown in Figure 3. The server side runs on Ubuntu 12.04.2 and it is programming using Java, Spring MVC and Mybatis. The developed software for Google phone is a native java application based on Android SDK (Li et al., 2012).

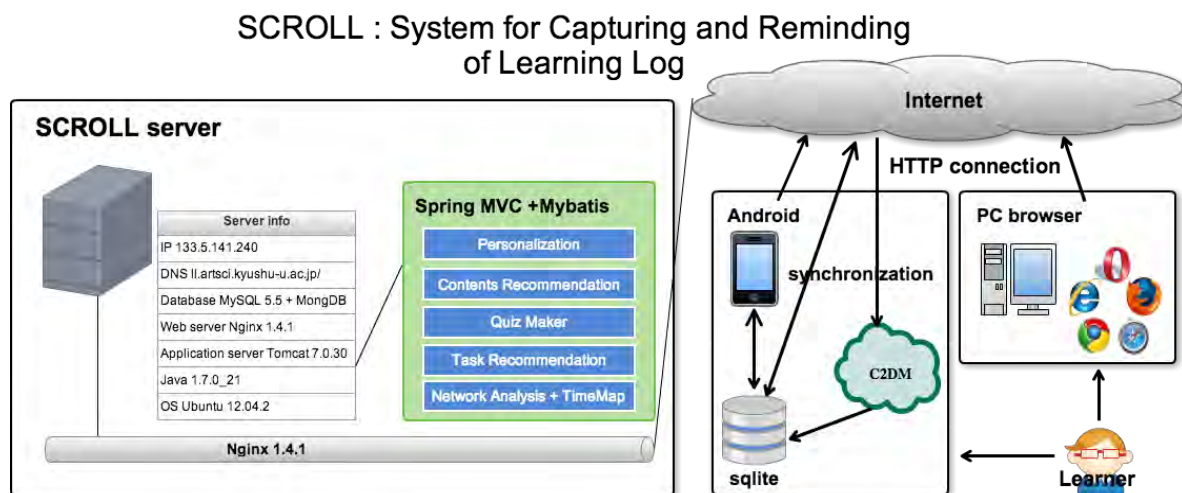


Figure 3. The architecture of SCROLL

### 3.2 Collecting a ubiquitous learning log on SCROLL

The learners can record some learning language such as English, Japanese and Chinese with a photo using android device and SCROLL as shown in Figure 4. Figure 5 shows a learning log on android device.

The learning log includes meta-data such as author, language, created time, location (latitude and longitude) and tag. The learners will record or review a learning log using these functions on android device. Such iterative learning is supported by our quiz function on SCROLL. There are three types of quizzes generated automatically by the system, which are yes/no quiz, text multiple-choice quiz and

image multiple-choice quiz. Figure 6 shows an image multiple-choice quiz interface generated automatically based on the meta-data of ULLs.



Figure 4. Learning note



Figure 5. A learning log

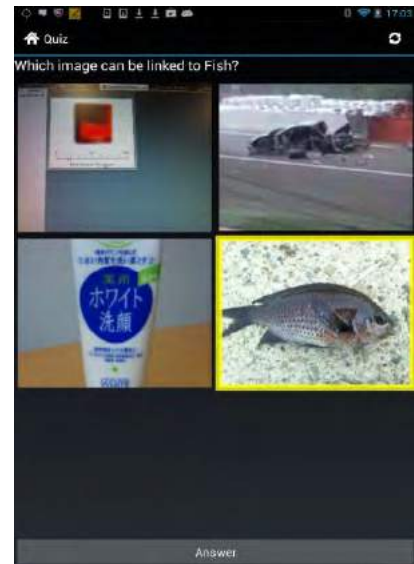


Figure 6. Quiz

### 3.3 Structure based on network graph in SCROLL

To reveal several relationships between the learners and knowledge or knowledge and location, we have uniquely defined them as three-layers structures as shown in Figure 7.

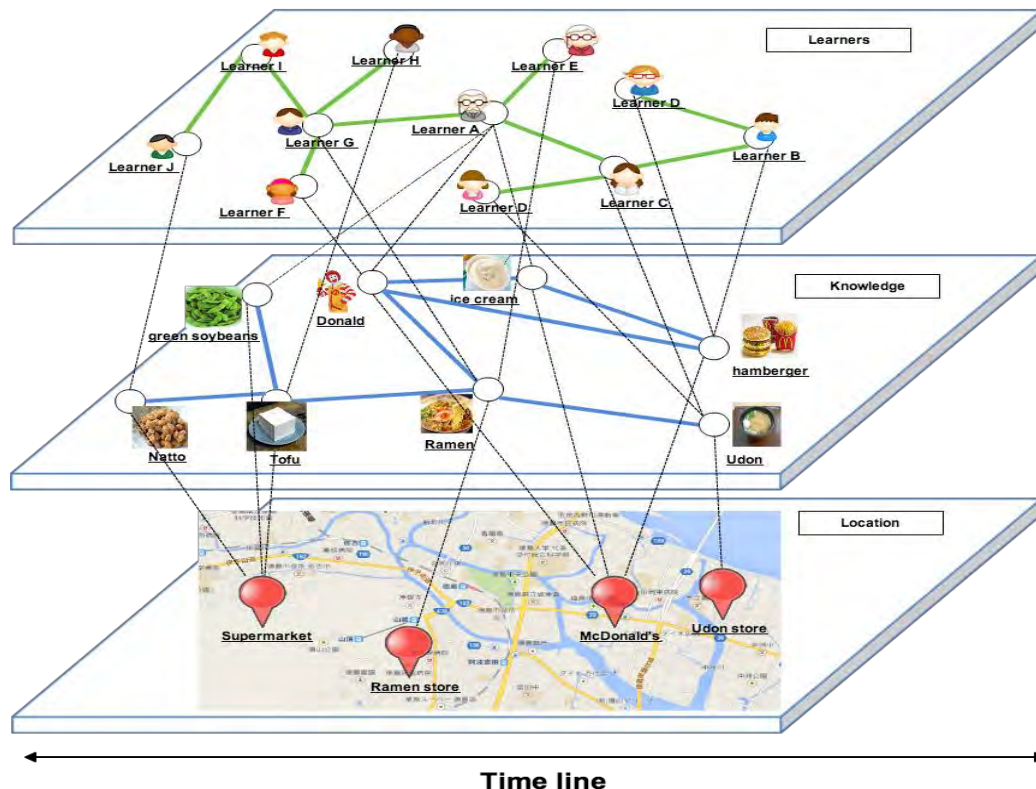


Figure 7. Three-layer structure in SCROLL

The upper layer contains each author in order to confirm position of own or other learners. The intermediate layer contains the knowledge that learners learned. Also, some fields of learning tasks can be included in this layer. For example, some task-based learning in ubiquitous learning environment can be carried out using knowledge and event (Mouri et al., 2013; Sharon 2013). The

scalability of the layers can be enhanced and the field of visualization can be widened by linking one's own learning logs to the knowledge learned by doing tasks.

The lowest layer contains data such as location and time. In order to realize spatiotemporal visualization of our learning logs, nodes on the intermediate layer are linked to the nodes on the lowest layer.

Analysis by categorizing three-layers has following advantages:

- Places with a large number of links to the related knowledge are the places where they can learn a lot of knowledge. For example, if a certain supermarket or convenience are related with a lot of knowledge such as natto, green soy beans, tofu, miso soup, and cup noodle, by analyzing relationships between the knowledge and the location the System can provide learners with a valuable learning information.
- Knowledge which is related to many places is the knowledge which we can learn in various places. For example, if a learner experience tea ceremony of a traditional Japanese culture at the university in Japan, a set of tea ceremony related knowledge (eg. tea, seize: to sit in the correct manner on a Japanese tatami mat) can be learned in other various places. The tea can be learned by purchasing at the supermarket and the seiza can be learned at the martial art gym.

## 4. Implementation

This section describes ways of the implementation of the system for visualizing the three-layer structure using network graph and Time-map.

### 4.1 System for visualizing network graph in SCROLL

#### 4.1.1 How to create node or connect edge on three-layers

Firstly, system for visualizing network graph will create authors' node on the upper layer. To date, the number of learners in SCROLL is approximately three thousand people.

Secondly, the system will create knowledge node on the intermediate layer. Then, the system will connect authors' node related to knowledge node that learners have learned. For example, if learner A learned a learning log like "natto (a traditional Japanese food made from fermented soybeans)", "tofu (bean curd)" and "sushi", the system will connect "learner A" of node on the upper layer to "natto", "tofu" and "sushi" on the intermediate layer.

Thirdly, the system will create location node on the lowest layer. Then, the system connect knowledge node on the intermediate layer to node of the location on the lowest layer. For example, if the learner A have learned knowledge of "natto" at the supermarket in Japan, the system will connect "natto" on the intermediate layer to the latitude and longitude of "supermarket" on the lowest layer.

#### 4.1.2 Color of visualized nodes

The learners might get confused when they recognize past learning logs because there might be too many of visualized nodes. Therefore, it is definitely necessary to establish some criteria for distinction of each node. To effectively distinguish kind of each node, we defined as Table 1 below using node color.

Table 1: Color to distinguish the kinds of nodes

| Node                    | Layer              | Node color |
|-------------------------|--------------------|------------|
| Learner's own name      | Upper layer        | Pink       |
| Names of other learners | Upper layer        | Blue       |
| Knowledge of learners   | Intermediate layer | Yellow     |
| Location of learners    | Lowest layer       | Red        |





It is a very fast algorithm with a good quality on large graphs. It combines a force-directed model with a multilevel algorithm to reduce the complexity. The repulsive forces on one node from a cluster of distant nodes are approximated by a Barnes-Hut calculation (Barnes and P. Hut., 1986), which treats them as one super-node.

The interface of Time-map on web browser is shown as Figure 9, 10. Figure 9 shows the sample of learners' timeline. It represents the shift of learning history in accordance with lapse of time. The learners might forget the learning logs when and where they have learned before. Therefore, the system can remind the learners of them by combining timeline with map as shown in Figure 10.

We have developed the system for visualizing who is learning what, and when, where and how by combining these interfaces. The learners will find it useful with the following respective reasons.

- The learners can be aware of relationship between their own knowledge and other knowledge. The new knowledge can be found easily by viewing the network graphs.
- The system will remind them of their learning logs recorded during the specified period of time by showing them on the timeline (default: two month before and after the setting time). Besides, the system will lead them to be aware of knowledge recorded right before or after the knowledge of their interest which was recorded by other learners. Therefore, it will give them a clue on what to learn next. For example, if learner A learned a natto at the supermarket, there is a possibility that learner B had already learned it. When the learner B learned a natto, he/she might have learned other natto related words such as tofu and green soybeans. Natto related words which learner B had learned would be recommendable learning contents for learner A. That way learners can learn their target language more effectively using visualized information.

## 5. Evaluation

### 5.1 Method

Eight international students studying at the university of Tokushima and Kyushu participated in the evaluation experiment. Participated students were from China aged between 21 and 34. Their length of stay is from 1 month to 5 years. The participant information is shown in Table 2.

Before the evaluation started, we explained about how to use the system for visualizing learning logs to them. They've never used SCROLL. Therefore, they used SCROLL for one day before using system for visualizing learning logs. They at least recorded five learning logs one day, and then they recorded learning logs using our proposed system for one week. After the evaluation, the participated students were asked to fill in a five-points-scale questionnaire, and they have evaluated the performance, usefulness and learning effectiveness on this system.

Table 2: Detail of students

|           | Age | Gender | Length of stay |
|-----------|-----|--------|----------------|
| Student A | 24  | Male   | 2 years        |
| Student B | 26  | Male   | 2 years        |
| Student C | 21  | Male   | 2 years        |
| Student D | 34  | Male   | 5 years        |
| Student E | 23  | Male   | 1 months       |
| Student F | 23  | Male   | 1 months       |
| Student G | 23  | Female | 1 years        |
| Student H | 25  | Female | 7 months       |

### 5.2 Result and discussion

The questionnaire results are presented in Table 3.

Q1-Q5 are the questions to ask its usability and usefulness of our network graph. Q6-Q9 are the questions to ask the importance and performance of the system combining the Time-map and the network graph.

From the results of Q1 and Q2, it reveals that the learners were able to efficiently grasp their own or others' knowledge using the network graph for visualizing learning log.

Q3 result indicates that the learners were able to grasp similar knowledge between their own knowledge and other knowledge. Q4 result indicates that they were able to grasp knowledge using different color. When they found other learners or knowledge, the most of students recognized them from nodes' color. Therefore, it was effective to distinguish other learners and learning log by color. Q5 result indicates that network graph of the system was useful.

Q6 and Q7 results indicate that the learners were able to discover other interesting learners or knowledge that they didn't know. When the learners discovered new knowledge or other learners, what they had discovered is shown in table 4. Table 4 shows the multiple-choice questionnaire. Most of them discovered the knowledge from the process number 2. This is because the learners were able to discover the knowledge in this system thanks to visualizing all learning logs.

Q8 resulted in the lowest average score in questionnaire. This seems to be because that effectiveness comes not only from grasping their own learning trend. Therefore, the system needs to recommend appropriate learning trend from other learners' learning trend in future. For example, if learner A learned the "natto" in the supermarket, and learner B already might have learned the "natto" at different or same location. After learner B learned "natto", he/she might have learned continuously some related words such as green-soybeans and tofu. Similarly, after the learner C learned the "natto", he/she might have learned some related word such as rice and soy sauce. Therefore, it is useful in future that the learners can be aware of next learning trend by other learners' trend being recommended.

Q9 result indicates that the learners were able to recall the knowledge using the system combining the network graph and Time-map.

Table 5 lists the open-ended comments of the participants about the problem they found using the system and their suggestions for the improvement of the system.

It was suggested that improving UI (User Interface) design and function would be helpful to recognize their knowledge. Taking these issues into account, our future works will be described in the next section.

Table 3: Result of the five-point-scale questionnaire

| Question   | Mean | SD   |
|--|------|------|
| 1. Were you able to grasp your own knowledge using network graph?  | 4.50 | 0.50 |
| 2. Was this system useful to find new knowledge?   | 4.62 | 0.48 |
| 3. Were you able to recognize relationship between yourselves and other learners?  | 4.12 | 0.59 |
| 4. Were you able to grasp whole knowledge and your own knowledge by the node color?  | 4.25 | 0.66 |
| 5. Was network graph of the system useful?   | 3.87 | 0.92 |
| 6. Were you able to discover knowledge of interest on Time-map and other learners' knowledge?  | 4.62 | 0.48 |
| 7. Were you able to distinguish one learner from another and to discover interesting learner?  | 3.37 | 1.40 |
| 8. Was it important to grasp your own learning trend on Time-map?  | 2.87 | 1.45 |
| 9. Were you able to recall the knowledge when and where you have learned by using system for visualizing learning log with Time-map? | 4.5  | 0.70 |
| 10. Please rate on a five point scale how much it helped you to grow your Japanese/English vocabulary.                               | 4.37 | 0.48 |
| 11. Please rate on a five point scale how much it helped you to improve your Japanese (English) ability.                             | 4.37 | 0.48 |

Table 4: The process of discovery of knowledge and other learners

| Process  | Total (8/8) |
|--|-------------|
| 1. The learners randomly chose one from all of nodes.  | 3/8         |
| 2. The learners discovered interesting knowledge by chance.  | 6/8         |
| 3. The learners discovered it because their own knowledge and other learners' knowledge were same knowledge. | 3/8         |
| 4. The learners discovered some knowledge from other learners (blue node).                                   | 2/8         |
| 5. Other (Free description)  | 0/8         |

Table 5: User comments

| Users' suggestions (Open-end questionnaire)  |
|--|
| 1. It is very easy to use. I was able to find new knowledge.   |
| 2. I think that you should improve the UI design on network graph. It was the complex screen.                |
| 3. There were too many learners on interface, so it would be confusing. I think that you need to improve it. |
| 4. The interface is difficult to understand.   |

## 6. Conclusion and Future work

This paper described the system for visualizing relationships between the learners and the learning logs. International students can add their knowledge as the learning log in SCROLL, and then SCROLL can provide learning contents to recall what they learned based on their learning contexts. By using the system that we proposed, the international students can discover the knowledge related to others learners and the interesting knowledge. The initial evaluation was conducted after implementing the function to visualize the learning logs and the learners. Five-point-scale questionnaire conducted after the evaluation shows that the system supported the international students by visualizing the learning logs. As mentioned in section 5.2 results and discussion, it needs improvement of its UI design and functions. Therefore, we will improve the system by excepting useless knowledge using filtering function.

In the future, we will develop a new function so that the system can analyze various situations focusing learning analytics such as network analysis (Freeman 1978; Shane 2014), decision tree (Bitner 2000) and association rule (Florian 2005). In addition, we will consider quantitative measures and user self-reported data when evaluating the function.

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# A Context-aware Dynamical Learning Environment for Multiple Objectives

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**Abstract:** In a real ubiquitous learning environment, different learners may have different learning objectives; a learner also has different objectives in different periods. Ubiquitous learning environment should be able to support different learning objectives. However, most of ubiquitous learning environments are designed for specific learning objectives, in which all learners only get learning resources related to the specific learning objectives with fixed contents. This research proposes a ubiquitous learning environment to support different learners' learning with different learning objectives at same time. This environment is called CDLEMO (Context-aware Dynamic Learning Environment for Multiple Objectives). It can provide available and suitable learning resources, and the contents of a resource can be adjusted dynamically according to learning objective. The results of a pilot experiment conducted in the botanical garden in Beijing Normal University show that CDLEMO can make learning become more convenient and fun, enhance learning motivation, stimulate learning interest, and it wins the learners' acceptance and approval.

**Keywords:** Ubiquitous Learning Environment, Context-aware, Learning Objective, Learning Resource, Learning Content

## 1. Introduction

Ubiquitous Learning has become an important direction of the next generation of e-Learning (Ley, 2007; Chu, Hwang, Huang and Wu, 2008; Hwang, Yang, Tsai and Yang, 2009; Hwang, Wu, Tseng and Huang, 2011). A growing number of researchers do researches in this field, especially in ubiquitous learning environment (Hwang, Tsai, and Yang, 2008; Hwang, Yang, Chin and Stephen, 2009; Feeney, Ahgre, and Westerlund, 2001; Kindberg and Fox, 2002). How to realize learners timely access to the needed learning resources anytime and anywhere is one of the most important research issues in the era of ubiquitous learning (El-Bishouty, Ogata and Yano, 2007; Shih, Chu, Hwang and Kinshuk, 2011). In a real environment, different learners may have different learning objectives, and different learning objectives need different learning resources and contents. But now most ubiquitous learning environments are designed without considering learning objective, so the learning resources in those environments are static and contents of learning resources cannot be adjusted according to learning objective.

Aiming at the problem that current ubiquitous learning environments are difficult to support a variety of learning objectives at the same time, this study proposes a ubiquitous learning environment, named context-aware dynamic learning environment for multiple objectives (CDLEMO). CDLEMO consists of learning resource space, context-awareness system and learning resource aggregation system. CDLEMO can provide learner learning resources with suitable content according to his learning objective and location. In addition, this study does a pilot study, and then interviews the participants to understand their recognition and acceptance of CDLEMO.

## 2. Relevant works

At present, there are more and more researches on ubiquitous learning environment. From the two perspectives of learning resource and learning objective, we divide current ubiquitous learning environments into ubiquitous learning environment with static resources for single objective, ubiquitous learning environment with personalized static resources for single objective, and ubiquitous learning environment with personalized static resources for multiple objectives.

In the ubiquitous learning environment with static resources for single objective, all learners will obtain the same learning resources, the contents of which all are static. For example, a ubiquitous learning environment for supporting language learning named TANGO (Ogata and Yano, 2004; Ogata and Yano, 2005), in which learners can obtain the language express about the object near him with the help of RFID and mobile device; Another is a ubiquitous learning environment for language listening and speaking named HELLO (Liu, 2009), in which learners can access to the English learning resources anytime and anywhere via QR-code and PDA. Both TANGO and HELLO aim at specific language learning objectives, all the learners will get the same learning resources with static contents.

Ubiquitous learning environment with personalized static resources for single objective also aims at specific learning objective, but it can provide learners personalized learning resources with static contents. For example, a ubiquitous learning environment for conducting complex experimental procedures (Hwang, Yang, Tsai, and Yang, 2009), we called CUECE, which can provide suitable operation guidance information to learners via perceiving learners' situation, such as learner's location, and the surrounding situation, such as environmental temperature; another is a ubiquitous learning environment for helping and guiding learning named CAULS (Chen and Huang, 2012), which can use test to understand learner's current learning situation, then choose the appropriate learning strategies and provide corresponding learning resources for learner. In both CUECE and CAULS, in different situations (such as learners' situation, environmental situation, etc.) learners will obtain different learning resources in their learning processes, but learners' final learning objectives are the same. That is, the learning objective supported by learning environment is the same. And although different learners get different learning resources, the contents of all learning resources are also still fixed.

Ubiquitous learning environment with personalized static resources for multiple learning objectives can support different learning objectives and provide personalized learning resources with fixed contents. For example, a ubiquitous learning environment named PERKAM (El-Bishouty, Ogata and Yano, 2006; El-Bishouty, Ogata and Yan, 2007) can recommend suitable and personalized learning resources and helpers around learner according to learner's location, surrounding and his learning objective. Although PERKAM can provide personalized learning resources for learners with different learning objectives, but the contents of the learning resources are still static. That means the contents of a learning resource are fixed, cannot be adjusted dynamically according to different learning objectives, so it is still unable to fully meet the needs of learners with different learning objectives.

### 3. Context-aware Dynamical Learning Environment for Multiple Learning Objectives

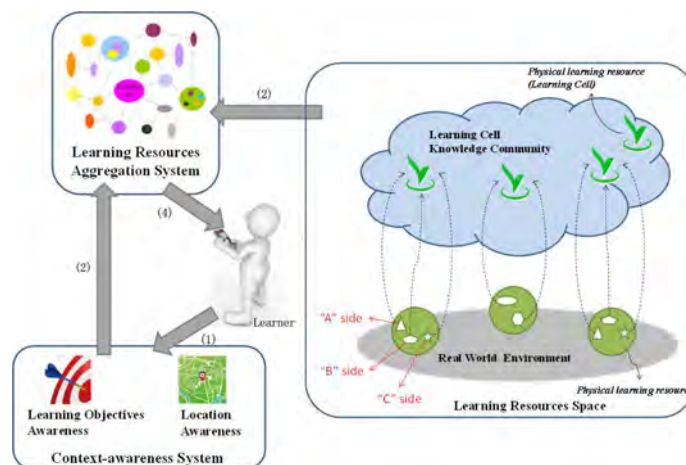


Figure 1. The Context-aware Dynamical Learning Environment for Multiple Objectives

CDLEMO proposed in this study is composed by learning resources space, context-aware system and learning resources aggregation system. CDLEMO is developed by JAVA, using GPS technology to get location information, achieving learning objectives based on location information, using AJAX technology to present learning objectives set and contents, using MySQL5.0 databases to store data.

In Figure 1, learner uses a mobile phone with GPS as his learning device. When the context-aware system obtains learner's location and learning objective, it will deliver the information to the learning resources aggregation system. Then the learning resources aggregation system will find the suitable physical learning resources around learner and the corresponding digital learning resources. A digital learning resource may contain several contents about different sides of a physical learning resource (such as "A" side, "B" side, "C" side in Figure 1), and the contents will be adjusted dynamically and presented to learner according to his learning objective.

### *3.1 Learning Resource Space*

In Figure 1, the learning resource space contains real world environment and digital learning resource space. There are kinds of physical learning resources in the real world environment, such as a tree, a flower. And Learning Cell Knowledge Community (<http://lcell.bnu.edu.cn>) is used as the digital learning resource space in CDLEMO, which can supply various digital learning resources, called Learning Cell(Yu, Yang and Cheng, 2009), short for LC. LC is a novel learning resource model, which can be presented on different learning devices in different formats according to the parameters of learning device. And the contents of LC also can be organized dynamically according to learner's current situation. According to learner's learning objective, when a learner selects a LC for learning, the learning contents in the LC will be adjusted adaptively based on learner's learning objective.

### *3.2 Context-awareness System*

The context-awareness system mainly obtains learner's location information and learning objective. It uses GPS technology to gain learner's location information. The importance of location information is to help the system gain available resources around learner, and get the learning objectives set finally. Once learner connect his phone to wireless networks and open GPS, the system will obtain his location information via GPS. Based on the location information, the system can get all surrounding available physical learning resources as well as the associated digital learning contents. Because of the digital learning contents have their own tags of different learning objectives, the system can aggregate all these learning objectives supported by the learning contents, then presents the learning objectives set to learner, and learner can choose his own learning objective.

### *3.3 Learning Resource Aggregation System*

According to the location information and learner's learning objective, the system will aggregate the surrounding physical learning resources and corresponding LCs, and then present them to learner. For example, there are some dicotyledons and monocotyledons in a garden, and a learner's learning objective is to learn the structure features of monocotyledons, then the system will automatically aggregate and present the pictures of monocotyledons in the garden to learner in order to help him recognize the monocotyledons. And when the learner chooses and clicks a monocotyledon picture on the phone, the system will aggregate the contents about the structure of the monocotyledon of the corresponding LCs dynamically.

## **4. A Pilot Study**

A pilot experiment was conducted in the botanical garden in Beijing Normal University for understanding learner's acceptance and recognition of CDLEMO. After the experiment, an interview was carried on to all participants.



#### 4.1 Participants and experimental procedure

There are six Beijing normal university students participated in the experiment. The researcher randomly divided them into three groups, each group of two people. The experiment was conducted three rounds with three learning tasks in total. Each round, the researcher assigned three tasks to the three groups respectively, and the tasks of the three groups are different. The learning tasks are: observing monocotyledonous leaf and learn leaf characteristics, observing monocotyledonous flower and learn flower characteristics, observing dicotyledonous flower and learn flower characteristics. Every participant used their own mobile devices to do the tasks. The mobile devices include android phone, apple phone and android pad, all of which have GPS.

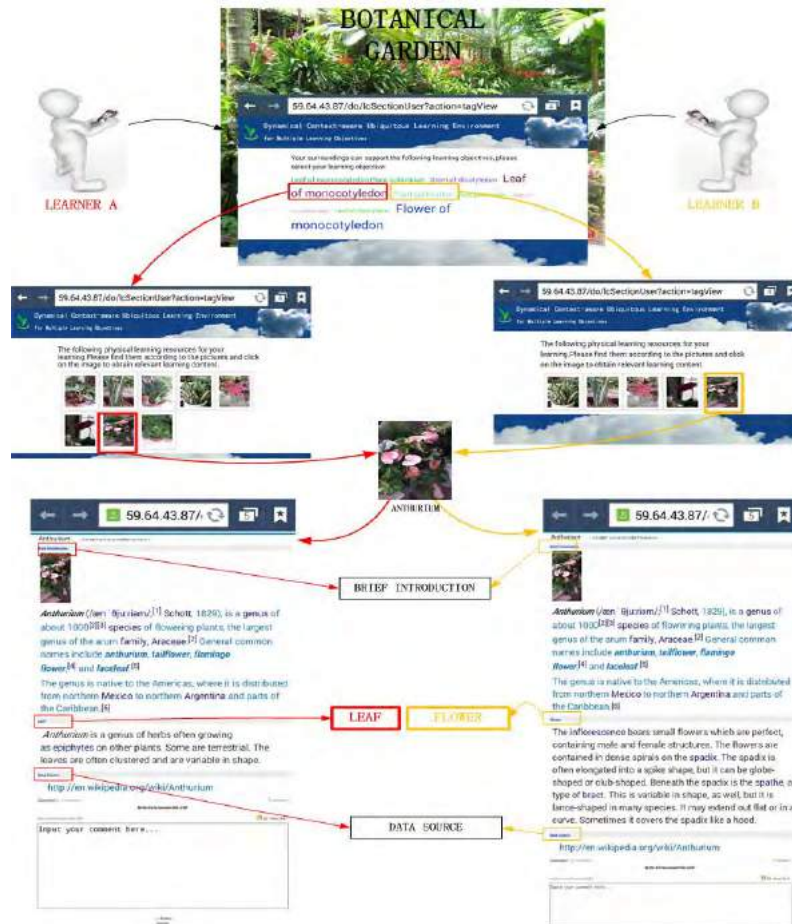


Figure 2. An example of learning in CDLEMO

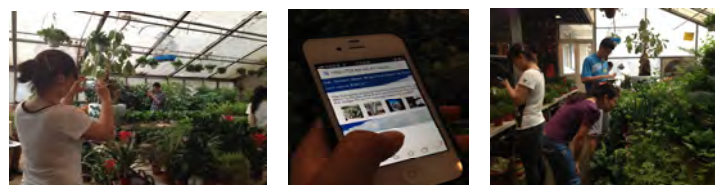


Figure 3. The learning scenarios in CDLEMO

As shown in Figure 2, take a round of experiment for example. After two learners (Learner A and Learner B) come from different groups enter the botanical garden with their mobile phones, the system will get their location via GPS. And then based on the location information, the system will know and present all learning objectives the garden can support to learners. Learner A chooses "monocotyledonous leaves" as his learning objective, learners B chooses "monocotyledonous flower" as his learning objective. Then the system will provide learner A the learning resources supporting learning "monocotyledonous leaves" in the garden, and provide learner B the learning resources supporting learning "monocotyledonous flower". Then the related physical learning

resources' photos taken in the garden will be presented respectively on their mobile phones. When both learner A and learner B choose anthurium as learning object, they will find anthurium in the garden according to the photo on their phones. Then they can observe the anthurium, and click its photo on the phones to access the LC. But when they access the same LC about anthurium, the contents presented on their phones are something different. The contents on Learner A's phone are comprised with three parts: brief introduction, leaf and data source, while the contents on Learner B's phone are comprised with three parts: brief introduction, flower and data source. Figure 3 shows the learning scenarios in the CDLEMO.

#### 4.2 Interview instrument

After the experiment, the researchers conducted an interview for all participants. The purpose of the interview is to understand the learners' acceptability and recognition of CDLEMO, and also collect suggestions for improvement of CDLEMO. S1, S2, S3, S4, S5, S6 were used to represent for the six participants in turn. The interview includes five questions: "Do you think it is convenient for studying in the CDLEMO and why?" "Do you think the learning resources and content provided by CDLEMO are closely related to your learning objective?" "Do you think CDLEMO is helpful to your study and why?" "Would you like to study in the CDLEMO?" "Do you have any suggestions on the improvement of CDLEMO?"

#### 4.3 Findings

After the interview, the data were collected and analyzed. Through the result of interview, we found that:

CDLEMO gains high reorganization from participants. Participants believe CDLEMO has great help in learning. CDLEMO provides learners physical learning resources in the real situation and LCs related to their learning objectives, makes learning become more intuitive and profound, and photos of physical resources help learners quickly find their learning objects within certain scope.

*"CDLEMO has great help in learning, let learners watch the objects in the real situation, makes the study more specific, and would not be so abstract." (S1, 2014.05.24)*

*"Learning is fun and active in real environment." (S2, 2014.05.24)*

*"The way of finding physical learning resources deepen learner's impression of the learning object." (S3, 2014.05.24)*

Participants have high acceptance of CDLEMO. All participants think Learning is very convenient and interesting in CDLEMO, which can quickly provide learning resources according to their learning objectives, and the pictures make learners easily find the unknown physical learning resources.

*"CDLEMO is convenient. It can quickly locate and provide related learning resources in this environment." (S1, 2014.05.24)*

*"CDLEMO is very convenient. It is particularly easy to find physical learning resources via pictures CDLEMO provided." (S2, 2014.05.24)*

In addition, participants gave some suggestions for CDLEMO. For example, providing different angle pictures to help learner find resources more quickly, providing a collaborative learning mechanism so that learner can get help from others.

*"Presenting several photos taken from different angles for each physical learning resource can make learner find physical resources more convenient and faster." (S1, 2014.05.24)*

*"Designing a collaboration mechanism that learner can get others' help when he cannot find the physical learning resource." (S4, 2014.05.24)*

### 5. Conclusions and future work

In a real world, different learners have different learning objectives. However, most of ubiquitous learning environments were designed for some specific learning objectives, and supply fixed learning resources with static contents. So that learners with different learning objectives are hard to get the

needed resources. To address this problem, this research proposes CDLEMO. Learners having different learning objectives can study in CDLEMO at same time, and CDLEMO will give them different learning resources related to their learning objectives. CDLEMO gets location information via GPS, and then gains learning objectives based on location information. When it knows learner's learning objective, it will search available and suitable physical resources according to the learning objective, and adjusts learning contents of the digital learning resource for matching learner's learning objective. A pilot experiment was conducted and the result showed that learners' acceptance and recognition of CDLEMO is high. Learners can gain needed learning resources and content quickly in CDLEMO. And they thought CDLEMO made learning become more intuitive, impressive, convenient and fun. Also, some participants put forward some suggestions for improvement of CDLEMO, such as providing more pictures taken from different angles for each physical resource.

Certainly, because of the number of participants is too small, so we need to check the result carefully. And our important future work is to design and do broader sample experiment to verify the effect of CDLEMO in learning, as well as to improve CDLEMO based on learners' suggestions.

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# A Pilot Study Comparing Secondary School Students' Perception of Smart Classrooms in Hong Kong and Beijing

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**Abstract:** This pilot study compared the difference in secondary school students' perception of smart classrooms between Beijing and Hong Kong using the Smart Classroom Scale (SCS). The study found that students in Beijing had more advanced requirement in physical construction of smart classrooms, while students in Hong Kong had higher expectation on pedagogical activities and deep technology usage in smart classrooms to their counterparts in Beijing. There were significant differences in scales of physical design, learning experience, flexibility, learning data, differentiation, investigation, and cooperation in the SCS. These differences were related to the investment on information technology infrastructure, and pedagogical conception of learning and teaching in smart classrooms which guide the design of learning and teaching activities. The results indicated that the students' perception to smart learning environment was affected by both educational technology investment and classroom pedagogical culture backgrounds. Both Beijing and Hong Kong students had the lowest score in learning data scale, this indicated that the smart use of learning data for pedagogical purpose was not yet thoroughly understood by secondary school students in smart classrooms.

**Keywords:** learning environment, smart classroom, smart classroom scale, students' perception

## 1. Introduction

Many researches like Lizzion, Wilson and Simons (2002) supported the view that learning environments could influence students' learning outcome and learning performance, so students' perceptions of learning environment had been studied by many researches. Trickett and Moos (1973) described the classroom environment through three dimensions as system maintenance and change, personal development, and relationship. With information technology integrated into the classroom, digital classrooms have obviously changed in above two dimensions, namely system maintenance and change, and personal development. Some new instruments like Technology-rich Outcomes-focused Learning Environment Inventory (TROFLEI) (Aldridge, Dorman, and Fraser, 2004), Technology Integrated Classroom Inventory (TICI) (Wu, Chang, Guo, 2009) for assessing students' and teachers' perceptions of digital classrooms have been developed. The instruments focused on computer usage and digital learning activities like individual learning, and inquiry learning in the classrooms.

With the introduction of richer and more diversified types of information technology in classrooms, this type of classroom is classified as smart classroom. Smart classrooms support students' learning in virtual and physical learning environments; support students' hands-on learning experiences; extend students' learning experiences outside classrooms; and give students adaptive learning help through massive learner data analysis. (Li zhang, Marco Gillies, Kulwant Dhaliwal, and et al, 2009; Minchi C. Kim, Michael J. Hannafin, 2011). Therefore, this type of classroom is considered to be conducive to cultivating students' learning skills which are needed in the 21<sup>st</sup> century. Many countries and regions have designed and constructed the cyber schools and smart classrooms to cope with the trend of e-learning development in the 21<sup>st</sup> century.

Beijing and Hong Kong are two renowned international cities. In recent years, a considerable number of primary and secondary schools in Beijing were invested with a substantial amount of budget for building cyber schools and constructing smart classrooms. Numerous teachers had accepted systematic development to change their traditional pedagogical conception such as changing the

teacher-centered pattern to student-centered paradigm. Hong Kong is one of the financial centers in the world, the primary and secondary students in the city have more cross-cultural background in their daily life. Hong Kong also has a long-term influence from UK in its education system, educational culture, and learning and teaching approach. The diversity of educational investment in Hong Kong did make a difference between the investment in building cyber schools and constructing smart classrooms between Beijing and Hong Kong.

Welch, Cakir, Peterson & Ray (2012) make cross-cultural validation of the TROFLEI in both Turkey and the USA in order to allow the comparison of classroom environments across these two cultures. They stated that comparison of educational practices, beliefs and attitudes of two countries provides deep insights into their relative positions. As there are a number of significant differences between the education systems in Beijing and Hong Kong as well as their cultural background, this pilot study is interested in the comparison of students' perception of smart classrooms in the two cities. The pilot study aims to investigate whether the differences in investment, the learning and teaching approach, as well as the cultural background are also reflected in students' perception of smart classroom. The results of the pilot study will be helpful for us to control the external factors which influence students' perception of the smart classroom environment. Li, Kong and Chen (2014) revised the details of the classroom environment of the three dimensions proposed by Trickett and Moos (1973) and developed and verified the Smart Classroom Scale (SCS) based on the current features of technology-rich classrooms. Therefore, this pilot study conducted the survey for students' perception of smart classrooms between a secondary school in Beijing and a secondary school in Hong Kong using SCS.

## 2. Method and Procedure

### 2.1 Instrument

The SCS was derived from a number of existing digital classroom instruments. They are TROFLEI, TICI, and Computerized Classroom Ergonomic Inventory (CCEI). SCS was validated as a reliable instrument by involving more than 300 students in primary and secondary schools in Shenzhen and more than 200 students in Beijing to answer to the scale. Finally ten scales and 39 items are included in the SCS which focus on the physical appearance, learning and teaching activities, and ecology of smart classroom (Li, Kong and Chen, 2014). The details of the SCS are summarized in table 1.

Table 1: A detailed description of the Smart Classroom Scale with sample of item in each scale.

| Scale                 | Description   | Sample of Item   |
|-----------------------|---|--|
| Physical Design (PD)  | The extent to which the spatial area, furniture equipment, and information technology infrastructure of smart classrooms. | I have adequate workspace for putting textbooks, tablet PCs and other resources.                       |
| Flexibility (FLE)     | The extent to which the flexible support for users by classroom environment.  | The classroom can be a theater, a group working place or other scenes for different learning purposes. |
| Technology Usage (TU) | The extent to which learners use information technology as a tool to learn and to access information.                     | I deal with my assignments using computer or other digital devices.                                    |
| Learning Data (LD)    | The extent to which the information technology was used to acquire and analyze the learning data of the users.            | I can find out my learning history, like my homework, and discussions in the last semester.            |
| Differentiation (DIF) | The extent to which teachers cater for learners differently on the basis of ability, rates of learning and interests.     | I can learn at my own pace.  |
| Investigation (INV)   | The extent to which skills and processes of inquiry and their use in problem solving and investigation are emphasized.    | I carry out investigations to test my ideas.   |

|                           |  |  |
|---------------------------|--|--|
| Cooperation (CO)          | The extent to which learners cooperate with one another on learning tasks.                           | I can cooperate with somebody through internet when doing assignment work.                                 |
| Learner Cohesiveness (LC) | The extent to which learners know, help and are supportive of one another.                           | I always help other students in the class.   |
| Equity (EQU)              | The extent to which learners are treated equally by the teacher.                                     | The teacher gives as much attention to my questions as to other learners' questions.                       |
| Learning Experience (LE)  | The extent to which learners' satisfaction and some special learning experience in smart classrooms. | The devices and software help me to get hands-on experience with the learning objects or learning context. |

## 2.2 Sample

A secondary school which was an e-Learning Pilot School in Hong Kong and a secondary school which had solid information technology infrastructure in Beijing were selected for this pilot study. Seventy-one students with age from 13 to 15 years old in the secondary school in Hong Kong, and 76 students with age from 13 to 15 years old in the secondary school in Beijing were invited to respond to the SCS. Table 2 shows the demographic data of the students in these schools. All students in these two schools had experiences of conducting e-learning inside and outside the technology-rich classrooms.

Table 2: The demographic feature of students in the two secondary schools.

| School           | Age |    |    | Gender |      |
|------------------|-----|----|----|--------|------|
|                  | 13  | 14 | 15 | Female | Male |
| <b>Beijing</b>   | 44  | 30 | 2  | 36     | 40   |
| <b>Hong Kong</b> | 17  | 46 | 8  | 36     | 35   |

## 2.3 Procedure

With the consensus of the school administrators, a questionnaire survey was distributed to the targeted students for collecting perceptions of students in the two cities. The questionnaire contained a cover sheet about the details of the participants such as age and gender, and the questionnaire. The questionnaire contains all the questions of the SCS. It asked students about their perception to the learning environment of smart classrooms. All questions asked students in a positive scoring direction and the 5-point Likert-type scale with anchors from almost never (scored as 1) to almost always (scored as 5) were used in the SCS. The students were provided with sufficient time to respond to the questions in the SCS.

## 2.4 Data Analysis

Data were analyzed using descriptive statistics including exploratory factor analyses, Independent-Samples T-test, and Cohen's d. The descriptive statistics such as means, standard deviations and Cronbach's alpha coefficient (as an index of internal consistency reliability) for each of the 10 scales of SCS were also calculated.

## 3. Results

Internal reliability was tested using the individual student as a unit of analysis for the Cronbach's alpha coefficient. The overall Cronbach's alpha coefficient is 0.93. A principal components analysis with varimax with Kaiser Normalization rotation yielded 10 scales for the existing form of SCS with total variance explained 69.31%. The Cronbach's alpha values and the exploratory factor loading results of the 10 scales of the SCS were shown in table 3.

Table 3: Cronbach's alpha values and exploratory factor loading results of the SCS.

| Scale | Cronbach's alpha | Factor Loading |       |       |       |       |
|-------|------------------|----------------|-------|-------|-------|-------|
|       |                  | Item1          | Item2 | Item3 | Item4 | Item5 |
| PD    | 0.69             | 0.73           | 0.68  | 0.74  | 0.63  |       |
| FLE   | 0.26             | 0.74           | 0.55  | 0.87  |       |       |
| TU    | 0.83             | 0.83           | 0.81  | 0.77  | 0.77  |       |
| LD    | 0.68             | 0.79           | 0.83  | 0.78  | 0.64  |       |
| DIF   | 0.87             | 0.74           | 0.85  | 0.80  | 0.82  |       |
| INV   | 0.86             | 0.80           | 0.70  | 0.67  | 0.79  | 0.65  |
| CO    | 0.86             | 0.78           | 0.57  | 0.62  | 0.75  |       |
| LC    | 0.84             | 0.74           | 0.80  | 0.78  | 0.79  |       |
| EQU   | 0.84             | 0.78           | 0.90  | 0.83  | 0.75  |       |
| LE    | 0.80             | 0.75           | 0.80  | 0.82  |       |       |

The Mean, Standard Deviation (SD), T-test, and Cohen's d in both schools in Beijing and Hong Kong were shown in table 4. Cohen's d is an effect size used to indicate the standardized difference between two means.

Both Beijing and Hong Kong students had the highest score (4.07 for BJ and 4.00 for HK) in Learner Cohesiveness (LC) and lowest score (2.23 for BJ and 3.04 for HK) in Learning Data (LD). In Beijing, the scales of Flexibility (FLE), Learning Data (LD), Differentiation (DIF), Innovation (INV), and Cooperation (CO) were lower than average level 3.00. In Hong Kong all the 10 scales were higher than 3.00. Except the two scales for relationship as Learner Cohesiveness (LC) and Equity (EQU), all other eight scales had significant differences in students' perception between the two secondary schools in Beijing and Hong Kong.

Table 4: The mean, SD, T-test and Cohen's d of the SCS of schools from Beijing and Hong Kong.

| Trickett and Moos Schema      | Scale Name | No. of Items | Mean |      | SD   |      | T-test   | Cohen's d |
|-------------------------------|------------|--------------|------|------|------|------|----------|-----------|
|                               |            |              | BJ   | HK   | BJ   | HK   |          |           |
| System maintenance and change | PD         | 4            | 3.52 | 3.37 | 3.86 | 3.43 | -2.04*   | 0.04      |
|                               | FLE        | 3            | 2.52 | 3.44 | 2.90 | 4.41 | 3.50**   | -0.24     |
|                               | TU         | 4            | 3.65 | 3.71 | 3.65 | 3.11 | 10.52*** | -0.02     |
|                               | LD         | 4            | 2.23 | 3.04 | 3.54 | 3.89 | 4.86***  | -0.22     |
| Personal development          | DIF        | 4            | 2.37 | 3.31 | 4.75 | 3.26 | 6.69***  | -0.23     |
|                               | INV        | 5            | 2.82 | 3.55 | 4.56 | 2.89 | 4.90***  | -0.19     |
|                               | CO         | 4            | 2.70 | 3.54 | 5.58 | 3.65 | 4.82***  | -0.18     |
| Relationship                  | LC         | 4            | 4.07 | 4.00 | 3.79 | 3.04 | -1.86    | 0.02      |
|                               | EQU        | 4            | 3.80 | 3.66 | 5.09 | 2.90 | -1.32    | 0.03      |
|                               | LE         | 3            | 3.61 | 3.62 | 3.79 | 2.40 | 2.54*    | 0.01      |

Notes: \*  $p < .05$ ; \*\*  $p < .01$ ; \*\*\*  $p < .001$

#### 4. Discussion

Based on Trickett and Moos schema, secondary school students' perception of smart classrooms between Beijing and Hong Kong had significant difference in both system maintenance and change, and personal development. As shown in figure 1, students' perception of Physical Design (PD) and Learning Experience (LE) in Beijing school are higher than those in Hong Kong. The study attributes these to the large amount of information technology infrastructure investments in primary and secondary schools in China during the past decade. Early in 2000, China carried out a series of projects in primary and secondary schools for digital schools construction in the mainland, such as connecting internet into every school. Beijing is the capital of China; there were a substantial amount of financial inputs to the construction of infrastructure in schools every year. Many schools in Beijing have equipped with tablet PCs, interactive desks, and large surface interactive screens, which enable it to precede in smart schools pilot programs in China.

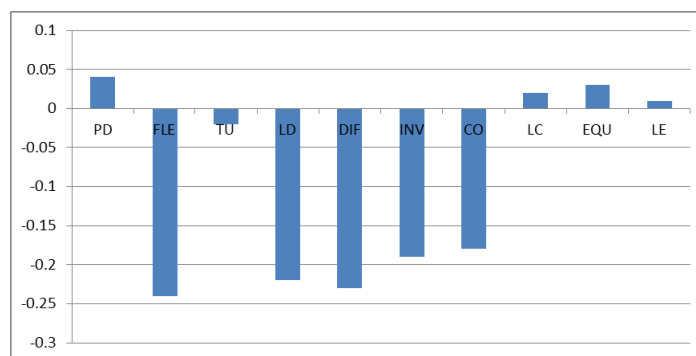


Figure 1. Cohen's d of two schools in Beijing and Hong Kong.

Primary and secondary schools in Hong Kong put more effort to develop pedagogy adopting constructivist's approach than their counterparts in Beijing, and class activities in schools in Hong Kong tend to put more effort in the student-centered approach in learning and teaching practices. For example, the selected school in Hong Kong is taking part in the pilot scheme on e-learning in schools. It uses the ICT to improve teaching and learning qualities, and to develop the learner-centered learning mode. In their learning process, it focus on inspiring students' creativity, cultivating students learn to analyze, learn to cooperate and learn to integrate ICT in their problems solving. With this regard, students in Hong Kong are more familiar with individualized, constructive, and collaborative learning. Therefore, perceptions of students in Hong Kong were much higher in the scale of differentiation (DIF), investigation (INV), and cooperation (CO) scales.

As all students involved in the survey are all having the learning experience in the technology-rich classroom, so the scores of Hong Kong students were a little bit higher than those of Beijing students in Technology Usage (TU) scale. Scores of Flexibility (FLE) and Learning Data (LD) in Hong Kong were much higher than those in Beijing; the study attributes these to the differences in the culture of using technology for more learner-centered learning for schools in Hong Kong.

Students in Beijing and Hong Kong are both influenced by traditional culture of Chinese like solidarity and friendliness, therefore both Beijing and Hong Kong students' perception to Learner Cohesiveness (LC) and Equity (EQU) had no statistical significant differences.

The differences in students' perception of each scale in smart classroom give ample evidence for the issue that the investment for ICT infrastructure in school, the teaching and learning approach in classroom, and pedagogical culture of the city do have some correlation with students' perception of learning environments.

Besides the differences, the study also found some similarities between the two secondary schools in Beijing and Hong Kong. The highest three scales in both schools are LC, EQU, and TU, the lowest scale in both schools is LD. The results indicated that in the technology-rich classroom the ICT technology do not change the traditional student-student and student-teacher relationship too much, but it give students more opportunities to use the devices and subject matter tools in learning. So in this survey both students in two different cities have highest perception of the three scales. Well, smart classroom is the higher level of digital classroom (Huang, et al, 2012), some new features, like learner analysis, are emerged. The students need time to adapt to the innovation learning style which based on the massive learning data analysis. So both students got the lowest score in the scale.

## Conclusion

This pilot study conducted a survey to students of a secondary school in Beijing and a secondary school in Hong Kong using the SCS for studying students' perception of smart classrooms. The study found that students in Beijing had more advanced requirement in physical construction of smart classrooms, while students in Hong Kong had higher expectation on pedagogical activities and deep technology usage in smart classrooms to their counterparts in Beijing. Li and Kong (2014) indicated that smartness of learner data is one of important smartness towards smart classrooms, the survey found both schools' students have lower perception of Learning Data (LD) scale, this indicated



that the smart use of learning data for pedagogical purpose were not yet thoroughly understood by secondary school students in smart classrooms in both cities. The result gave ample evidence for the conclusion that the students' perception of learning environments were effected by financial investment, pedagogical culture, teaching and learning approach in schools, and their own culture background. The conclusion inferred that physical equipment is the basic element for smart classrooms, and students have the most intuitive perception of its change and its usage in classrooms. But the change of the students' perception of the constructive learning activities, learning data based learning support are relative indirect. The innovation of smart teaching and learning activities, and cultivation the technology enhanced learner-centered pedagogical culture in schools are the bridge to improving the students' perceptions of the smart learning environment, as well as the students' learning outcomes.

The secondary school in Beijing should pay more attentions on how to improve students' participation and interaction in their classroom through its advanced information technology infrastructure for e-learning to improve students' perception of the learning activities in the whole smart learning environments. Both secondary schools in Beijing and Hong Kong should develop more teaching and learning modes based on massive learner data to guide the students' deep understanding for the importance of learner data in smart learning environments.

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# A Study of Student Behavior in Classroom Response Systems

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**Abstract:** The Classroom Response System (CRS) is a useful tool for enhancing interactivity between teachers and students in the classroom. Through its use of smart devices and PCs, CRS is expected to be effective at aiding both classroom interaction and learning. However, these devices can be used for more than CRS; they may also serve as entertainment tools. This study investigates the behavior of students who use CRS on such devices. Specifically, it analyzes log data of student behavior, focusing on student responses and their behavior of switching application programs on CRS. The results of analysis show a trend that students who immediately switch applications after answering a question on CRS have a low correct answer rate.

**Keywords:** Classroom Response System, Clicker, Smart Devices, Student Behavior

## 1. Introduction

The Classroom Response System (CRS) is a well-known tool for enhancing interactivity between teachers and students in the classroom. In recent years, many studies have used Clicker. Because Clicker makes the communication between students and teachers more interactive in the classroom, its use in pedagogy has spread recently in various fields of education. (Crews, T. B. et al., 2011; Raes, A., et al., 2013; Kulesza A. E. et al., 2014; Han, J. H. et al., 2013). However, Clicker cannot improve the interaction between a teacher and an individual student due to its system architecture, as described below.

- Clicker has only one-way messaging from a student terminal to a teacher PC on the system.
- Generally, students' wireless terminals are composed only of buttons.
  - ✓ The message is only the information that the student has clicked the button. The student cannot send a teacher a message or question.
  - ✓ The teacher cannot provide teaching materials that include text, images, sounds, and video, to an individual student. In addition, teacher cannot send a message to an individual student.

To resolve these problems, researchers have developed CRSs that use various devices such as cell phones, smart phones, tablets, and PCs, as the student terminals. For example, Robbins, S. (2011) used ClassQue, a PC application, in courses on MATLAB programming, Java programming, computer organization, and operating systems. ClassQue has several unique functions such as seating charts, review messages, and comment sharing in a group. Especially in recent years, the number of studies using smart devices (e.g., cell phones, smart phones, tablets) has been increasing. Andergassen, M. et al. (2012, 2013) developed browser-based mobile clickers called Learn@WU. Nielsen et al. (2012) presented their project that is developing a Student Response System (SRS) co-funded by the European Commission. Dunn, P. K. et al. (2012) implemented a low-cost, mobile-phone-based CRS named VotApedia. They evaluated the system by collecting data specifically related to interacting with the user interface, the in-class delivery, and instructor perceptions of student engagement. The author of this paper is also developing a web-based CRS that has the functions for real-time interactions using HTML 5 and WebSocket that are new technologies for the Web (Mizutani, K., 2013).

On the other hand, smart devices can run not only CRS but other software applications as well, and thus, they can serve various functions, such as providing entertainment. The GSM Association's

(2013) international survey on children's use of mobile phones revealed that most children access the internet and download applications, and entertainment is the most popular among the child users.

For this reason, the devices used in classrooms often have limitations on which software programs or device functions can be accessed. Yet because smart devices offer useful software for learning, it is not an easy task to decide the policies of such limitations. Not only the limitations of the devices but the functions of CRS and its practical implementation must be considered to improve student understanding.

In this paper, as the first step toward finding behavior patterns that represent the relations between students' understanding and their using events on CRS, investigates the relations between the events of student responses and user behavior events, namely, window switching of applications on PCs. It is thought that the correct answer rates of students who lack sufficient understanding will be lower than those of students who understand well. One hypothesis is that the number of times these students switch windows will be relatively high because they will switch to a web browser to search for answers to the questions. Also, if the students are not interested in listening to the teacher's lecture, they might answer the questions randomly or without putting much thought into their choices, then switch quickly to entertainment contents on their smart device.

If there is indeed a relationship between students' responses and their behavior of window switching, the findings may be used to identify students who are in need of learning support. Therefore, this paper seeks to identify these relationships by using the originally developed CRS.

## 2. Methods

### 2.1 *Developing a Real-time Classroom Response System, "Response Analyst"*

For the purpose of this study, an original CRS called "Response Analyst" was developed because the existing systems, including CRS products, have the following problems.

- The interaction on CRS is not in real-time.
  - ✓ Every student behavior on the CRS has to be in real-time and logged with precision. Otherwise, the data on the students' behavior will be inaccurate.
- The existing systems lack functions for providing teaching materials to each student.
  - ✓ Student terminals often consist of only buttons; they cannot display the teaching materials.
  - ✓ Even if the student terminal has a screen, it often shows only text, not multi-media content.
- The existing systems cannot monitor the events of switching windows on a PC.
  - ✓ This is an important function for this study. Student behavior events such as receiving teaching material, starting thinking, answering, switching windows, etc. have to be recorded.

To implement these functions, Response Analyst has been developed as an application for PCs instead of smart devices. It might have been developed as a software program for smart devices such as smart phones or tablets, but it is difficult to monitor the events of student behaviors, especially switching windows (or applications), on the security models of the smart devices. Therefore, this study hypothesizes that student behavior does not differ between PCs and smart devices.

Response Analyst has a Server-Client model architecture. Its server program communicates to the teachers' client program and the students' client program. To realize real-time processing, the communication has been defined as original protocols.

Figure 1 shows examples of the user interfaces of the teachers' client program (A) and students' client program (B). When students click the answer button, their response is immediately reported to the teachers' program. The teacher can check each student's answers or view a graph that summarizes all the students' answers on the external screen, such as a projector (Figure 1, A-2).

### 2.2 *The basic sequence of Response Analyst and the design for logging student behaviors.*

Figure 2 shows the basic sequence of each of the programs of Response Analyst. The messages between Teachers' Program and Students' Program are communicated keeping TCP/IP connections for real-time processing, because establishing the connections of each messaging worsens the system's real-time

processing. However, for precisely logging the events of student behaviors, the delay of the TCP/IP communications should be considered. Also, the time stamp of the events might differ by device because a device's clock may not be correct.

This study focuses on student behaviors on the student devices. Of particular importance is the behavior of the students between receiving a question and answering it on their student devices. Therefore, Response Analyst logs the events on both the server and each student device. As shown in Figure 2, the client program logs section data, which are a set of the events between the user receiving a question and answering it. When the student program is closed, the section data are sent to the server in a lump.

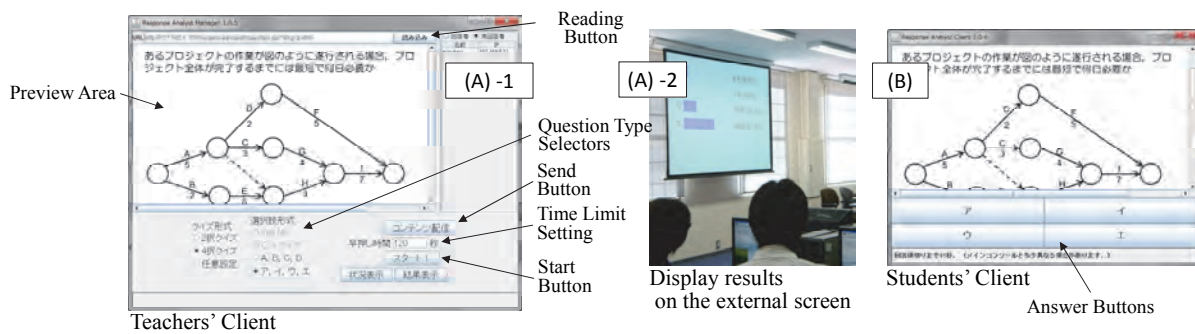


Figure 1. Example screenshots of Response Analyst.

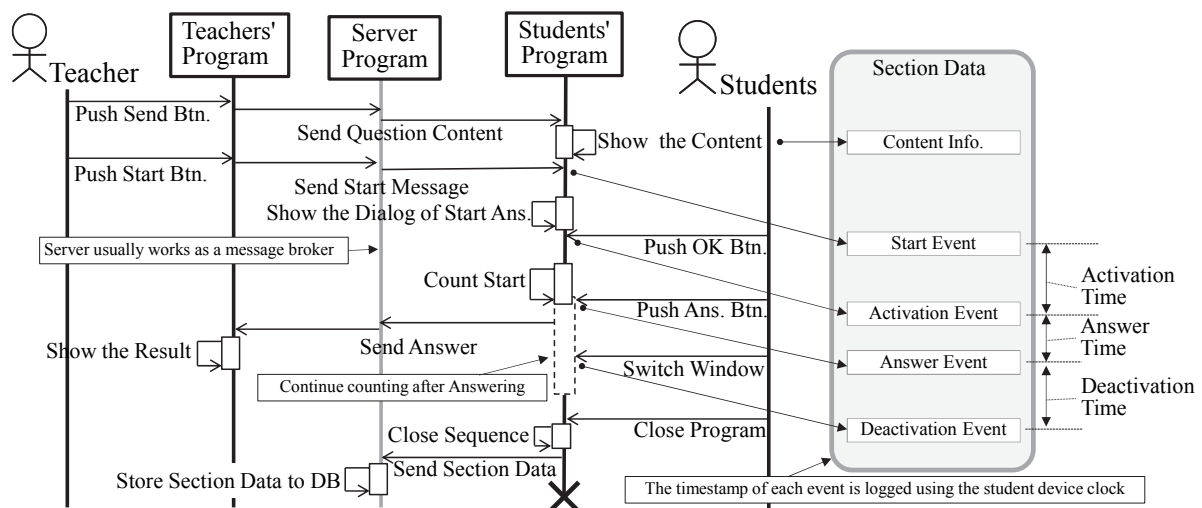


Figure 2. The basic sequence of Response Analyst and the abstract of event logging.

### 2.3 Log analysis

The section data include the timestamp that is based on incorrect clock on the student device. To reduce the inaccuracy of the timestamp, the section data are analyzed using the time that is the span of one event from the event of receiving the message to start answering. Specifically, as the preprocessing of the log analysis, the time span data is calculated as follows and as shown in Figure 2.

- Answer Time: The time between the start of answering and the user's click on the answer button
- Activation Time: The time between the start of answering and the activation of the window of the student client
- Deactivation Time: The time between user's click on the answer button and the deactivation of the window of the student client

Moreover, because the limit time for each question is different, the time span data are normalized by using the limit time of each question.

To determine the relations between these events, the time span data are analyzed as follows.

- The difference of the answer events between correct and incorrect answers
  - ✓ First, to roughly gauge the trend of the difference in correct and incorrect answers, the mean values of the Activation Time and Deactivation Time are compared by a t-test.
- Making clusters of the students' behavior
  - ✓ To reveal the differences in student behavior, after the average values of Correct Rate, Answer Time, Activation Time, and Deactivation Time are calculated for each student, K-means Clustering is applied to the average values.

### 3. Results

#### 3.1 Practical use of Response Analyst

Response Analyst was used in a class designed for students to learn the basis of knowledge of information technology. The course syllabus includes solving the past versions of the Information Technology Passport Examination (IT Passport Exam), one of the Information Technology Engineers Examinations in Japan. The IT Passport Exam consists of multiple-choice questions. Examinees select one answer from among four choices in response to each question.

In the class, students were given questions from past issues of the IT Passport Exam by Response Analyst. The teacher explained the issues to the students while referring to the results of the answers in Response Analyst. When sending questions, the teacher set the limit time for a question based on their own judgment. A total of 1,863 section data were logged in the class. This included the logs of 53 students who attended the class, 50 questions from past versions of the IT Passport Exam, and activation/deactivation events.

#### 3.2 Analysis Results

##### 3.2.1 The difference of the answer events between correct and incorrect answers

Table 1 shows the results of a t-test comparing the correct and incorrect answers, answer time, activation time, and deactivation time. These results exclude the section data in which the deactivate time is over 1, because this shows that the student changed the window after the time limit was over. Of course, the data received after the limit time are also important. However, because the purpose of this study is to identify behavior patterns in the course of using Response Analyst, the events that fall within the limit time are more important than those occurring after it. The results of the logarithmic transformation of the activation time and deactivation time were used in a t-test, because the distribution of activation time and deactivation time seems normal.

In each of the results, if the value of the f-test is  $> 0.05$ , the value of the t-test shows the results of the t-test assuming equal variances (Student's t-test). If the value of the f-test is  $< 0.05$ , the value of the t-test shows the results of the t-test assuming unequal variances (Welch's t-test).

##### 3.3 Making clusters of the students' behavior

K-means Clustering that is a cluster analysis method in which the value of  $K$  is the number of the clusters. Before the K-means Clustering, the data of the students who had given only a few answers were excluded. The average number of times a student answered is 25.00 times. The maximum and minimum are 51 times and 1 time, respectively. Because the standard deviation is 13.74, the minimum threshold is defined as 11.26. Eleven students' data that are less than the threshold were excluded from the target of K-means Clustering.

In this study, the optimal  $K$  value was calculated using the reconstruction error that is the sum of the mean squared error between all data in the cluster and the centroid of the cluster, in each  $K$  value (Alpaydin, E. 2004). As the result of the reconstruction error, it is assumed the optimal value of  $K$  is 4 or 5. Then, Table 2 shows the detailed results for each cluster with  $K$  values 4 and 5. The clusters are ordered by their average correct answer rate.

Table 1: Results of a t-test about the difference between correct and incorrect answers.

|                   |           | Mean  | Median | SD    | f-Test ( $P$ , two-tail ) | t-Test ( $P$ , two-tail ) |
|-------------------|-----------|-------|--------|-------|---------------------------|---------------------------|
| Answering Time    | Correct   | 0.423 | 0.390  | 0.245 | 0.385                     | 0.364                     |
|                   | Incorrect | 0.403 | 0.375  | 0.249 |                           |                           |
| Activation Time   | Correct   | 0.117 | 0.064  | 0.132 | 0.027*                    | 0.407*                    |
|                   | Incorrect | 0.133 | 0.076  | 0.157 |                           |                           |
| Deactivation time | Correct   | 0.133 | 0.057  | 0.163 | 0.769*                    | 0.006*                    |
|                   | Incorrect | 0.106 | 0.046  | 0.147 |                           |                           |

\*The results using the values by logarithmic transformation.

Table 2: The clustering results and mean values for each student.

| $k$ | Cluster No. | Count | Average Correct Rate | Average Time |            |              |
|-----|-------------|-------|----------------------|--------------|------------|--------------|
|     |             |       |                      | Answer       | Activation | Deactivation |
| 4   | 1           | 12    | 0.412                | 0.519        | 0.148      | 0.580        |
|     | 2           | 11    | 0.419                | 0.442        | 0.167      | 0.290        |
|     | 3           | 6     | 0.523                | 0.572        | 0.127      | 0.930        |
|     | 4           | 13    | 0.716                | 0.507        | 0.115      | 0.757        |
| 5   | 1           | 16    | 0.364                | 0.459        | 0.149      | 0.399        |
|     | 2           | 5     | 0.528                | 0.562        | 0.116      | 0.964        |
|     | 3           | 11    | 0.559                | 0.536        | 0.130      | 0.725        |
|     | 4           | 6     | 0.682                | 0.498        | 0.158      | 0.470        |
|     | 5           | 4     | 0.823                | 0.515        | 0.133      | 0.890        |

#### 4. Consideration

Table 1 shows the results of the t-test for the difference of the average of correct and incorrect answers. In regard to answering time, the mean value between correct and incorrect answers is not significantly different at the significance level of 5% because the t-test result is 0.364. Similarly, for activation time, there is no significant difference because the t-test result is 0.407. On other hand, the t-test result of deactivation time is 0.006, showing that the mean values of deactivation time are significantly difference between correct answers and incorrect answers. The mean value of the incorrect answer of deactivation time is 0.106, which is smaller than the mean value of the correct answer. The results point to a trend in which the answer is incorrect when the behavior of switching program windows after answering occurs earlier.

Similarly, a trend is also revealed by the results of the K-means Clustering, as shown in Table 2. A comparison of the smallest and largest clusters in terms of the average of correct rate in each  $k$  value shows that the deactivation time of the smallest cluster is shorter than that of the largest cluster. For example, when  $k$  is 5, the deactivation time of the smallest cluster in the correct rate (No. 1) is 0.399, and for the largest cluster (No. 5), it is 0.890. To validate the difference of these two clusters, a t-test about the deactivation time data was tried. The result was  $P < 0.000$ , it showed a significant difference at the significance level of 5%.

These results point to the following:

- Because the mean values of deactivation time are significantly different between correct and incorrect answers, when the deactivation time of answering behavior is smaller, the answer might be incorrect.
- The students with low correct answer rates immediately switch program windows after answering questions on CRS, in contrast to the students with high correct answer rates. When a student's deactivation time is short, his or her correct answer rate might be low.
- Predicting incorrect answers based on answer time and activation time is difficult. This study identified the significant differences between these times and students' answer behaviors.
- It may be possible to use deactivation time as a means of identifying students who need help from the teacher. To realize this, CRS on smart devices should have a function for catching the event of switching applications. However, the necessity of this function has not generally been discussed so far.

This finding presents the possibility to realize a learning support function that automatically detects the state of a student. For example, it is able to realize a function that detects a student who is low correct rate and switch quickly to other window after answering on CRS, calls the student attention and notices the detection to a teacher. The author of this paper also plan to implement the automatic learning support function to the original CRS of oneself and to evaluate the instructional effects.

## 5. Conclusions

The purpose of this study is to investigate the behavior of students who use CRS on smart devices. This paper describes the results of an analysis of log data on student behavior, focusing on student responses and the behavior of switching applications on CRS.

An original CRS “Response Analyst” was used in a class aimed at teaching the basis of knowledge of information technology. The log data were analyzed using the statistical methods of t-test and K-means Clustering. The results revealed a trend that the correct answer rate of students who immediately changed applications after answering questions on CRS was low. However, this trend was not found out from the time of answering the questions to the time of activation events, that is, switching application windows. The results of the K-means Clustering showed a relationship between students who have a low correct answer rate and short deactivation time after answering. This finding presents the possibility that CRS can identify students who may need help from the teacher.

## Acknowledgement

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# An Approach to Electronic Textbook Linking Chemical Experiment - Esterification of Acetic Acid and Ethanol -

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**Abstract:** A computer graphics (CG) teaching material of the esterification of acetic acid and ethyl alcohol was made based on quantum chemical calculations. The teaching material could simultaneously display realistic shapes and electrostatic potentials of the intermediates of the reactants on the way of the reaction profile besides the ball-and-stick model of the intermediates. The material was tried to combine with chemical experiments of student's laboratory of the university for the purpose of making electronic textbook.

**Keywords:** CG, visualization, chemical reaction, electronic textbook, tablet computer.

## 1. Introduction

Understanding the observed phenomena, chemists use to imagine and explain observations in terms of molecules (Figure 1). Observed phenomena and molecular level models are then represented in terms of mathematics and chemical equation (Gilbert, 2009 and Tasker, 2010).

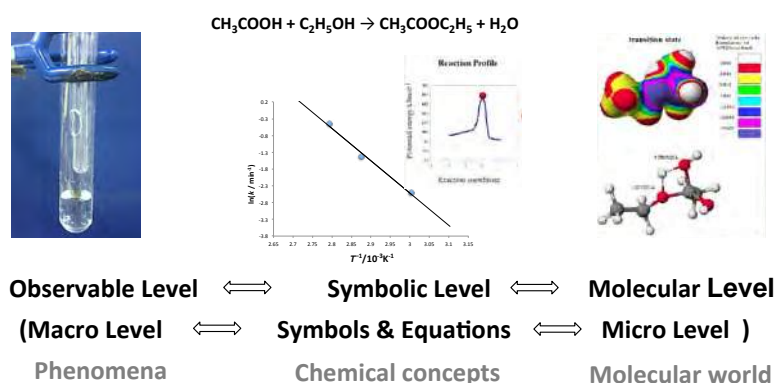


Figure 1 Dividing the image into the three thinking levels

Student's difficulties and misconceptions in chemistry are from inadequate or inaccurate models at the molecular level (Kleinman, 1987). A molecular structure visualized by the computer graphics (CG) provides a deeper understanding of molecular structure (Tuví-Arad, 2006). It is our aim to produce a CG teaching material based on quantum chemical calculations, which provides realizable images of the nature of chemical reaction (Ikuo, 2006 and 2009). Molecular level animations combined with video clips of macroscopic phenomena enabled students to predict the outcome better (Velazquez-Marcano, 2004). If the CG teaching material is combined with chemical experiments of student's laboratory, students would observe the reaction from three thinking levels, namely, phenomena in the actual observable level and CG teaching material in the molecular level, and chemical equation in the symbolic level. The CG teaching material on the tablet computer was effective to provide image of "Energy" change and also effective to provide image of "Structure"



change and “Migration of Electron” during chemical reaction (Ikuo, 2012). Our ultimate goal is to produce an electronic textbook linking chemical experiment, which integrates these three levels.

Chemical reaction is generally expressed by a chemical formula that provides information of the reaction about its stoichiometry; however, chemical formula does not provide information about its realistic shape and reactivity of molecule. This information is essential to realize images of chemical reaction. Molecular models such as wire, ball-and-stick, and space filling, are popularly used to realize images of molecule. They are used properly for the purpose of providing information of molecule about bond length and its angle, shape, and so on. Generally, the electron density iso-surface on CG is displayed with realistic shape of molecule, and electrostatic potential on CG provides information about electrical character of a certain part of molecule.

In this paper, we report here a CG teaching material adopting the CG with electrostatic potential on electron density that represents both realistic shape and electrostatic potential of molecule for the purpose of making electronic textbook for university student laboratory, which integrates the observable level experiment and the molecular world of the esterification.

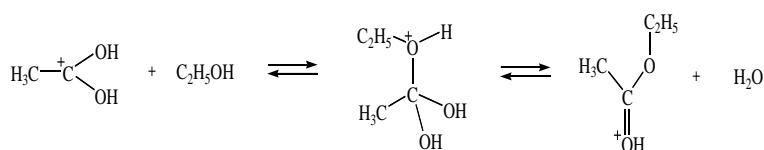
## 2. Procedure

### 2.1 Quantum Chemistry Calculation

Esterification of acetic acid and ethyl alcohol is described as shown in the equation (1).



The mechanism of the reaction is well known (For example Loudon, 1984), and generally, the esterification proceeds in the presence of proton catalyst. The rate-determining step includes the paths of an attack of the oxygen atom of hydroxyl group of ethyl alcohol to the central carbon of the formed carbonium ion and release of water as shown in the Scheme 1. This step dominates all over the reaction, and then the calculation based on quantum chemistry on the rate-determining step was carried out. Although another mechanism that involves more than a pair of reactants is possible as reported in the case of carbonic acid formation (Nguyen, 1984), it was not considered in this paper for simplicity of program.



Scheme 1 Mechanism of the esterification on the rate-determining step

Structures of intermediates on the esterification of acetic acid and ethyl alcohol and their electrostatic potentials on electron density were calculated as follows: the semi-empirical molecular orbital calculation software MOPAC (Stewart, 1989) with PM5 Hamiltonian in the CAChe Work System for Windows (Former name of SCIGRESS, ver. 6.01, FUJITSU, Inc.) was used in all of calculations for optimization of geometry by the Eigenvector Following method, for search of transition state by use of the program with Saddle point Search, and for search of the reaction path from the reactants to the products via the transition state by the intrinsic reaction coordinate (IRC) calculation (Fukui, 1970). Details of procedure of the quantum chemical calculations were described in the previous paper (Ikuo et al., 2006). The electrostatic potential on electron density (EPED) (Kahn, 1986) was calculated based on structures from the results of the IRC calculation (Ikuo et al., 2014).

### 2.2 Production of Teaching material of CG and Electronic Textbook

A movie of the reaction path was produced by the software DIRECTOR (ver. 8.5.1J, Macromedia, Inc.) following the display of the bond order of the structure of the reactants in each reaction stage,

which was drawn by the CAChe. The obtained CG of EPED model was combined with those of ball-and-stick model and reaction profile in the same reaction stage. It was confirmed that the drawn CGs of the molecular models of reactants moves smoothly. The green ball, which indicates progress of the reaction, was arranged on the reaction profile and simultaneous movements of the ball and the reactants were confirmed. Created movie file was converted to the Quick Time movie for iPad by the Quick Time PRO (ver. 7.66, Apple, Inc.). Electric textbook was produced with iBooks Author (ver. 2.1.1, Apple, Inc.) and was saved to iPad (Apple, Inc.) by using the iTunes (ver. 11.2.1, Apple, Inc.).

### 3. Results and Discussion

#### 3.1 CG Teaching Material

The Quick Time movie file was created as teaching material by use of 100 frames of combination CGs.

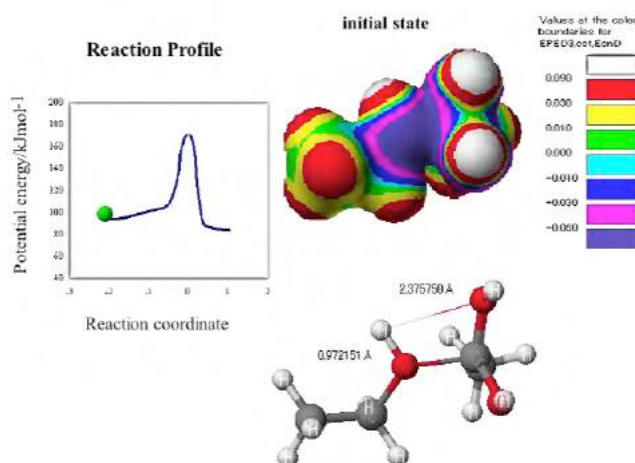


Figure 2 CG teaching material

The Figure 2 shows the combination CGs on the way from the state of reactants to that of products via the transition state. The teaching material demonstrates the changes of electrostatic potential and realistic shape of the intermediate of the reaction on the reaction profile in all stages at the same time.

The values of electrostatic potentials were represented in different colour on the model of intermediate, and figure legend of colour boundaries for electrostatic potential was also listed. Distribution of the electrostatic potential among the intermediate can be seen by the colours. For example, oxygen of ethanol is negatively charged with relative value of -0.06 based on evaluation of energy of interactions of prove proton to the charge of iso-surface, and hydrogen of carbonium ion is positively charged with the relative value of +0.09. The model by electrostatic potential provides information about electrostatic distribution of the intermediate on the way of the reaction.

The green ball on the reaction profile can move by users' choice of the way of automatic movement or manual movement along the reaction coordinate, which indicates the most probable pathway of chemical reaction according to the IRC theory (Fukui, 1970), by use of the Quick Time control bar. Other CGs such as EPED and ball-and stick modes are also synchronized with the movement of the ball so that the degree of the reaction progress and structural change of the molecules of all stages could be demonstrated simultaneously. The CG teaching material provides details of the chemical reaction mechanism dynamically.

#### 3.2 Electronic Textbook

The teaching material was tried to combine with chemical experiments of student's laboratory for the purpose of making electronic textbook of basic chemistry to provide experiment at the

observable-level, CG visualization at the molecular-level, and chemical equation at the symbolic-level.

The electronic textbook was inserted with images of experimental procedure in the flow charts and pictures, which can be enlarged by students touch (Figure 3). CG teaching materials of reaction profiles were also inserted (Figure 4). When student touches the CG teaching material in the tablet computer, the teaching material appears to show image of the structural change during the reaction. When student touches the material again, the Quick Time control bar appears and the green ball on the profile can move by student's choice. Student can manipulate the reaction back and forth until they obtain the image of the reaction.



Figure 3 Experimental procedure from the electronic textbook

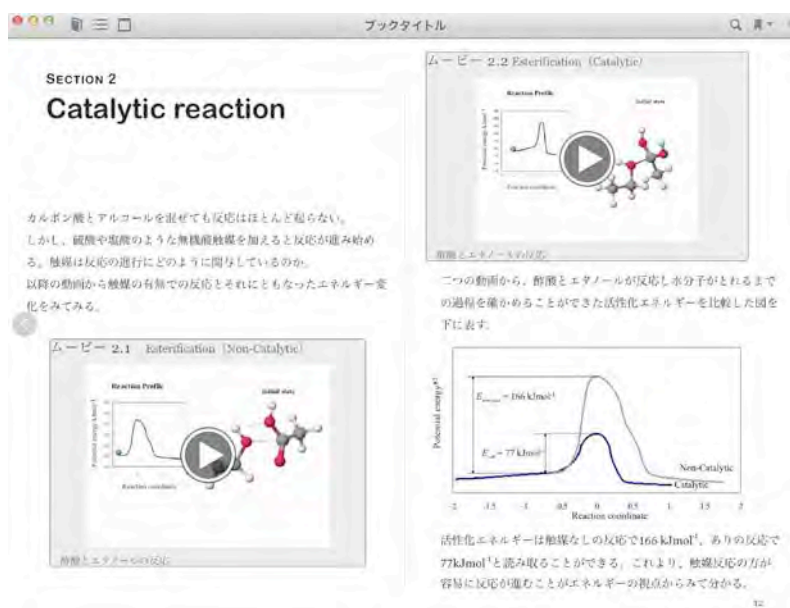


Figure 4 CG teaching material in the electronic textbook

## 4. Conclusions

A CG teaching material of the esterification of acetic acid and ethyl alcohol was made based on quantum chemical calculations. The teaching material could simultaneously display realistic shapes and electrostatic potentials of the intermediates of the reactants on the way of the reaction profile besides the ball-and-stick model of the intermediates. The material could demonstrate these images of dynamical reaction mechanism for the esterification. The material was tried to combine with chemical experiments of student's laboratory of the university for the purpose of making electronic textbook. The textbook could display picture of apparatus and flow-chart of experiment in addition to the CG teaching material. The electronic textbook could integrate the observable level experiment and the molecular world of the esterification.

## Acknowledgements

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# An Online Course for Active Participation and Interactive Learning: An Exploratory Study

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**Abstract:** Learning is a highly social process. However, Asian students are often found quiet and passive in the classroom. How to promote their active participation and interactive learning becomes a challenge. In this study, a course that was previously conducted in the face-to-face classroom was redesigned and conducted online. This paper describes the design of the course from pedagogical, social, and technical aspects, and presents the students' perceptions of the design and implementation. Results show that students became more active and interactive; technical infrastructure played a critical role; and monitoring students' participation and engagement was a new challenge in the course implementation process.

**Keywords:** Active participation, Interactive learning; Online learning; Pedagogical design; Social design; Technical design

## 1. Introduction

Asian students are often found quiet and passive in the classroom, and they seldom speak out unless they are called upon by instructors (cf. Thompson & Ku, 2006). How to promote their active participation and interactive learning becomes critical. School teachers in Asian countries often teach in traditional ways where teaching is perceived as disseminating information and learning as a passive activity (Lim, 2007). Simply encouraging student to actively interact with peers and with the teacher but without changing instructional strategies would hardly work (Livinston & Condie, 2006). For more active participation and interactive learning to take place, teachers often need to redesign lessons to involve more student-centered learning activities.

Integrating technology into the teaching and learning process has the potential to promote students' active participation and interactive learning. A technology-enabled learning environment often provides an equal and comfortable space where students are willing to participate and interact (Thompson & Ku, 2006). However, few cases about using technology to support teaching and learning in the context of China have been reported in international journals (Thompson & Ku, 2006). This study was initiated to promote students' active participation and interactive learning by redesigning an existing course, which was previously conducted in the face-to-face classroom, into an online module. This paper describes the design of the course from pedagogical, social, and technical aspects and also presents students' perceptions of the design and implementation of the course.

## 2. Design

The course entitled *Introduction to Educational technology* was a core module offered to the undergraduate students at a Chinese university. A total of 50 students (12 males and 38 females) were enrolled into the course in that semester. Their average age was about 24. They majored in various subjects such as English language (N=22), Psychology (N=6), or Physical Education (N=4). They had taken a basic computer literacy course and their computer competency levels were equivalent. They would become primary or secondary school teachers after completing a four-year study.

### *2.1 Pedagogical Design*

Before a lesson, learning resources including PowerPoint slides and other learning materials were online available for the students to download and study. The students were required to go through the resources and complete the learning activities embedded in the slides in groups or individually.

During the lesson, all students were required to login to the online course at the fixed time. The purpose of having a real-time lesson was to provide them with opportunities to share and interact with others simultaneously. Individual students or groups were invited to present their understanding in the lesson. During the presentation, other students were reminded to concentrate on and participate in the presentation. They were encouraged to ask questions in written text. After the presentation, the teacher picked up some issues from the presentation to further discuss with the class. The lesson implementation process was recorded and uploaded online for future reference.

After the lesson, students were required to write reflections in their individual weblogs to further think about what they had learned from the lesson and how to apply what they had learned. Every student was encouraged to read and give comments to others' reflections.

### *2.2 Social Design*

The social design of the course aimed at providing a safe and comfortable environment where students would actively participate and interact with peers. The online course was set as a closed space where only approved users were able to access. To a great extent, this would keep the course safe by preventing strangers from accessing it. The teacher decided to use voice communication as well as text chat in the online course after considering the shyness of students and the capacity of voice in conveying emotions (Aragon, 2003). In addition, the teacher played music before a lesson, which served the purpose of creating a comfortable environment and letting the students know that he was online ready.

### *2.3 Technical Design*

The tools selected for hosting the course were YY Voice and QQ Group. YY Voice is a free software program in which virtual classrooms can be created and users can have real-time communication via voice or text. Teachers can broadcast their voice or share the whiteboard with students. The students can talk to the whole class after getting permission from the teachers.

Another free tool - QQ Group - was selected for group members to share resources and discuss ideas. The QQ Group also provides members with personal spaces where they can bookmark useful websites and write diaries. In this course, the personal spaces were used for students to write individual reflections, read others' reflections, and give comments. Both YY Voice and QQ Group could be accessed on any platform (e.g. Windows, Android, or iOS) using any device (laptops, Tablets, Mobile phones).

### *2.4 Research Question and Instruments*

This study aimed to answer the following main research question: How did the students perceive the design and implementation of the online course? More specifically, this research question aimed at identifying the students' perceptions of the pedagogical, social, and technical designs of the online course. A survey consisting of 22 5-point Likert Scale (from 1-strongly disagree to 5-strongly agree) items, which were adapted from the existing survey validated by Wang (2009), was used to collect quantitative data. Forty-seven students responded to the survey with a responding rate of 94%. The survey items were found to be highly reliable ( $\alpha=.924$ ). An open-ended question was included in the survey to collect students' comments and suggestions. Lesson observation notes taken by the teacher were also collected.

### 3. Findings

#### 3.1 Pedagogical Design

Table 1 shows the respondents' perceptions of the pedagogical, social, and technical designs of the online course. The students were generally satisfied with the pedagogical design of the environment. They liked the way of involving online learning in the course, as they could interact and collaborate with others. In their answers to the open-ended question, they mentioned that they gained knowledge and skills from this course, as participating in this course required them to put a lot of efforts in reading and discussion. They had opportunities to share their understanding, discuss ideas, and clarify doubts with peers. These opportunities enabled them to learn from others and construct knowledge. Also, they could review the instructional process as the recorded lesson was available online.

The students became more active in the implementation process of the course compared to that in the face-to-face classroom. They actively asked the teacher or peers questions or responded to their questions in written text. A student' answer to the open-ended question well explains why she kept active in the course:

*I have to be very careful and active in the online class. Online learning is unlike in a classroom where I have neighbors to ask when I miss out something. I won't know what to do next if I do not concentrate or when I drift away.*

#### 3.2 Social Design

The students commonly felt that this course offered a comfortable space. They could attend class while resting in the hostel with a cup of tea. They could ask questions and get prompt feedback from the teacher and peers without interrupting them. However, certain students indicated that participating in online learning at the hostel lacked a learning climate. Their roommates might be walking around, eating, or watching movies on their computers, which caused much distraction to their learning. The students were more confident in asking questions and/or giving answers in the online course. They were less worried about losing face since the others could not see them. Nevertheless, they felt they were socially connected with others. To a great extent, communication via text and voice in the online course enabled them to establish social presence. A student responded that:

*It is a little bit pity that I never saw the teacher and classmates. I may not be able to recognize them when I see them. But it does not matter. I still remember them as I am familiar with their voices and tones. E.g. the funniest voice is from a PE male student, and the sweetest soprano voice is from a girl of the Music College.*

Lesson observation notes showed that students' online discussion frequently lagged behind the pace of an oral presentation. Occasionally, students were still discussing about the content on the previous slide after the presenter had moved to the next slide. This observation suggests that the teacher as a facilitator should closely monitor the discussion progress and give student sufficient time to reflect and type in their thoughts. In addition, it was a challenge for the teacher to monitor every student's participation and engagement as some of them kept quiet or did not take part in the discussion.

#### 3.3 Technical Design

The students could conveniently access the online course without technical difficulties. Also, they could view the teacher's shared whiteboard and annotations. A student shared in her response that:

*When I first knew I was enrolled into an online course, I was very upset as my friends told me that taking an online course requires high technical skills but I am not technology savvy. After installing the YY Voice, I found it was not hard to use. ... I realized that an online classroom was not that scaring but quite interesting.*

However, some students encountered certain technical problems. A common problem was that the Internet access speed was slow and unstable sometimes. As a result, they could not watch the shared whiteboard or the video played by the teacher.

#### 4. Discussion

This study showed that the students were active and the learning process was interactive. A few reasons might contribute to this result. Instructional (re)design played a vital role. Many student-centered learning activities were involved in the course. The activities included studying and discussing on learning materials before a lesson, having students' presentations during the lesson, and writing reflections after the lesson. This finding supports the notion that it is a combination of many instructional design endeavors rather than simply putting a course online that contributes to the often-reported positive outcomes of online learning (Means, Toyama, Murphy, Bakia, & Jone, 2010).

Also, students had the tendency to behave more actively in an online environment. Physically being there and listening to the teacher's instruction are typical behaviors of students in a classroom (Thompson & Ku, 2006). In a virtual learning environment where the teacher cannot see them, however, students often have to participate actively to indicate their social presence.

Social presence is heavily affected by social interactions rather than the intrinsic attributes of the media used (Garrison, et al, 2000). The result of this study confirmed that using voice enabled social presence to be easily established, as voice can easily reflect the emotions and friendliness of the speaker (Aragon, 2030).

In addition, text chat also played a vital role in promoting social presence and social interactions in this online course. Text chat provided a backchannel for students to interact with others while they were attending a presentation. This backchannel could ". . . [change] the dynamics of the lecture room from a one to many transmission to a many to many interaction, without disrupting the main channel communication" (Ross et al., 2011, p. 215). However, the teacher should closely monitor the content and progress of backchannel discussion to make the discussion more effective.

The success of using technology for teaching and learning depends on the implementation support in the education system (Fullan & Donnelly, 2013). The result of this study indicated that the technical infrastructure in the university needed to be further improved. The low networking speed negatively affected the students' perception of the course implementation. This finding confirms that technical design provides conditions for effective pedagogical and social designs to take place. Without sufficient technical design and support, theoretically sound pedagogical or social design will not function well (Wang, 2008)

In addition, other supporting facilities such as the classroom or library also needed to be renovated. Online learning usually enables learning to take place anytime anywhere. However, almost all students took part in the online course at the hostel in this study. The campus was not fully covered with a wireless network and the library did not allow them to talk loudly. In this case, staying at the hostel was nearly the only choice left. To make online learning more flexible and effective, the university should provide more venues like small rooms in the library for students to engage in online learning.

This study did not examine the students' actual learning outcomes. Even though the students responded that they learned more knowledge and skills from this course, no concrete results showed that the students could perform better. Future research can investigate students' learning outcomes after taking the online course. In addition, video has become a ubiquitous means of communication that it has been labeled the 'new text' (Prensky, 2012). Future studies will incorporate video conferencing to investigate its feasibility and effect on learning.

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# Checkpoints for Integration of a One-to-One Tablet Configuration in a School Learning Environment

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**Abstract:** The hereby given article focuses on challenges and potentials of the integration of a one-to-one tablet computer environment in schools. On the basis of advantages and disadvantages of the use of tablet computers in learning scenarios and especially in classroom use, actual approaches to implementation of one-to-one tablet configurations in formal education system will be discussed in a practice-driven way by exemplarily starting from the point of given technological, organizational, personal and educational preconditions from a southern German Community School. These will be generalized and thus lead to a comprehensive view on the integration of one-to-one tablet computer configurations in given complex settings of institutions in formal education system. This article will therefore result in general and system-independent conclusions and recommendations practicable for school institutions, which are presented in terms of Checkpoints for One-to-One Tablet Integration in Schools.

**Keywords:** Tablet Computers, iPads, Learning Environment, Schools, ICT Infrastructure.

## 1. Introduction

Tablet Computers are supposed to bring one of the groundbreaking changes to learning inside and outside classrooms (cf. Johnson et al., 2013; and McLester, 2012;), even though their integration in school systems is far from natural or unproblematic (Armstrong, 2014). Since the 2010 introduction of the iPad, tablet computers grew immensely in importance, in private life as well as in professional settings (Griffley, 2012, p.8), which is for instance shown by the school tablet project map of Germany (Ludwig, 2014). Speaking of the field of education, approaches related to the use of tablet computers are mostly project-oriented, offering students a device for testing purposes but not for long-term use (cf., e.g., Hahn and Bussell, 2012, p.43).

Actually it can be stated that there are two main directions of research going into the use of tablet computers in formal education system: On the one hand side, the devices are being offered by institutions representing the educational system, such as schools or media centers. This can be the case in terms of tablet devices being used in a specific subject or project for some time, where students are using the technology just in classroom. The initial point for this procedure regularly is to be seen in the strong financial limitation of most educational institutions leading to a missing capability to comprehensively introduce one single device for all of the students, as well as in the comparatively low effort that has been invested before using the devices. Unfortunately, the additional benefit is also strongly limited because of missing continuity and missing opportunity for the students to get in contact with the devices in every day grid.

To overcome these issues, on the other hand side, there is another approach being discussed called BYOD (Bring-Your-Own-Device), which is partially seen as forward-looking approach because private available and already existing devices are being integrated in learning scenarios. Advantages are obvious: Since students are allowed to use their own technical devices, schools are not confronted with large costs for the purchase of these and, furthermore, students are responsible for the maintenance of the devices. The most important disadvantage of this approach is the integration of a variety of different

devices and different operating systems. This is not only challenging on a technical layer, but also from a pedagogical point of view, since educators have to check whether a specific app is available for Apple iOS, Google Android and Microsoft Windows Mobile. Furthermore, not every student might be equipped with a respective device, what strengthens the well-known digital divide (e.g., Ritzhaupt, Feng, Dawson, and Barron, 2013).

This article will further discuss a third possibility, a combination of these two approaches in terms of an one-to-one tablet computer equipment, which is supposed to combine strong advantages and minimize disadvantages that have been named above.

## **2. Learning with Tablet Computers**

Mobile devices in general and Apple iPads in specific have been proposed for a while now as an enhancement for classical school and class setting. Corresponding approaches may be classified into one-to-many and one-to-one configurations (Hahn and Bussell, 2012, pp.46; Pamuk et al., 2013; Miller, 2012, pp.54). In one-to-many settings, specific classes or projects are equipped with such devices. Also, class-sets may be made available for lending for use in specific subject fields. In one-to-one settings, on the other hand, schools or other institutions either target to equip each student with an individual device, possibly also for private use, or they allow for the use of privately owned devices in school. The latter approach is typically denoted as Bring-your-own-technology (BYOT) or Bring-your-own-device (BYOD) (Lee and Levins, 2012).

Different forms of this will be shortly presented in the following, which will be followed by the description of the specific situation at a southern German school, the Alemannen Community School Wutöschingen (ASW).

### *2.1 One-to-One Tablet Computer configurations*

While most experiences from the use of mobile devices in schools originate from one-to-many settings and pilots (for instance, Culén and Gasparini, 2011), corresponding studies and experiences in the one-to-one-field are less prevalent. The Portuguese Magellan initiative represents an example for the state-wide introduction of mobile technology in schools on a one-to-one basis. In this initiative, primary school children were provided with a low-cost laptop between 2008 and 2009. While this project received much recognition in the public, the results were less satisfying: The Magellan laptops were little used by teachers and students, on the one hand because of the lack of access to wireless Internet in schools, on the other hand apparently due to a lack of appropriate teacher training (Carvalho, 2011). These experiences highlight the imperative of appropriate infrastructure and teacher support when trying to implement a one-to-one strategy.

Foote (2012) describes a district's approach in the direction of establishing a one-to-one iPad program and first positive results from a pilot. For instance, 88% of the students reported an enhancement of learning experience, and 90% stated a somewhat positive or positive effect on their motivation to learn. Foote also highlights the value of supporting activities, such as the installation of a help-desk and voluntary after-school meetings. The Steve Jobs Schools in the Netherlands represent a recent case for the implementation of a one-to-one configuration with iPads at elementary school level (O4NT, 2014). The O4NT approach without doubts can be seen as exemplary, since here the focus is on a new pedagogy, leading to a novel curriculum, where iPads play a crucial role. However, evaluations of this approach are still missing.

BYOT or BYOD initiatives at school level are more rare, and reports on the implementation of such programs even more. McPhail and Paredes (2011) report from some pilots in this area, the development of a corresponding district's policy, and directions to successfully implement a BYOD approach.

### *2.2 Situation at ASW*

Tablet-related situation at schools often is that students are just punctually equipped with the devices in terms of specific lessons or short-term projects. They thus are regularly confronted with a short usage time of the devices and extensive potentials of these aren't used, because they are not understood as personal learning environment (PLE). At ASW, school and commune found a way to cooperatively offer students the proposal to lease a tablet computer (in this case, an Apple iPad Air). Students are allowed to use the devices for private life, leading towards a personal device, which is also used for

learning purposes. For the leasing itself, a public advertisement was offered and the computer leasing company offering the best proposal was chosen. For the specific understanding of the next steps of tablet integration at ASW, a short excursus on the school system at ASW itself is of relevance.

### *2.2.1 Excursus on ASW School System*

Over the past five years, school system in the German federal state Baden-Württemberg changed immensely. While the classic German educational school system mostly differentiates three school forms (low track, middle track and high track), some schools in Baden-Württemberg chose to move beyond this manifested external differentiation and integrated all tracks in one school, implying huge requirements related to individual learning and advancement. At ASW, this new system was integrated for fifth graders four years ago and was continued the following years. For now, students of the fifth grade, sixth grade as well as seventh grade (and from September 2014 on also 8<sup>th</sup> grade) are learning in this self-directed way. In total, about 450 students are visiting the ASW.

### *2.2.2 Technical Requirements*

Before the students are equipped with and actually can use the devices in their daily grid in school, the school has to make different technical as well as pedagogical arrangements. In a first step, the availability of an adequate internet connection has to be named, which is capable of offering an enduring and stable internet connection via wireless networks. An adequate internet connection with good data transmission as well as router devices with the respective capacity are necessary (Armstrong, 2014, p.45). At ASW, we use a 120 mbits/s connection in combination with an Apple MacMini Server is caching the internet data to improve the connection. Additionally, web access monitoring is necessary.

Besides these aspects related to the internet connection, the maintenance of the devices is another aspect of particular importance. Not only related to the procedure in case of problems or technical failures, but also related to installed apps, updates and general software settings. The respective school has to decide what aspects it can come across by own employees (mostly teachers) and which aspects should be outsourced. Accordingly, system administrators have to think of effort neutral ways to keep the systems up-to-date, what points towards installed apps and software settings. One interesting and helpful endpoint management software package which is being used at ASW for the management of Apple products is the Casper Suite offered by JAMF Software.

Although the above described technical requirements are themselves extensive in preparation and lots of additional work where ICT-experts are needed, the real challenge is not to offer the technological framing of learning processes, but to amend the given school system in a reasonable way.

### *2.2.3 Pedagogical Requirements*

Anyway, to achieve this added value, a pedagogical concept, which names concrete procedures how to come across the technical possibilities and problematic issues besides the technical aspects, has to be developed. It has to begin at the school-specific situation, including teachers, involving different existing committees (with students, parents and teachers), to consider the peculiarities of different departments, taking into account technical infrastructure and furthermore. The situation often differs a lot, because schools in German federal state Baden-Württemberg are often missing in a media development concept, leading to technology being irregularly used, not finding its way into every-day use at schools.

At this point, a concept has to be developed, connecting the given resources and technological surroundings to the capacity of teachers as well as students. While professional training programs especially for teachers are (independent of the teachers' age) necessary and have to support teachers in integrating new technology in their working schemata, students regularly need introductory courses to be aware of critical aspects of the devices. Ideally, students would use their own tablet device without extensive software-based restrictions, but are self-consistently aware of the use of their device. Limiting the access of internet (in school or at home) or specific apps are said to possibly lead to a reduction of interest in using the devices (Pamuk et al., 2013, p.1819).

## **3. Educational Concept at ASW related to tablet computers**

As we are speaking of the ICT-related training of students: Every ICT-affine teachers knows that there are always some kids around, which are good in using ICT. Sometimes, they are even better than the respective teachers. While some teachers see this as challenge of their authority, the relation between

student and teacher should be understood as educational partnership, where both can learn from each other. So why not taking some ICT-competent learning partners and give them some challenges in terms of providing other students or even teachers in case of ICT-related questions? At ASW, we are about to integrate a student ICT team called “Junior IT-Supporter” in our concept. But this is just one point of the respective concept, which will be extensively discussed in the following.

### *3.1.1 Situation at the time of tablet integration*

As was described above, the tablet-related concept is closely related to the general pedagogical concept of the ASW, which is pointed towards the individual development and promotion of the students. They are learning in a self-directed way and teachers are more or less understood as educational companion who can be asked in case of uncertainty or questions. For this system, equipping every student with his own digital device seems to be a proper way of facilitating the learning processes.

One aspect worth mentioning is the decision for really equipping every single student with one Apple iPad Air using a leasing model, which leads towards the discussion whether students are allowed to use the devices in private context, too. Since especially the private using space allows for extensive media educational experiences, we decided that students are not only allowed to use the devices in private context, but also that they are being motivated to do so. Following this argumentation, it's both the teachers and the parents who have to support students in case of problems and questions. Since parents are just partially involved in these digital devices, workshops for parents of students are an aspect of particular importance, too.

Another aspect of importance is the personal responsible for the introduction of the new devices, which in the case of ASW are two regular teachers. Integration of the tablet computers had to take place during regular school semester, causing demands from the teachers, students and especially the organizing team. Of course, respective teachers had to do most of the related work besides their regular lessons, depicting the given system-dependent limitations. This also shows the meaning of an early and sufficient development of a detailed technical as well as pedagogical tablet computer concept. Without it, the necessary work might overwhelm respective teacher personal.

### *3.1.2 Educational Concept*

To enable to relate to the situation at ASW, a short timetable should be given at this point presenting the first steps towards the tablet-integration at the school (see table 1). Because of the immense demands, all teachers of ASW were trained in terms of an Apple Professional Development (APD) training, including first steps towards using tablets, but also including specific subject-related ideas for classroom use. By this procedure, anxiety and skepticism of most participants could be reduced. As was described above, the students need some sort of training, too, especially related to technical possibilities of the devices but also to security issues such as password security or the use of mobile and wireless connected internet. In specific, the amount of training at the beginning of iPad integration is supposed to be higher than some time after the beginning. This leads to the punctual necessity of support, which supposedly cannot be given by regular teacher stuff.

At this point, one possibility is an external company, which regularly is way too expensive for schools and, thus, in most cases unrealistic. Another opportunity is the development of the above mentioned concept of Junior IT-Supporters, which have to be trained in advance but can be motivated by, e.g., a certificate. These might be able to answer some of the basic questions of students, and thus are supposed to massively lower the long-term every-day involvement of respective teacher personal.

In a long-term view, most of the below mentioned requirements are from time to time coming back again, at least every year where new students are coming to school and have to get equipped with tablets, too. Furthermore, concepts like this are in need of an ongoing critical evaluation, analyzing and supporting the related processes. Extensive information about the evaluation of the presented concept cannot be given at this point, because the related concept is just at working status at the moment. Nevertheless, it is planned to include quantitative paper-based questionnaires as well as qualitative interviews with students and teachers.

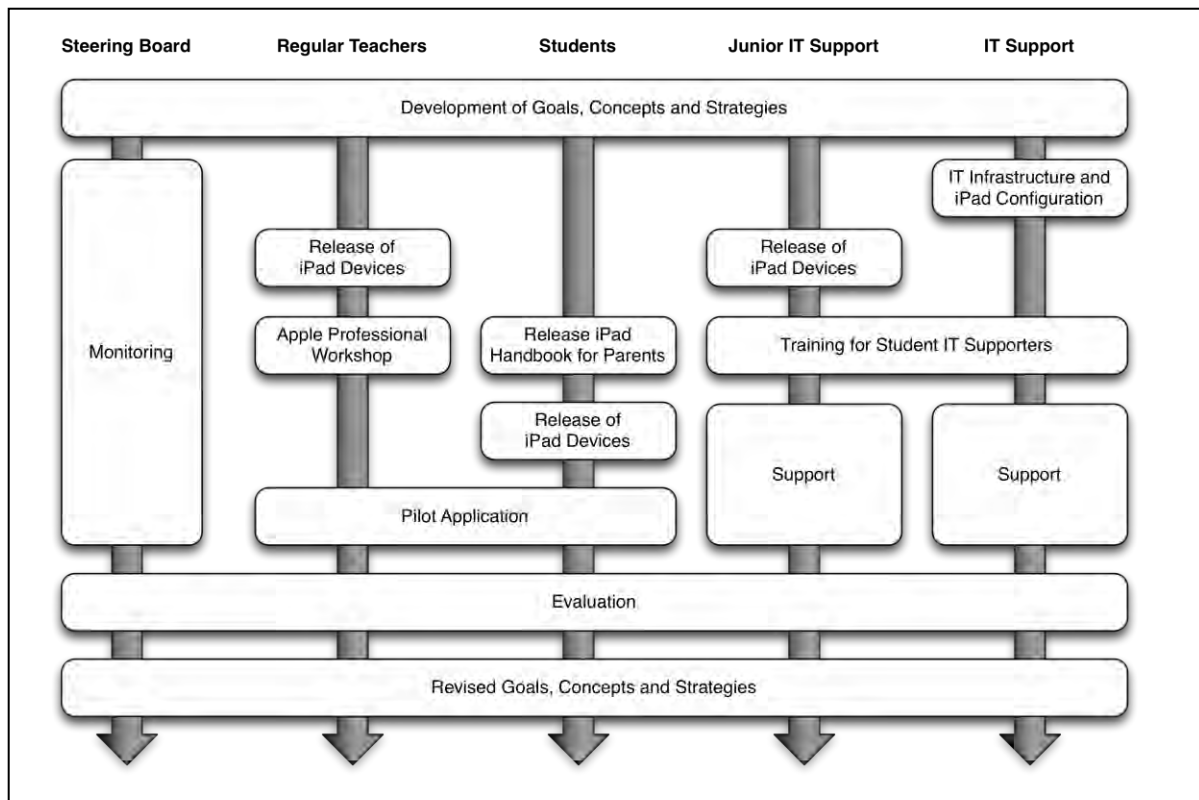


Table 1: First steps towards the implementation of a One-to-One tablet solution at ASW.

### 3.1.3 Resulting Checkpoints for the Integration

From the actual point of decisions and experiences during the first months before introduction of the tablet devices, some advices can be given for implementing a One-to-One tablet learning solution. It is supposed that these checkpoints are covering all necessary aspects, but whether or not these aspects proved to be good in the given context, is to be proven in terms of the evaluation. At this point, we cannot give extensive information on evaluation results or else, since first evaluation results will be available at the end of September, 2014.

- **Think about the effort that comes with the tablet PC integration.** How can the tablet devices be organized? Is it practicable for your school to administrate the devices, do you need an extern supporter? What are the consequences for the technical equipment at school (e.g., the network?).
- **Decide, which system you will use.** This decision has to be carefully taken in respective of the given preconditions. Because of the variety of possibilities, some helpful hints might be: What system do you use on your school computers? In case you use Apple iOS, it's a lot easier to use iPads than, for instance, Google Android tablets. What is your local ICT supporter good at? What's the opinion of students, parents and teacher stuff?
- **Carefully choose the point of delivery.** It's not important to deliver the devices as fast as possible to teachers and students, but to have a practicable implementation concept before delivery. At least, some stepstones should be clear. Otherwise, the risk of missing structure is at hand what might lead to long-term problems such as missing use standards or missing support structures.
- **Don't leave the students alone with the new device.** Students will be motivated and interested, but will also need support related to, e.g., security issues or taking responsibility for the device.
- **Discuss the concept in advance.** The respective concept is to be discussed with teachers as well as with students to broaden the acceptance of the devices as well as the concept. This is a factor of underestimated importance in terms of really changing individuals internalized procedures and thinking (cf. El-Gayar, Moran, and Hawkes, 2011), which is linked to literature on technology acceptance and the corresponding theories (Fishbein & Ajzen, 1975).
- **Don't forget the parents!** In this case, students were also allowed to use the devices at home, (and not to forget: parents are supposed to pay the leasing fee in our case!). It's thus an essential part to keep the parents involved. They need training, support and understanding for their sorrows, too – just the way students and teachers need it, when they are confronted with a new device.

- **Teachers need ongoing support!** They are in need for trainings related to the new devices. It's not just how to privately use the device and to learn some basic facts on it, but also how to implement the devices in different learning scenarios and working schemata.
- **Use given resources!** There's always the question how the effort can be overcome. Think about ICT literate students supporting other students and thus minimizing the effort for teacher personal.
- **Question your way.** Think about the possibility of a practicable and ongoing evaluation with low additional effort to reveal problems of integration of tablet computers in schools.

Keeping these checkpoints in mind during the integration of technical devices in learning scenarios, chances are good that new devices really get integrated in learning. Furthermore, these aspects are not just applying for the tablet device integration at schools, but also for other technical devices such as laptop computers or smartphones.

#### 4. Future Work and Conclusions

The presented article discusses the potential of One-to-One tablet configurations in terms of formal educational system and finally highlights the relevance of different dimensions which have to be taken into account when thinking about an One-to-One tablet equipment. On this basis, it finally presents checkpoints for the integration of tablet computers in schools, which resulted from an adequate literature review as well as extensive discussions with school principal and respective teachers. These can also be understood as dimensions fostering or restrain the integration of tablet computers, showing a good starting point for the development of respective qualitative and quantitative research approaches. Nevertheless, the above named aspects are in need of evaluation in short-, middle- and long-term view. First experiences as well as first evaluation results will be named in the forthcoming presentation.

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# CHiLOs: A New Virtual Learning Environment for Large Scale Online Courses

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**Abstract:** This research reports the development of a new online platform for Large Scale Online Courses (LSOCs) that combines e-textbooks and a Learning Management System (LMS) such as Moodle or Canvas in an effort to increase course completion rates. The platform, called Creative Higher Education Learning Objects (CHiLOs), consists of e-textbooks, e-lectures, digital badges, and learner's communities.

**Keywords:** Peer-to-peer learning, Open Education, Large Scale Online Courses, e-book, e-textbook Learning Management System, GakuNin, Massive Open Online Courses, lurker

## 1. Introduction

One of the main goals of Massive Open Online Courses (MOOCs) like Coursera and edX is to make higher education available to everyone. Many people worldwide experience barriers to higher education such as social restrictions, geographical disadvantages, and academic expenses. Anyone who wants to study at higher education institutions should be able to learn any time and any place. Large Scale Online Courses (LSOCs) using videos, assigned readings, and problem sets can provide hundreds or thousands of learners with access to higher education in a stable format.

LSOCs provide access to learning content, distributed content, and virtual learning environments (VLE) after users apply for the course and are authenticated (see Figure 1). However, LSOCs face some challenges:

- **Network stability:** Relying on a specific vendor (vendor lock-in) causes less stable operations. This was seen when Coursera experienced a partial outage caused by failure of the Amazon Web Services system (Gupta, 2012).
- **User authentication:** Biometric authentication and video monitoring are less cost-effective than examination at the traditional classroom (Arnold, 2013; Young, 2012).
- **Completion rate:** The average completion rate of a MOOC is less than 10% (Hill, 2013).
- **Peer-to-peer learning:** The face-to-face learning experienced in traditional classroom environments is not always possible in LSOCs because a number of learners.
- **Ubiquitous learning environment (ULE):** The use of the web paradoxically prevents diverse learners from studying in the ULE (Yang, 2006).

The authors propose an architecture for LSOCs using e-textbooks as a learning management system (LMS) interface, 1-minute nano lectures, and Academic Identity Federations (AIF) (see <http://refeds.org>) by dealing with open education in Japan's higher educational community as well as focusing on lurkers and tutors called by Connoisseur such as experts in our online communities. E-textbooks are advantageous due to their portability and learnability (Jamali et. al., 2009). Therefore, our user-friendly LMS interface using e-textbooks can create a ULE for diverse learners regardless of their computer skills or network access.



Scope of LSOCs

|                              |                            |                     |
|------------------------------|----------------------------|---------------------|
| Content                      |                            | Learning content    |
| Content platform             |                            | Distributed content |
| User authentication          | Application                | Distributed VLE     |
| Cloud computing              | High performance computing |                     |
|                              | High-speed networks        |                     |
| High-speed internet services |                            |                     |

Figure 1. Scope of LSOCs

## 2. CHiLOs project

### 2.1 CHiLOs structure

We developed the Creative Higher Education Learning Objects (CHiLOs) project for open online courses in Japan. CHiLOs consist of 1-minute lectures, e-textbooks, digital badges, and learners' communities (Figure 2).



Figure 2. CHiLOs structure

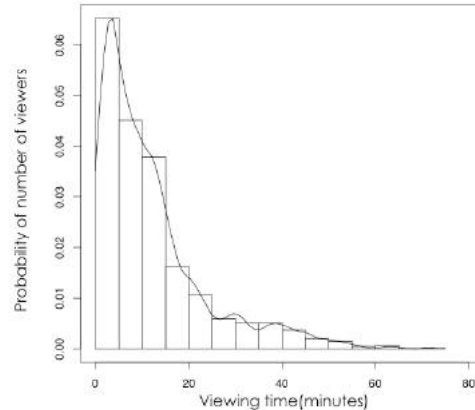
Through the CHiLOs project, the authors of this paper aim to develop a new VLE based on an e-textbook user LMS interface called CHiLO Book. The CHiLOs' VLE consists of 1-minute nano lectures called by CHiLO Lecture and will provide digital badges called by CHiLO Badge based on the user authentication by means of the AIF. Additionally, each CHiLO Book is granted a digital object identifier (DOI) (see <http://www.doi.org>) to ensure that it is traceable and is discoverable in web searches. Finally, CHiLO Book will contain varied Internet resources to replace a traditional web browser (Hori et al., 2012; 2013). These elements will achieve a flipped classroom, which may facilitate the creation of several small communities of learners within the LSOC called CHiLO Community; peer-to-peer learning will be achieved through these communities. The CHiLO Book and CHiLO Lecture distributed and the presented CHiLO Badge in the CHiLO Community will help develop educator-to-learner and learner-to-learner links and further promote mutual understanding of the educational content.

### 2.2 Lurkers in online communities

90% of the users in most online communities accessed by the general public are lurkers who only browse and do not actively participate (Nielsen, 2006). In LSOCs, it is common for learners to drop out because they do not want to try a quick quiz or assignment and many do not contribute to message boards. This is referred to as pedagogical lurking (Dennen, 2008; Rodriguez, 2012) and such lurkers are prominent in MOOCs. In short, LSOCs should aim to motivate pedagogical lurkers to contribute.

### 2.3 CHiLO Lecture

In designing our system, we analyzed data obtained from an actual 2008 experiment with open courses involving 30,000 learners (Hori et al., 2013). As shown in Figure 3, the probability of the number of viewers decreased over viewing time.



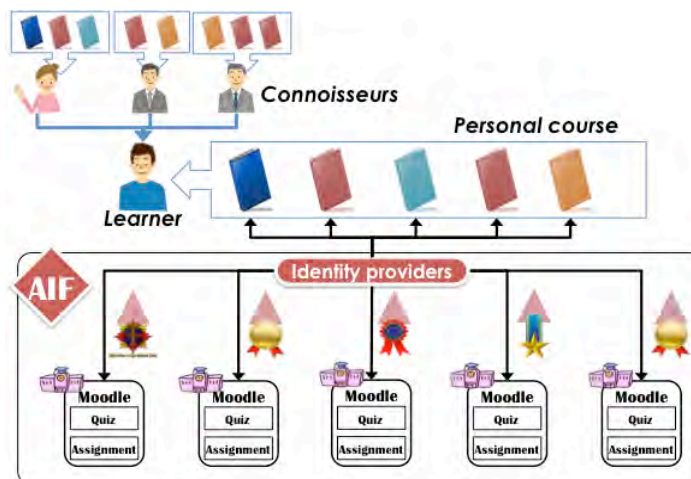
**Figure 3. Learners' viewing time**

The results of the experiment showed that most learners prefer short, 1-2 minute lectures. Therefore, in the present study, we focused on creating 1-minute nano lectures and developed an LMS interface using 1-minute nano lectures in CHiLO Book. This structure is called CHiLO Lecture.

A complete CHiLO course consists of 15 CHiLO Books and each CHiLO Book includes approximately 10 CHiLO Lectures. Learners receive a CHiLO Badge after they complete each the CHiLO Book and the CHiLO course. Diverse learners and lurkers can easily and repeatedly access these short lectures and gain CHiLO Badges. The present study showed that repeatedly viewing a series of CHiLO Lectures and receiving CHiLO Badges for completing assignments provided the same learning effects as “the mastery learning approach” advocated by Bloom in Coursera’s experiment (Do et al., 2013).

### 2.4 Peer-to-peer learning in CHiLO Community

LSOCs should be diverse enough to attract a wide range of learners, including lurkers. Lurkers have a tendency to passively disseminate and search for information (Bishop, 2007), and supportive learning communities can help them become more interactive. Peer grading in MOOCs is currently not adaptable to lurkers who only browse and lack motivation. Although face-to-face teaching is required for learners on LSOCs, it is impossible for so many learners.

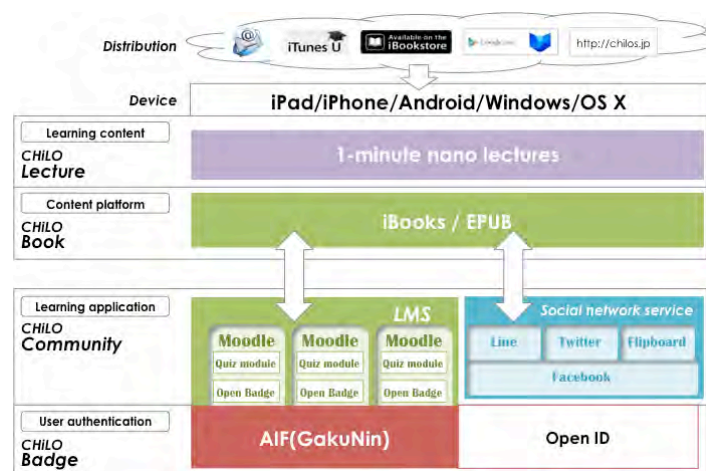


**Figure 4. Relationship between educational Connoisseur and learners**

We propose new peer reviews of the CHiLO Lecture, encouraging learners to become Connoisseur. University educators manage learning communities in traditional higher education online courses; however, learners themselves organize the communities in peer-to-peer learning. Our Connoisseurs are not teachers, but reputable learners. They create small groups or classroom communities, support learners through peer-to-peer learning, and integrate information according to the learners' levels. Figure 4 shows the relationship between Connoisseurs and learners in CHiLO Communities using CHiLO Books with AIFs (<https://refeds.org/resources/>) of which authentication trust framework is maintained by each country..

### 3. Implementation of CHiLO Book and CHiLO Badge in CHiLO Community

CHiLO Book and CHiLO Badge are developed under the above-mentioned concept of peer-to-peer learning in CHiLO Community. Figure 5 shows the development of CHiLO Book, CHiLO Badge, and CHiLO Lecture.



**Figure 5.** Components of LSOCs by the CHiLO Books

#### 3.1 Moodle-based development using GakuNin

The LMS of CHiLO Book was configured and developed on Moodle, a commonly used open source LMS, using the present Application Programming Interface (API). Since Moodle is an open source system, each university can run it independently. Moodle 2.x is the basis of the CHiLO LMS, so Open Badge from the Mozilla Foundation can be issued as CHiLO Badge. The Moodle LMS have to be configured to activate SAML authentication and then be registered as one of the service provider in GakuNin; the Japanese AIF. This helps us to solve the identity management issues in LSOCs in the sense that providing and updating GakuNin user data is the responsibility of the affiliated universities (Yamaji et al., 2010).

#### 3.2 CHiLO Book configuration

A typical CHiLO Book is about 20 pages and consists of a lecturer video, a lecture summary, lecture content and a unit examination. There are 1-minute lectures, the lecture scripts, slides, a link to a comment box allowing the user to post to Facebook, and each page of the book has a link to quizzes on the material presented.

### 4. Discussion

#### 4.1 Micro LSOCs in CHiLOs

Online content in CHiLO Lectures is divided into 1-minute nano lectures. Online content in CHiLO Books is distributed by many LMSs using e-textbook interfaces. CHiLO Community encourages peer-to-peer learning so that each individual in the community becomes an active learner as well as a Connoisseur. Therefore, the CHiLO project consists of various micro systems distributed within LSOCs.

The benefits of micro LSOCs in the CHiLO project are as follows:

- CHiLO Book has desirable features for VLE which have scalability for distributed systems in LSOCs.
- CHiLO Lecture enhances learning effects through distributed 1-minute nano lectures that learners can repeatedly study.
- CHiLO Community creates a supportive peer-to-peer VLE for lurkers because the content is easily accessible and do not to require learners to be computer literate.

However, micro LSOCs in the CHiLO project also have the following disadvantages:

- Management of the integrated system for the distributed LMS is complicated. Therefore, it is difficult to process high volumes of data relevant to learners' private information and learning outcomes.
- Creating many 1-minute lectures is laborious and requires specific skills and knowledge.

#### 4.2 *Integrated micro LSOCs*

CHiLOs' distributed architecture enables scalability of LSOCs. Learners are required to find the relevant information from the distributed learning resources. That is, connecting with other learners who have a similar learning target is an important functionality offered by CHiLOs.

Within a CHiLO course, there is an option for users to allow their CHiLO Badges, which are issued from each individual LMS, to be aggregated into the main CHiLO LMS server. CHiLO Badges can contain embedded principal information of the learning process such as selected CHiLO Books, meaning that the CHiLO LMS server plays a role in allowing learners to discover and connect with each other. In addition, CHiLO Badges can be seen as a certification of user attributes, especially in the e-learning field. Although the identity provider in the AIF can provide minimum user attributes which are managed by the users' home organization, the CHiLO LMS server can provide additional course certificates in the form of CHiLO Badges. The CHiLO LMS server will play an important role as an attribute provider of micro LSOC networks based on the AIF.

### 5. Conclusion

The MOOCs movement has created a new educational environment that impacts a large number of learners. New merits of MOOCs are expected to emerge as a greater number of learners with different skills and values use the same VLE. On the other hand, Dennen (2013) showed that weaknesses such as prior experience, external vision, support needs, faculty incentive, and political climate are disadvantages of MOOCs. Furthermore, to provide stable and instructive services to many learners, we must radically change the way online learning is compared to traditional education.

In traditional education, university teachers provide educational content to students according to the curriculum (content platform) designed by the university. Students physically gather on a campus to receive guidance from the teachers. The university provides accreditation for their achieved learning outcomes. In other words, universities centrally manage all aspects of a student's learning. This method can only provide learning opportunities to a limited number of people and is unable to fulfill the learning demands of modern society.

CHiLOs LMSs are designed not only to serve as a system that conforms to LSOCs, but also to significantly change the framework of traditional education. In traditional education, universities only exist to grant degrees and teachers just transmit information. In future LSOCs, there will be significant changes to academics as students can freely select the content that they want to learn and create their own curriculums.

Furthermore, the support provided to lurkers by introducing social network service and 1-minute nano lectures in the CHiLOs-based environment cultivates intellectual curiosity among learners and can be a good learning environment for increasing online course completion rates.

We believe that the educational roles of traditional universities should incorporate MOOCs and CHiLOs as they are better able to meet the diverse requirements of modern society. CHiLO book is one of many possible strategies universities could implement to meet the diverse educational needs of individuals, organizations, and society.

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# Mobile 2.0 learning: Empowering mobile learning with socialized context sharing

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**Abstract:** With an experience in the development of web-based learning, mobile learning, and web 2.0-based learning, we have seen an emerging trend in the integration of web 2.0 technology into mobile learning, so called Mobile 2.0 Learning. By analyzing previous studies with the model of social cognitive theory, we reveal that their integration is not in conflict with each other; in contrast, Mobile 2.0 Learning may reframe the relationship between environments inside and outside of school. The social interactivity of Web 2.0 can improve students' sense of community and collaboration in mobile learning. Mobility and context capturing facilities can support learners to exchange information in daily life and further develop context-specific competences in an informal social community. This study first introduces the components of Mobile 2.0 learning and its unique characteristics. Next, the key elements driving Mobile 2.0 were illustrated by an example to show their processing flow. Finally, further research issues of Mobile 2.0 learning were proposed. It is hoped to provide readers a potential research blueprint by this study.

**Keywords:** Mobile learning, Web 2.0, Mobile 2.0, social networking

## 1. Introduction

In recent years, researchers have focused on the use of mobile devices to facilitate students' learning, called mobile learning. For example, (Y. S. Chen, Kao, & Sheu, 2003) demonstrated that embedding an encyclopedia of ecology in mobile devices might help students to better understand animals they may encounter. Smordal and Gregory (2003) also showed that use of mobile devices could provide learners more immediate and relevant knowledge, and might help their problem solving. In addition, a mobile device supporting a guide agent could suggest students an effective path when visiting certain wetlands (Tan, Liu, & Chang, 2007). In short, one benefit of mobile learning is to help learners to understand content immediately and efficiently (Hsiao, Lin, Feng, & Li, 2010).

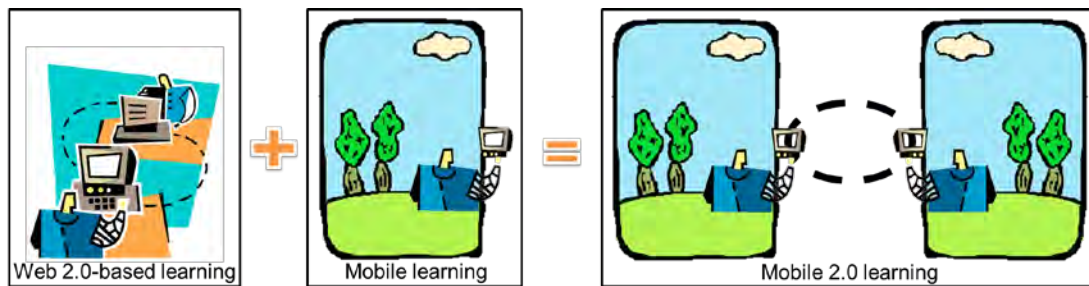
The other major advantage of mobile learning is to connect students to nature, which is a knowledge-enriching experience (Maldonado, Pea, Spikol, & Milrad, 2010). As noted by Wan and Lam (2010), students perceived authentic objects or examples can acquire a deep understanding of concepts. Roschelle (2002) also pointed out that mobile learning could effectively motivate learning by augmenting physical space, leveraging topological space, and aggregating coherently across all students. In other words, mobile learning helps encourage students to explore the outdoors and learn actively.

While considerable attention paid to either mobile learning or web 2.0-based learning, the current development still has much room to advance (Frohberg, Gothe, & Schwabe, 2009). For example, Frohberg et al. (2009) found that most mobile learning projects occur in independent and formalized contexts, but hardly in a socializing context. Similarly, Hughes (2009) noted that there was high use of Web 2.0 tools for playful activities, but low use for collaborative knowledge construction. To cope with these limitations though involving an experience in the development of both technologies, we have seen an emerging trend in the integration of web 2.0 technologies into mobile learning, so called Mobile 2.0

learning (M2L). Our main goal thus is to introduce educators an innovative instructional tool and provide researchers a potential research blueprint.

## 2. The components of Mobile 2.0 Learning

In recent years, we have seen mounting evidence of the usefulness of educators' incorporating E-learning systems into their teaching, but we also noticed a shift in patterns of E-learning systems. The ensuing section describes each type of environment that configures M2L. Figure 1 shows the relationships among Mobile learning, Web 2.0-based learning, and M2L.



**Figure 1.** Relationships among web 2.0-based learning, mobile learning and "Mobile 2.0 learning"

Nowadays, many students are used to communicating with each other through voice or short messages by mobile phones. Traditionally, students used mobile devices mainly to *pull* resources passively from web-based contents (Sharples, 2002). Contrary to passively accessing traditional web-based contents, most students are now willing to actively use Web 2.0 technologies to create, *push* and share information. For example, students can actively upload learning content or a lecture video in a blog system. Peers can immediately access the information just uploaded and then post their responses to it. However, these prompt *pull* and *push* actions are foiled by using desktop computer facilities (Y. M. Huang, Jeng, & Huang, 2009).

Thus, the integrated M2L cannot be defined simply as extending the Web 2.0 services to mobile learning. What is more, through the convergence of the social interaction and situated learning, M2L should reshape a new paradigm of educational experience for instructors and learners.

## 3. The key elements driving Mobile 2.0 learning platforms

The analysis in the former section showed that the purpose of MW2 is to create higher levels of interaction and value-added outcomes through the integration of learning contents and contextual information. As follows, aggregation, dynamics, sensors and alerts are the key elements in driving M2L:

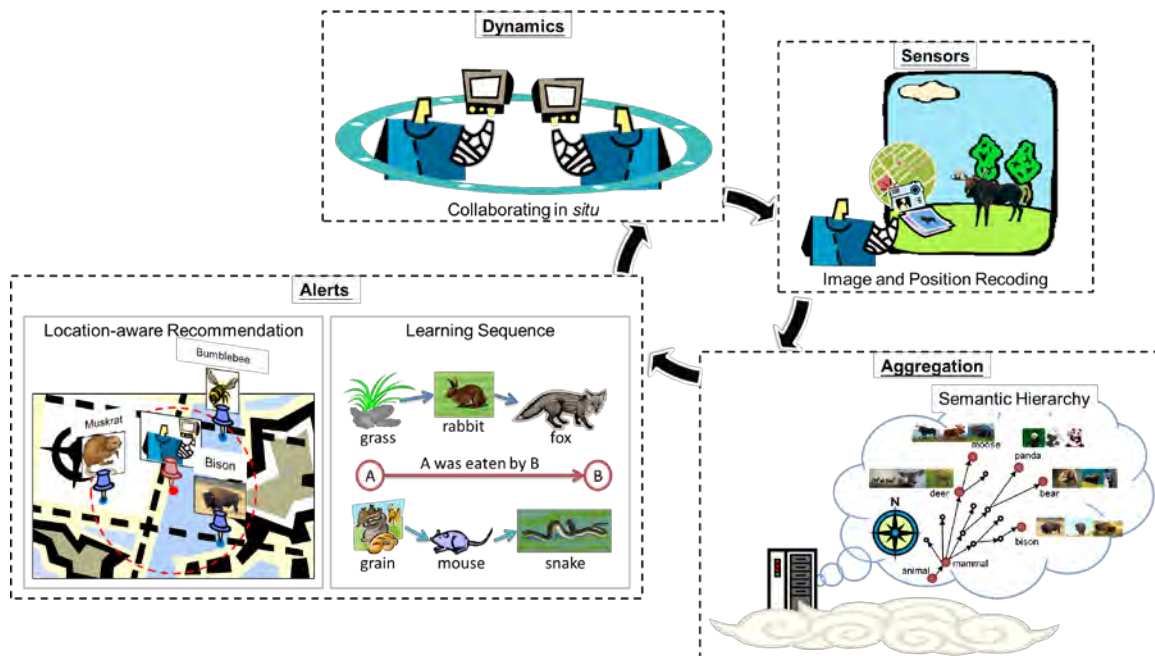


Figure 3. Illustrative example of the processing flow of the four key elements supporting the mobile 2.0-based ecological learning

*Aggregation* is a key interface element for M2L. The functionality of an aggregation is to harness collective intelligence (Bosse, Jonker, Schut, & Treur, 2006). Thus, it is necessary to create content, represent it with the current context, and publish it to the web. For example, G. D. Chen and Chao (2008) developed a web-based discussion forum for collecting students' contextual messages from traditional paper textbooks, and then to facilitate collaboration among community members and offer timely, contextual assistance in students' study based on their reading status.

Because mobile devices generally suffer from limited resources, the usability of an aggregation is a vital element driving the usability of M2L. Therefore, the interactive means provided by mobile devices must be short and make learners willing to communicate more frequently and instantly in a natural environment (Counts & Fisher, 2010). The learning management system (LMS) could be modified to achieve this goal. Environment implementers need to take responsibility for the usability of the aggregation, not just by easily gathering content, but also by representing content according its context. Summarization methods serve as an intermediate agent to build effective aggregation for interchanging content on different mobile devices (Carpineto, Mizzaro, Romano, & Snidero, 2009).

*Dynamics* refers to the capability of M2L to create a host of collaborative environments caused by both the mobility of devices and the varied contextual information of individuals. M2L environments will create dynamic grouping techniques. These techniques can group learners based on the instantaneousness of their context (N. S. Chen, Kinshuk, Wei, & Yang, 2008; El-Bishouty, Ogata, Rahman, & Yano, 2010; J. J. S. Huang, Yang, Huang, & Hsiao, 2010). On the one hand, learners can provide their knowledge according to its contextual information and get a deeper understanding of concepts through a merged view of context. On the other hand, learners will interact with each other in a heterogeneous group because this kind of grouping will have a higher variety within a group (Hooper & Hannafin, 1988).

*Sensors* provide the rich situated contexts for M2L experience. Besides location, sensors will capture more of the learners' surrounding information such as data-logger, audio recording, photo, camera, physiological signals, and so on. A true M2L application will integrate these sensor data to know the exact context of your surroundings as well as your profile of preferences and then match them with relevant learning services and learning contents. For example, Hsiao et al. (2010) offer a location-based service to present the learning materials and activities related to the learning zone to the students automatically.



*Alerts* let you know what you need to know. Many mobile learning applications are already taking advantage of alerts, which can notify learners of a variety of events, such as moments of vocabulary learning (C.-M. Chen & Chung, 2008) and recommendations for peer mentors depending on one's schedule (G. D. Chen, Chang, & Wang, 2008). Nevertheless, as learning becomes Mobile 2.0, new opportunities for motivation enhancement will emerge: for example, noticing near learning companions (J. J. S. Huang et al., 2010), guiding a student to the target learning object (Hwang, Kuo, Yin, & Chuang, 2010), or recommending a learning task according to a learner's context (Ogata, Saito, Paredes, Martin, & Yano, 2008).

Figure 3 depicts an illustrative example of a hypothetical learning process driven by the four key elements of Mobile 2.0 tools. Consider the "Identification of Animals" task in a natural science course of an elementary school. First, the students discuss the characters of the deer family in their own micro-blog, which can be grouped by their instant interests. Students can temporarily collaborate to understand the similarity and differences among the deer family's animals. This can be done even with students who are not in the same city or country. Next, students can visit zoos, villages, or wildlife parks to investigate the species of deer near their places. If students meet a Moose in the field, they can take a picture of the moose as well as embed the contextual information such as the original geographic position and the moose's voice in the image. Moreover, students can use a data-logger to collect environmental information such as temperature, humidity, or the pH of water and soil. The sharing of *in situ* behavior could facilitate students to contribute their personal knowledge to the learning community. Third, when students finish the animal tour, they can send the surveyed data to update the knowledge aggregation on the cloud-based server. This aggregation can represent the deer family with a hierarchical knowledge structure. The hierarchical knowledge structure can summarize the tree items into a compact tree according to the students' context. Finally, during the next tour, the students can request and receive information about the other nearby animals. With the support of semantic technology (e.g., the feeding relationships between animals), it is possible to recommend an adaptive learning sequence and students will be able to acquire a deep understanding of the concept of feeding relationships in an ecosystem.

#### **4. Conclusions**

M2L can create a learning environment that is authentic, collaborative, communicative, engaged, and effective. It also can provide improved collaboration efficiency, enhanced learner communication, increased content contextualization, and continuous interactivity. Current implements are already demonstrating the effect of collaborative context sharing with mobile devices, even though they are pilot investigations and affective in orientation. However, a great deal of research effort is required to realize the complete idea of M2L and to understand its pedagogical implications.

Finally, it is worth emphasizing that M2L is not a replacement of other types of learning environments, but an extension of them since the M2L concept is complementing the features of web-based learning, mobile learning and Web 2.0 concepts. In the ideal situation, M2L will be expected to support a real-situated collaborative learning, where the feature of context-awareness comes from the portability and flexibility of mobile devices, and the feature of collaboration comes from the people's interactivity of the Web 2.0. Before such situations can be achieved successfully, we need to address these challenges and further research issues explored in this study.

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# Enabling a Positive First Year Experience in Higher Education through Social Media and Mobile Technologies

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**Abstract:** The first year experience for students within Higher Education institutions has become increasingly important as these institutions strive to improve student retention rates. With many universities also focusing on transforming teaching and learning in an effort to attract and retain students, there is a growing demand to understand and respond to individual student requirements, such as the need to feel a sense of belonging. The literature identifies a sense of belonging as being paramount to a student's satisfaction with the institution and it is within this context that this paper reports on a three year study of how first year pre-service education students use social media and mobile technologies in their personal lives and their formal education. More specifically, the study identifies trends in the use of these technologies and the growing need for students to use digital media sharing tools to connect and engage with their peers. The paper contrasts the differences in use between these groups as it seeks to identify the role these technologies can play in their teaching and learning, as well as in promoting an overall positive first year experience.

**Keywords:** Social Media Technology, Mobile, First Year Experience, Connected Technologies, Pre-Service Education, Higher Education, Sense of Belonging

## 1. Introduction

The Higher Education landscape is currently in a state of change with many institutions focusing on transforming their teaching and learning and attracting students through new online initiatives and courses. While the notion of adopting online tools to support teaching and learning is not new, many academic staff still struggle with ways to use these tools effectively to connect and engage with students, especially with the ever-increasing adoption of new social and mobile technologies by students. Teaching and learning experiences for students are often quite mixed, with reports of dissatisfaction by students and a gap between how students perceive satisfaction and how instructors perceived satisfaction. Most recently, this was reported by Khalil and Ebner (2013), as they explored the experiences of students in online courses, with a particular focus of their research being MOOCs.

In recent years, there has also been a “significant decline in the amount of time first year students spend on campus” (James, Krause & Jennings, 2010, p.2) as more and more undergraduate students increase their working hours and rely on recorded lectures and online resources. Understanding the student and the challenges that face them as they enter into the higher education scene has become a necessity for educators. Consequently, many Higher Education institutions now have a focus on the first year experience of students with the aim of improving student success and retention. While the concept around retaining students is not new (Wilcox, Winn, Fyvie-Gauld, 2005) and there are many theories (see Jensen, 2011) aimed at retaining students, there is some consensus that inclusiveness and a sense of belonging may improve student satisfaction and retention (Hoffman, Richmond, Morrow & Salomone, 2002; Napoli & Wortman, 1998).

The literature concerning the First Year Experience in tertiary education highlights the need for students to feel a connection to their institution; students must “engage academically, socially and personally with their institution” (Nelson, Quinn, Marrington, & Clarke, 2012, p. 2). It is within this context that Menzies and Nelson (2012) identify peer development as being central to a student's personal and academic development. However, despite the importance of peer support, not all

students have equitable access to peers: impediments to such access can be work or family commitments, or differences in gender, age or cultural backgrounds (Menzies & Nelson, 2012).

The literature also discusses other first year experience concerns, such as feelings of intimidation experienced by academically weaker students when in group work settings. According to Wilkinson and Fung (2002), minority students often found group discussions to be dominated by majority group students, and many researchers have reported that in mixed gender groups, male students can be more active participants than female (e.g., Underwood, Underwood, & Wood, 2000). It is such social comparison concerns of first year students that have been shown to affect the academic outcomes of students (Micari & Drane, 2011). In identifying social comparisons and their impact, social comparison indices were derived from an instrument that asked students to agree or otherwise with statements concerning academic intimidation in a groupwork setting and self-efficacy. Bandura (1997) further defines self-efficacy as the beliefs the learner holds about his or her ability to perform well in a particular academic domain. Micari and Drane (2011) reported how initial self-efficacy was significantly related to social comparison concern and comfort in a cohort of undergraduate students in one institution, with students who dropped out reporting significantly higher levels of social comparison concern than those who remained. In their findings, social comparison concern was seen to be significantly higher for minority students at one measure, and generally higher for women than men. While this has been the case in face to face learning environments, online environments can provide different experiences for students, which will be discussed next.

Virtual environments allow all students to engage in peer to peer social and learning centred activities (Menzies & Nelson, 2012), and it is possible that the ambiguity of identity that social media affords might ameliorate the concerns raised above. McCarthy (2010) used the social media site Facebook to create connections between first year students and found that social media created links between the international and local students. The local students reported that although they were interested in engaging with students from different cultures: “sometimes it can be hard interacting with some of the international students because of the language barrier but with Facebook, because it was online, it was really easy and enjoyable - so many different perspectives and opinions coming together” (McCarthy, 2010, p. 5). It was also recognised that the “best thing about the Facebook galleries was that they got everyone talking from day one - all of sudden I had all these new friends on Facebook and from there had friends in class” (p. 5).

This study was interested in determining whether the extent of the literature reported student use of social media, was taking place in the researchers’ institution and how this contrasted with the patterns of usage from the academic staff teaching these first year students. Arteaga Sanchez, Cortijo and Javed (2014) assert that as academics “it is necessary to reach a full understanding of our students’ perceptions of Facebook for academic purposes” (p. 146). Their results reported that social influence was the dominant factor in predicting the adoption of Facebook, and maintaining social relations with people with whom they share interests was the most important purpose for using Facebook. Students believed that using Facebook would be “free of physical and mental efforts” (Arteaga Sánchez, et al., 2014, p. 146) and it would allow them to improve their communication, collaboration and information exchange. In addition to increasing collaboration with students and instructors, Facebook could create a more comfortable classroom climate and increase learners’ motivational levels (Goertler, 2009). Facebook can also expand learning beyond a traditional classroom into informal learning settings (Bull et al., 2008; Yang, Wang, Woo, & Quek, 2011).

In terms of social media platforms used in Higher Education, Facebook has been the focus of many studies (see McGuckin and Searly, 2013; Roblyer, McDaniel, Webb, Herman, Witty, 2010 and Nykvist, Daly and Ring, 2010), though many of these studies have had quite small sample sizes. A large number of these studies have focused on supporting students or enhancing learning (often through communication strategies), hence being used in a social manner. The study by Nykvist, Daly and Ring (2010) focused on education students supporting one another as they undertook their practicum experience in Malaysian schools and once again reinforced the supportive nature of this medium. There is little doubt that social media and mobile technologies can support students, however, there is a need to better understand how pre-service education students and academics can embrace these to cater for and respond to student needs.

In an attempt to better understand the strength of these technologies and how students use them in their studies and private life, this paper will describe a study conducted over a three year

period. Although this study is still underway, we are able to provide some initial recommendations for future teaching and learning practices to support students in their first year experience through the use of these technologies.

## **2. Methods**

A mixed methods approach was adopted for this research. Using Creswell and Plano Clark's (2011) definition and core characteristics (p.7), the study combines 'methods, a philosophy and a research design orientation'. During the research, data was collected and analysed using both qualitative and quantitative methods. A qualitative case study methodology based on Yin's (2003) model for exploratory case study using multiple sources of evidence was applied in this study. The study was designed to understand how students entering a pre-service teacher education program used mobile devices and social media and the possible impact that these technologies had on student retention and student first year experiences. It also explored how academics, teaching first year students, used social media and mobile technologies in their academic and personal lives, while drawing upon the experiences of students and staff in an attempt to identify the role these technologies play in teaching and learning.

The data was collected over a course of three years from each new cohort of first year pre-service teachers (N=1472) from the teaching areas of Early Childhood, Primary and Secondary Education. The study employed a "wide range of interconnected interpretive practices" (Denzin & Lincoln, 2000, p.3) to identify the use of mobile devices and social media technologies by students and staff through a range of surveys, interviews and focus groups to elucidate rich and meaningful data for analysis. Students were asked to voluntarily complete an online survey at the beginning of the semester and a follow up online survey at the end of the semester. In the most recent year of data collection this survey was extended to academics teaching in first year units, and semi-structured interviews and focus groups were conducted with students and their teachers throughout the semester and at the end of the teaching period.

## **3. Findings and Discussion**

The findings discussed here are based on data collected from each of the initial surveys that were conducted over the three years of the study (2012 – 2014). Each new cohort of students completed the survey at the beginning of their first semester in their first year with an adapted survey given to staff teaching into the first year units in 2014. Each of the surveys had a high response rate, with a response rate of over 80% for each of the years. Over 70% of respondents in each of the surveys were female, which is in line with the higher number of female students enrolled in pre-service teaching degrees. The age profile of first year Faculty of Education student respondents showed a majority were aged 15-22, with 62% in the 18 – 22 years age range and 22% in the 15 – 17 years age range.

The data from the student survey indicates that there was a strong use of social media tools by the students in each of the years with Facebook being the most popular social media technology with an increase from 84% usage by students in 2012 to a usage of 86% in 2014. Other social media technologies such as Instagram, Twitter and Tumblr also showed similar trends with minor growths in usage by the students with the respective usage of each platform in 2014 being 53%, 18% and 6% of students. While Twitter has remained quite low over the three year period the application Snapchat went from a 13% usage in 2013 to a 45% usage in 2014. Email still remained the most popular tool for students over the 3 year period with its usage moving from 88% in 2012 to 90% in 2014.

With Facebook clearly being the most popular social media technology with first year pre-service teachers, the results contradict contemporary media reports that suggest teenagers are deserting Facebook, in favour of sites such as Twitter, Instagram and WhatsApp (Kiss, 2013). The data also indicates that students primarily use mobile technologies for email or messaging with ownership of a laptop remaining at over 90% for each of the years. This trend was not the case for other mobile technologies with the strongest growth in ownership being with the iPhone and iPad. The data indicates that ownership of the iPhone rose by 33% from 2012 to 2014 with 79% of students owning the device while the iPad had an increase of 46% from 2012 to 2014 resulting in a 56% ownership.

Staff ownership of iPads and laptop computers was also high with ownership of both being 83% and iPhone usage at 67%. The data from the staff survey also indicated that their patterns of usage of social media and mobile technologies, were similar to that of the students with Facebook being used by all staff (N=6). While one staff member reported regular usage of Twitter, no staff reported using social media technologies such as Instagram, Flickr or Snapchat where digital images are shared and/or exchanged. Hence, the range of social media technologies used by staff, was more limited than the range used by students. The age range of the staff respondents was primarily in the 40 – 49 years age category and while they felt comfortable using the social media technologies and mobile devices in their personal lives the majority were hesitant in using them in their teaching and learning. When staff were asked to comment about their use of these technologies, Staff A (2014) commented that “I feel confident, but don't think I use them that well pedagogically for teaching.”

The survey data thus indicated that students found a need to use social media technologies (SMT) and mobile devices, and that they used them regularly in their personal lives. It was within this context that students were asked about why they use social media in the 2014 survey. The responses to this are indicated in Figure 1.

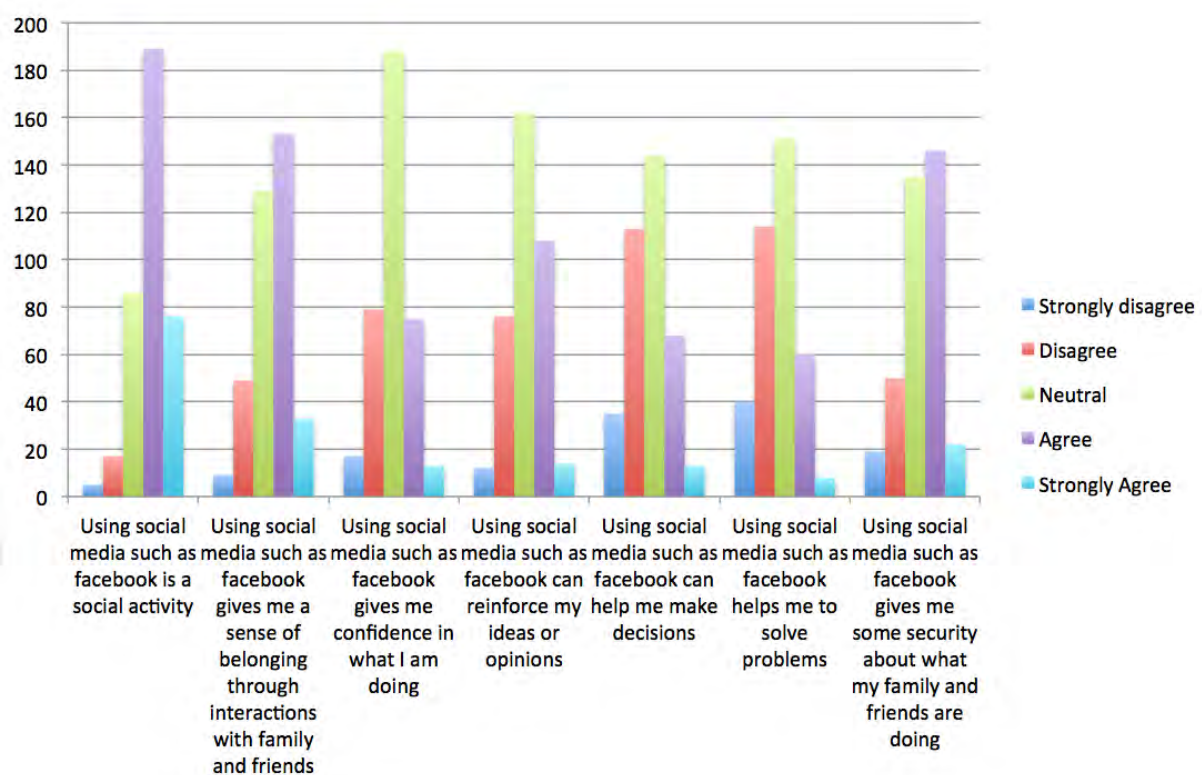


Figure 1. Student reports of the purpose of using social media in 2014

From Figure 1, it can be seen that students felt that social media gave them a sense of belonging, which has been identified in the literature as an essential component in creating a positive first year experience and consequently the retention of students. The data also indicated that social media technologies, such as Facebook, are used as a social activity, giving students security about the current state of wellbeing of friends and family. Very few students (n=68) perceived a use of social media would be suitable for problem solving, however 33% of students did indicate that social media technologies are able to reinforce ideas and opinions.

The familiarity with social media technologies felt by students and the sense of belonging that many students associate with using these technologies suggests social media technologies could be used more strategically by academics to create a sense of community and a safe place for students to express opinions and share experiences. These findings support earlier research where Facebook was identified as a means through which students could express opinion (McCarthy, 2010) and create a more comfortable classroom environment (Goertler, 2009). The research data indicates that staff are

not comfortable using social media and mobile technologies in teaching and learning and this presents problems when trying to respond to the needs of students and improve the first year experience.

#### 4. Conclusion

While it can be argued that information and communications technologies are rapidly changing and that it is difficult for educators to keep up with these, the results of this study over a three year period indicate that there is some stability in the range of technologies adopted by pre-service education students. The results from this study indicate that students are comfortable using these technologies and that the use of social media technologies can be associated with a sense of belonging and acceptance by a large percentage of students. The most striking difference between the staff usage of the social media technologies and that of students, is in the wider sharing of digital images by students who use image sharing technologies such as Instagram, and more recently, Snapchat.

With the positive first year experience, and ultimately the retention of students, being of great importance to many Higher Education Institutions, it is critical that institutions respond to the needs of students by not just using these tools in their teaching and learning practices, but by transforming their approaches to teaching and learning to utilise these technologies in an authentic and meaningful way for students. There is a gap between how students use social media and mobile technologies and how academics use these technologies. The students feel a sense of belonging when they use these technologies and by closing this gap, there is an increased opportunity for students to feel secure and develop a sense of belonging. The mere creation of a Facebook page, or many Facebook pages, will not automatically create a sense of belonging for students, especially if it is just used for updates or the advertising of events. This paper reports on a study in progress and while early results do indicate that social media and mobile technologies can play a crucial role in the first year experience and can act as an enabler, there is a need for further research into how academics and institutions can embrace these technologies to create a sense of belonging and respond to student needs.

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# Implementing and Validating a Mobile Learning Scenario Using Contextualized Learning Objects

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**Abstract:** Substantial research in the field of mobile learning has explored aspects related to contextualized learning scenarios. Nevertheless, the current context of a mobile learner has been often limited to his/her current position, neglecting the possibilities offered by modern mobile devices of providing a much richer representation of the current learner's context. In this paper, we show that a detailed contextualization of the learner may provide benefits in mobile learning scenarios. In order to validate this claim, we implemented a mobile learning scenario based on an approach that allows for a very rich and detailed contextualization of the mobile learner. The scenario that we implemented allowed exchange students to be guided at Linnaeus University in Växjö, Sweden in order to get familiar with the campus and prominent institutions on it. We carried out a study including two groups; one that performed learning activities with contextualization support and one other without it. The results of our evaluation showed significantly better results for the contextualized approach, especially with respect to the acceptance of the Perceived Ease of Use.

**Keywords:** mobile learning scenarios; learning objects; contextualization; cross-platform development

## 1. Introduction

With the growing population of mobile devices, especially smartphones and tablet PCs', also their usage in mobile learning scenarios increased tremendously. A significant amount of research has been conducted in recent years, providing both, new technological approaches and pedagogical scenarios to support learning. According to O'Malley et al., (2003) mobile learning can be defined as "any kind of learning when the learner is not at a static or fixed location, or when the learner takes advantage of mobile technologies". For the purpose of this study, we understand mobile learning as learning that occurs outside of a traditional classroom and when the learner uses a mobile device in order to perform some tasks in the context of the learning activity. The context of the learner may include different contextual information about the environment, device, user's needs and interests. Mobile learning scenarios that take into account the learning context are called contextual mobile learning (Chuantao, Bertrand, & Rene, 2009). The mobile device allows collecting user's current context information, e.g., by collecting data from various sensors, to provide a convenient and easy way of learning independent of time and space (anywhere and anytime).

In order to investigate whether a richer contextualization model, as described in (Sotsenko, Jansen & Milrad, 2013a; Sotsenko, Jansen & Milrad, 2013b) really provides benefits to mobile learning scenarios, we developed a guided tour activity at our university, both with and without contextualization support. The objective of this study was to understand if the implementation including contextualization support provides significant differences with regard to an implementation without that support. The results of these efforts are described in this contribution.

The rest of the paper is organised as follows: next section provides a short overview about the current state of the art. Afterwards, a description of the implementation of our scenario is provided,

followed by the presentation of the results of our evaluation. In the last section, we conclude by discussing our results and providing some ideas for future lines of research.

## **2. State of the art**

The experiment carried out by Hung et al., (2014) shows that using multimedia content of Learning Objects (LO) is more convenient and satisfactorily than just LOs in textual form. Approaches utilizing multimedia LOs can be used in mobile learning scenarios, e.g., for data collection in science education (Vogel, 2013), for quizzes with access to learning content (Geisler & Jansen, 2011) and/or field trips (Giemza A. , Bollen, Jansen, & Hoppe, 2013). in which mobile devices assist the learners in a convenient and efficient way. For instance, Wang et al., (2012) have developed a context-aware mobile application for navigating university campus maps in which personalized maps show important and relevant buildings, e.g., providing services to students. The results of this experiment indicate that a contextualized approach could improve its usefulness and navigation efficiency. Unfortunately, in this research contextual support only consisted of GPS location information and the user needed to specify the type of buildings/services he/she have been interested in. Moreover, no indoor navigation support was provided and the application was implemented only for the iOS platform. Another multimedia based mobile application is the Mytilene E-guide (Kenteris & Economou, 2011), implemented as a tourist guide allowing users to select certain content and to download an application for an appropriate mobile platform. The advantage of this app is its ability to also work in an offline mode while, at the same time; a disadvantage is that it was not implemented as a cross-platform application. In the work discussed in this paper, we present a cross-platform mobile app with contextualization support for which a much richer context model was used not just relying on the current user's location. The scenario that we implemented allowed exchange students to be guided at the Linnaeus University (LNU) in Växjö, Sweden in order to get familiar with the campus and prominent institutions on it. Therefore, the app provides relevant information about the university, its campus, cafes and other facilities. Here, the mobile app provides different activities, subdivided in to different tasks that allow foreign exchange students to get familiar with their new university.

## **3. Implementation**

This section describes the implementation of a mobile application utilizing the contextualization approach described in (Sotsenko, Jansen, & Milrad, 2013a), implementing a three dimensional (environment, device and personal context) vector space model in which LOs' are represented. The context data is collected by: a) accelerometer, to define the movement (e.g. moving, sitting/standing) of the user; b) GPS location, to define the current place by using Google Places API; c) GPS location, to define the current weather condition; d) battery service, to define the battery status; e) screen size (width, height); f) camera, to confirm user location by scanning QR codes (e.g., for indoor navigation); and g) the user profile in a corresponding Learning Management System (LMS), to define users with similar interests. All LOs' to be used are stored in different media formats (.pdf, .html, .mp3, .mp4) in a standard LMS (Moodle) in order to make them accessible to the app.

The implementation of the app was done in a platform independent way (Sotsenko, Jansen, & Milrad, 2013b), for allowing a cross-platform deployment. The server-side implementation was done in Node JS for the main functionality of the mobile app. The client side is implemented by using the jQuery Mobile framework, allowing for the creation of user-friendly mobile interfaces. For persistency, a MongoDB database was used in order to natively store JSON objects, used for the complete communication in the system. Additionally, to collect the information about the current context of the user we used additional Web Services: a) Free Weather API provides the current weather condition for the location of the user; b) Google Places API provides the information (e.g. name, type, image, etc.) of current place of the user. These two types of data have been necessary in order to provide an appropriate description in the rich context model; c) Moodle Web Service extension (Piguillem, et al., 2012) allowing access to the LOs' that we provided to users as main learning content in the app; and d) a QR code service used for reading QR codes in order to identify the current location of the user in an indoor scenario.

### 3.1 Description of LnuGuide mobile application

The following sub-section describes the main functionality of the LnuGuide mobile app. At the login view, the user should login with a username and password from the LMS. The main view (Figure 1) is responsible for helping users to navigate in the activities. The Google Maps API v3 along with the Google Places API are used in order to provide an easy and convenient navigation. For inside navigation, the QR code service was used in order to determine the current position of the user.

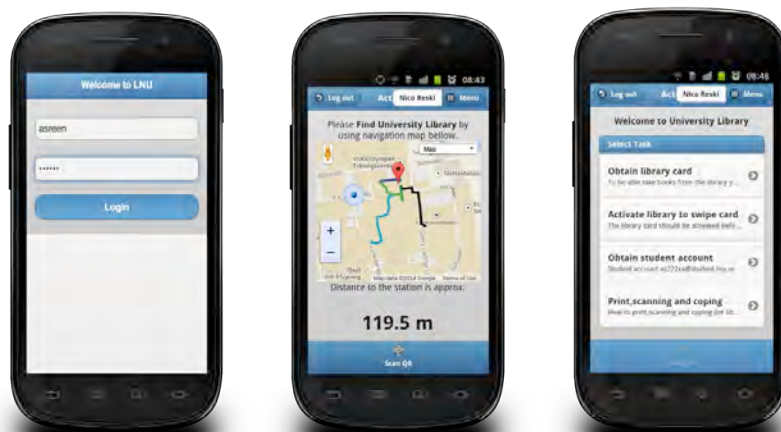


Figure 1. Screenshots of *login* and *main* view in LnuGuide app

The activity lists the tasks that a user can choose within his/her current station. Based on the user's current location the application will provide different tasks that are retrieved from a database. The task view shows the learning material in an appropriate format, according to the current context of the user. The profile view allows filling and saving the users' profile, e.g., with data like a picture by taking a photo, the study program of the learner, interests and hobbies. In order to facilitate collaboration between students the real-time chat is provided by application. The application determines other users with similar interests that are of the database and applies a filter to just show which users are currently online.

### 3.2 Description of the Learning Scenario

Mobile learning scenarios can be designed for guiding mobile learners to gain information about their current learning environment and how to work in it. For instance, students can learn about how to use the different services at the university library (e.g. registration in the library, usage library card, etc.) if he/she is inside the university library. Another example might be that students can be guided to learn how to print and scan papers by using universities printing system. The scenario described in this paper was designed for allowing international exchange students to familiarise with LNU and to learn about the different facilities and services available on campus. The Student Guide activity contains three stations (e.g. University Library, Administration Building and a café on campus) where students can get useful information to facilitate his/her "student life" (e.g. obtain the library or student card, to be able scan and print at Library, etc.). Each station provides a number of tasks, where, e.g., the app will provide information on how to scan documents at the library including instructions that the user should easily be able to perform. In this scenario, the LOs represent learning materials describing certain tasks that need to be carried out by the students.

## 4. Evaluation

An evaluation was performed to address the following research question: does the contextualized version of the LnuGuide provide benefits compared to the implementation of the LnuGuide app without contextualization support? In order to investigate this, we carried out a study including two groups of students; one group performed the scenario with contextualization support (Group№1) and a control group without contextualization support (Group№2).

#### 4.1 Participants

The participants of the study were 25 exchange master students arriving to LNU on January 17th 2014 and invited via a Facebook event to participate in the Student Guide Activity during the universities' orientation week. The participants were divided into two groups where the Group№1 had fourteenth students and Group№2 eleven students.

#### 4.2 Description of Study

The participants were enrolled in the course in our Moodle system manually with username and password. Before the Student Guide Activity started, a Samsung Galaxy S3 mobile device with the installed LnuGuide app and headphones has been provided to each one of the participants.

The Group№1 with contextualization support performed the different tasks of the activity in 45 min.. Below, we provide a short example of the type of contextualization support provided by the app. For example, the task "How to use the library card in order to be able to gain access to computer facilities at the university and enter universities buildings at any time?" Considering the current context of the user: user is walking near the university library and the weather condition is cloudy with the temperature -4C and his/her mobile device charged with 90% and with 3G connection. The learning material would be provided in audio format because light conditions are too bad for video and during movement it is probably not convenient to consume a text-based format. Considering a different context of the user: user is standing inside the university library and his/her mobile device charged with 40% and with Wi-Fi connection, the learning material would be presented in text format due to the low battery load, the different lightning conditions and the user not moving.

The Group№2 without contextualization support performed the activity also in 45 min. Here, different tasks provided the material only in text format and without taking into account the current context of the user. After the activity finished, participants from both groups were provided with the questionnaires including additional open feedback text questions.

#### 4.3 Limitations

According to a previously performed pilot test with a few students, we defined that 45 min should enough to complete all tasks that were part of the university guide scenario. Still, in our final study, the external students complained that 45 min was not enough to perform all tasks. The overall number of students ( $N=25$ ) resulted from the fact that we implemented the first prototype of the LnuGuide application in order to validate our approach, test and improve the application before running a larger study. At the end, the different number of students in the groups did not significantly influence the results of the quantitative analysis.

#### 4.4 Study Results

The evaluation was conducted using questionnaires according to the Davis' Technology Acceptance Model (TAM) (Davis, Bagozzi, & Warshaw, 1989). From this set of questionnaires, we haven chosen two that fit well with our aims: the Perceived Usefulness (PU) and the Perceived Easy of Use (PEU). A seven-point likert scale (Likert, 1932) was applied for each question. The questions have been adapted (Giemza A. , Bollen, Jansen, & Hoppe, 2013) to our study. In order to determine whether or not the increased contextualization support provides some statistically relevant improvement, we deeply analyzed the gathered data from the questionnaires. First of all, we calculated the total average for the Perceived Usefulness to 4.83 in Group№1 and 4.69 in Group№2. For the Perceived Ease of Use the total average is 5.03 for Group№1 and 4.2 for Group№2. In order to test these results for significance, we conducted an independent-samples t-test for the PU and for the PEU. The results for PU indicate a not significant difference with regard to the total scores in Group№2. Still, the results for PEU show differences in question 2.2, 2.5 and 2.6 regarding the total scores in Group№2. So, we decided to conduct a t-test comparing the mean scores of questions 2.2, 2.5 and 2.6 in Group№1 and Group№2. Since we had a relatively small group of participants ( $N=25$ ), we decided to calculate the

effect size offered by (Cohen, 1988). This test shows a significant difference in the question 2.5 ( $M=2.79, SD=1.67$ ) for Group№1 and ( $M=4.82, SD=2.32$ ) for Group№2;  $t(13)=4.55, p=0.001, d=1.0$ . In the question 2.6 ( $M=3.15, SD=1.7$ ) for Group№1 significantly less then ( $M=4.63, SD=2.1$ ) in Group№2;  $t(13)=3.29, p=0.006, d=0.7$ . Results for question 2.2 indicates non-significant difference for Group№1 ( $M=3.57, SD=1.5$ ) and ( $M=4.63, SD=2.01$ ) for Group№2;  $t(13)=1.73, p=0.106, d=0.59$ . All statistical tests have been conducted with an alpha level of 0.01.

#### 4.5 Discussion of Results

The results for the Perceived Usefulness show almost no difference between the two groups, which is not surprising since the scenario and the provided learning content was the same for both groups. Figure 2, shows the average values both for the group using the contextualization approach (Group№1) and the control group (Group№2). From the t-test results we found that there are not significant differences for question 2.2. Furthermore, the corresponding Cohen’s effect size (Morgan, 2002) value ( $d = .59$ ) suggests a high significance. Still, significant differences could be found in question 2.5 indicating that using the LnuGuide mobile app with contextualized approach is less exhausting than the LnuGuide mobile app without contextualization. Here, the corresponding Cohen’s effect size value ( $d = 1.0$ ) also suggests a high significance. Furthermore, the results from question 2.6 show that with rich contextualization support, it was easier for the students to remember how to perform certain tasks within the provided scenario. Last but not least, here, the corresponding Cohen’s effect size value ( $d = 0.7$ ) suggested medium significance. Therefore, it could be said that the implementation based on the rich contextualization support is easier to use.

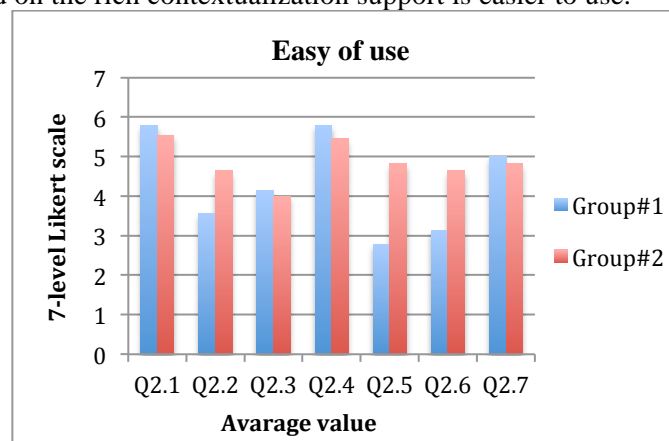


Figure 2. Average rating for PEU questionnaire

## 5. Conclusions and Future Work

The mobile learning scenario to guide exchange students at Linnaeus University was designed to identify the possible benefits of a rich contextualization support in a mobile learning scenario. The cross-platform LnuGuide mobile application was developed using jQuery Mobile, Node JS and Web Services, providing a stable and reliable technology stack for the development of cross-platform apps. Positive comments and feedback from the students showed that the LnuGuide app with contextualization support is more convenient to use and beneficial in order to achieve their goals (or to perform the tasks) easily. The evaluation also showed significantly better results for the contextualized approach, especially with respect to the acceptance of the Perceived Ease of Use. The results of the study provide some new insights with regard to the usage of the multi dimensional vector space model for modeling user’s context for a mobile context based recommender system. The contextualization allows adaptation of the LO’s format and the delivery of the LO’s to mobile devices according to the user’s context in order to keep learner’s concentration and convenient study in anywhere and anytime. Our next research steps include a modification of the contextualization support to expand it to mobile health scenarios, where the usage of contextual information provided an important opportunity to create new personalized mobile healthcare applications. Additionally, we

plan to refine our approach on how to provide LOs' in different multimedia formats and to further improve the contextualization mechanisms.

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# Learning Log Dashboard: to see your own progress

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**Abstract:** This paper proposes a learning log dashboard interface design issues for a mobile learning system called SCROLL (System for Capturing and Reusing Ubiquitous Learning Log). SCROLL allows learners to record and share their daily learning experiences as ULL (ubiquitous learning logs) with locations, photos, words, sentences and/or videos using their smartphones. Moreover SCROLL provides quiz that are generated from ULL so that they can remember past learning experiences. Learners add many words, photos on their account and always repeat this action, like as continuous training. It will be sometimes happened forgetting quiz even works on those words in the past. The overall goal of this learning log dashboard is to enable learners to reflect on their own activity, to reinforce what they have learned and to learn from each other. Learners also can see the information about her/his progress on learning log dashboard.

**Keyword:** Learning log dashboard, ubiquitous technology, language learning, memory

## 1. Introduction

In today's world a great revolution is occurring in the mobile device with the release of new generation smartphones represented by iPhone and Android. The new generation smartphones accommodate learners with many advanced functions such as the multi-touch interface, virtual keyboard, GPS navigation, a full browser and record notes. It allows learners for immediate access to data online wherever one is at home, travelling or at work. One key feature of smartphones is that they are equipped with a range of sensors such as the accelerometer, GPS, compass and so on. Using such functions of smartphones, SCROLL (System for Capturing and Reusing Ubiquitous Learning Log) has been developed originally (Ogata et al., 2011).

SCROLL is a system to assist learners to simply capture, review and reflect their learning logs, reuse the knowledge when it is needed. It adopts an approach of sharing learner-created contents among learners. It means that a learner's learning log cannot merely available for her/him, but also can be shared with other learners who have the same learning needs.

The term "learning log" is originally used for personalized learning resources for children (Wikipedia, n.d). In this study, learning log is defined as a recorded form of knowledge or learning experience acquired in our daily lives. It serves as memory storage for notable or important knowledge to review, to remind and to reflect. For example, a learning log can be a Japanese word or a piece of English sentence taken down by a language learner.

The target learners of SCROLL are overseas students who study Japanese language in Japan. It is because they acquire lots of knowledge from their daily lives, for example, when they go to a post office, shopping in a market or seeing a doctor in the hospital. Such a learning activity is a kind of episodic memory (Tulving et al., 1973) for the learner for which it can help the students to remember the knowledge for a long term (Tulving et al., 1973). Butler and his colleagues find that testing can also improve long-term retention and the strategy of repeated testing enhances learning more than repeated reading (Butler et al., 2007).

Learners' vocabularies increase highly by learning many new words everyday and by sharing them with others. In order to help learners to see their own progress and reflect information they add, we

propose the function "Learning log dashboard" (L2D). L2D uses the log of learners in SCROLL to enable learners to reflect on their own activity and recall what they have learned. The dashboard also enables learners to see their own progress at a glance. For example: updates, success, statistics, information and how many logs they need practice. Thus, a learner will repeatedly practice words by the quizzes in order to avoid from repetitive mistakes, and eventually s/he will be greatly motivated.

Therefore L2D will give learners an easy way to find the best next things to do and increase motivation of them. This paper is organized as follows: in the next section we present L2D. Future work and conclusion are presented in section 3.

## 2. Learning Log Dashboard

Learning Log Dashboard (L2D) is a function of SCROLL, which is to enable learners to reflect on their own activity and to see their own progress. L2D focuses on statistical data on every learner's usage of the system. L2D shows the number of learning logs that a learner uploaded and the number of completed quizzes, as well as memorized learning logs and incorrect answers of the quizzes. It is easy to see incorrect answers on a word and to control in the dashboard.

Learners can distinguish each learning log, which is differently represented in several colors. Last results are presented in scores distinguished in colors: if a learner answers incorrectly for the first time the learning logs are marked in **green**, for the second time the learning log color turns **yellow**. If an incorrect answer is repeated for the third time, the color becomes **red** in turn (Figure 1). It means that learners have to deeply concentrate on their mistakes and use incorrect answers in practice. If a new learner has not added a log to the system yet, L2D is blank. Figure 2 shows a workflow of L2D. Explanation of figure 2 :

1. First, learners need to register themselves to SCROLL system. Learners can work on quizzes. Initial logs are learner's learning log.
2. When a learner finishes working on the quiz, the incorrect answers are marked in green and stored in the L2D. Correct answers will be saved in memorized logs.
3. The next time if the learner repeatedly answers incorrectly while reworking on the same quiz, the answered learning logs shall be marked in yellow. If the learner makes mistakes on the same word 3 or more times, such word shall be marked in red color.
4. If the learner completes the quiz successfully without any making mistakes on the same words s/he previously answered incorrectly, then color of the logs will be changed back. For example, if the learner correctly answers the same words 3 times, the color of the logs will continue to change until they move to memorized logs. After finishing a quiz the L2D will automatically update the information.
5. Memorized learning logs consist of memory of learner's last quiz and s/he can see it at least 100 last words. Moreover it will be easy to see updates, simple to work on it.
6. The recommended learning logs (Figure 3) are summarized on the display which shows the incorrect and correct answers of learner's past works. According Pimsleur's proposal (Pimsleur 1967) of memory schedule, which defines the length of recall interval, it is 5 times of the previous interval's length. He also discovered tenth recall of a word of second language that will not take place until 113 days or more than four months later. That one should hold the learner for well over a year. According to the memory schedule after three months, learning logs will be reappearing previous learning logs to a learner for reinforcement in recommended logs. Learners also can examine themselves by practicing the quizzes in recommended learning logs. If a learner answered correctly to the quiz, the learning log disappears from the dashboard.

Learners usually repeat mistakes on one word even if they worked quiz previously. Learners especially who are studying Japanese letters and characters should practice more to memorize. Figure 1 shows the information of learning logs that a learner answers the questions incorrectly (once twice, or more than 3 times). Learners are also able to see their progress and achievements. Then they are able to concentrate on the words answered incorrectly. If a learner clicks on the "Enjoy the quiz" button in green color, the dashboard system will automatically provide a set of quiz (Figure 4). The set of quiz contains learning logs of a learner who answered incorrectly once. According to the colors of the buttons a learner can work on quizzes. For example: red color button provides the set of quiz that



contains learning logs of a learner who answered incorrectly 3 or more times. If the learner skips the set of quiz without completing it, the dashboard will remind her/him about the necessity of completion of the task via a message to encourage her/him to study. A learner eventually will know all of the words by heart.

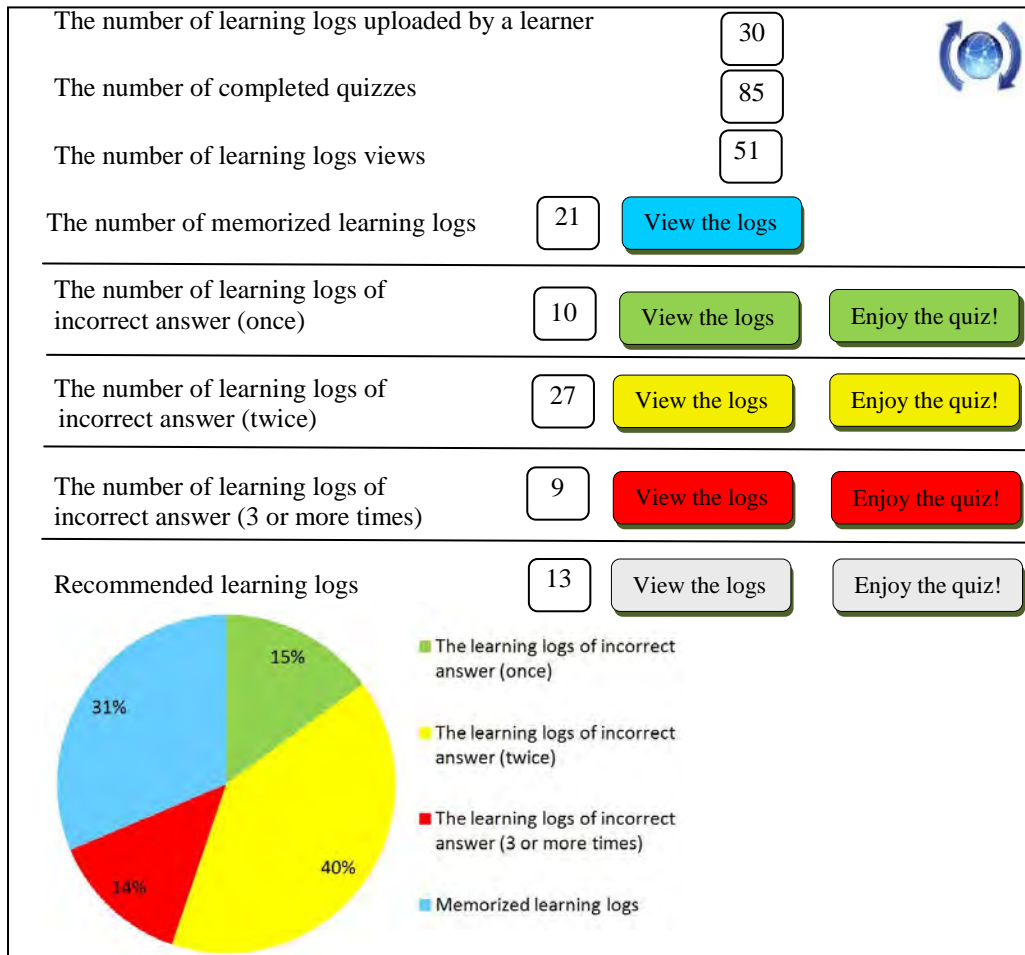


Figure 1. The image of the designed L2D

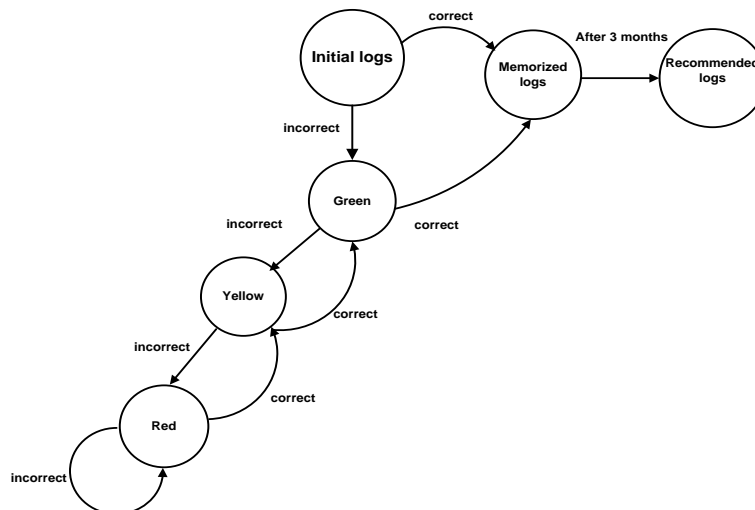


Figure 2. Workflow of the learning log dashboard



Enjoy the quiz!

Figure 3. Recommended logs

The dashboard presents a table that indicates the quiz overview of each learner. Figure 4 shows the information of learning logs of a learner who answered incorrectly once. If the learner successfully performs the quiz, then the learning logs of correct answers will move to the memorized section.



Enjoy the quiz!

Figure 4. The information of the learning logs of incorrect answer (once)

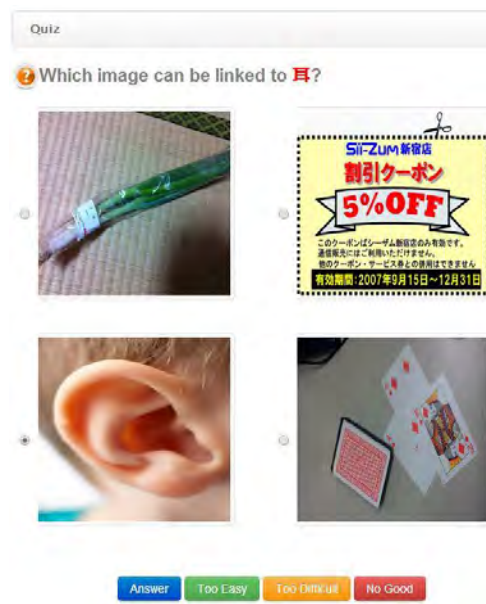


Figure 5. Actual quiz of SCROLL

Basic research on human learning ability and memory has shown that practice of information retrieval (information testing) has powerful effects on learning process and long term retention of information in human memory (Karpicke et al., 2009).

The quiz function of the system (Li et al., 2011) is based on the following two theories: the theory of encoding specificity (Tulving et al., 1973) and the theory of test-enhanced (Karpicke et al., 2009) learning. According to the former theory, a number of factors including the place where we obtained knowledge or we took photos can be encoded as initial retrieval cues. The initial retrieval cues are very effective for activation of stored memory (Tulving et al., 1973). Regular testing enhances learning process more than repeated reading. Because repeated reading often confers limited benefit beyond that gained from the initial reading of the material. (Karpicke et al., 2009).

Three types of quizzes can be generated automatically by the system: including yes/no quiz, text-based multiple-choice quiz and image-added multiple-choice quiz (Figure 5). These quizzes are interesting and attractive method for learning. For example, “quiz with image” is designed to ask learners to choose a word in order to describe images given by the system. The system immediately checks whether the answer provided by the learner is correct or not (Ogata et al., 2011).

With the learning of a new word, the process of forgetting begins at the same time once and proceeds very rapidly. If a learner remembers the word until s/he completely forgets it, her/his memory potential shall be increased.

### 3. Conclusion and Future work

This paper aimed to describe issues on Learning Log Dashboard System interface design in SCROLL. Learners can add their words into the system, which is designed to recall memory of students (especially who are learning foreign languages) based on their learning contexts. Learners can examine and make self-assessment by practicing the quizzes. It is common, when learners repeat the same mistake even though they repeatedly work on the quiz. Those especially who are studying Japanese letters and characters should practice such quizzes more often to improve their memory capacity. Learners can see their own progress as well as control their activity from the dashboard. A learner shall be aware of common mistakes, too.

Learner's eventual interest in dashboard focuses on its role in primary meaning of word and usage, word-board. Incorrect answers, the repeated mistakes of a learner are also important for a learner because s/he does not make mistakes anymore on that word. It is a good promotion and a big opportunity for a learner to know what is her/his incorrect answers and learn everywhere and anytime.

It is essential in the future to conduct in-depth researchers and experiments on evaluation of L2D's efficiency. How does it help the learner in their tasks?, How much does it help?, Do learners find the effort needed to use the system worthwhile in regards to the impact on their learning?.

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# Relationship of Ubiquitous Technology Usage with Technology Competency

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*Abstract*— The objectives of the study were to (i) identify the level of U-Tech usage, (ii) determine the undergraduates' U-Tech competency level and (iii) determine whether there was a significant relationship between U-Tech usage and U-Tech competency. A total of 400 undergraduates from four faculties were randomly selected. The study employed the survey method in which the data were gathered through a 5 point-Likert scale questionnaire. The questionnaire consisted of 5 items (demographic information), 42 items (U-Tech usage) and 42 items (U-Tech competency) with the reliability of 0.958 for U-Tech usage and 0.971 for U-Tech competency. Data were analyzed descriptively (mean, percentage, frequency and standard deviation), and inferentially (Pearson correlation). The findings of this study revealed that majority of the undergraduates were at high level of U-Tech usage (mean = 4.39, SD = .895). The overall level of u-tech utilisation among the undergraduates was moderate, and the overall competency level of the undergraduate in using u-tech was observed to be moderate. Finally, results revealed that, there was a significant and positive relationship ( $r = 0.335$ ;  $p < 0.01$ ) between the undergraduates' use of U-Tech and their competency level.

*Keywords*- ubiquitous technology, Technical Undergraduates, Use, Competency

## 1. Introduction

In this digital era and with the technology-innovation pace, the most recent form of technology, the ubiquitous technology or *U-Tech*, has emerged and played an important role in diversifying educational settings. U-tech devices such as smartphones, laptops and tablets (Lei, 2010, Saadiah, 2010, Levin & Bruce, 2001) are gaining recognition as tools, not only to serve their original and basic purposes for communication, entertainment and organization, but also to be used as a strong mediator in education to support learning. Majority of the undergraduates incorporate U-Tech in classrooms and laboratories to assist them learn more effectively because this technology provides better understanding to them on what they are learning (Guetl, Chang, Edwards & Boruta, 2013). There are many factors that influence U-Tech usage including competency which have been identified to have affects on the use of U-Tech among undergraduates. Such factors have been explored in previous research (eg. Kadel, 2005; Mudasiru & Modupe, 2011). Successful integration of U-Tech depends largely on the competence of undergraduates in using and understanding the role of these digital and advanced technologies either for learning or leisure purposes.

Simply having the sophisticated U-Tech in hand and in the institution will not guarantee effective usage. Regardless of the quantity and quality of technology placed in classrooms, the key to how those tools are used is the undergraduate themselves. Therefore, undergraduates must have the competence and the right attitude towards technology (Kadel, 2005). Major technology competencies required were highlighted by Ahmad, Abdul Karim and Albakri (2013) to include competency in making personal use of the tools, mastery of a range of educational paradigms that make use of it, competency in making use of the tool as mind tools, competency in using technology as tools for learning which involves use of the technology and competency in understanding the standard dimensions of the use of U-Tech for learning.

### *Utilization of Technology in Technical University*

Higher education system in Malaysia is designed to ensure that public higher education institutions will have the ability to build a reputation to be dynamic, competitive, able to anticipate and overcome the challenges ahead and be prepared to act effectively, as well as keep pace with globalization. It also focuses on the efforts to improve the ability of universities to perform the functions and responsibilities more efficient, transparent and effective in creating an excellent facilitating environment for their students. To date, MoE has listed out 11 universities as a focused university including four Malaysian Technical Universities which focusing more on the technical and engineering field and committed to be an excellent innovation-driven university. The four Malaysian

Technical University Networks or MTUN are Universiti Teknikal Malaysia Melaka (UTeM), Universiti Tun Hussein Onn Malaysia (UTHM), Universiti Malaysia Pahang (UMP) and Universiti Malaysia Perlis (UniMAP).

These universities are committed in producing excellent and skilled manpower to contribute to the advanced industrial countries especially in Malaysia, and at the same time aim to produce a ready technology-competence graduates for a direct fit with the requirements of the IT industry (TaskForce on Meeting and Human Resource Challenge for IT and IT enabled Services, 2003). On the other hand, the Engineering Accreditation Commission (EAC) of Accreditation Board for Engineering and Technology (ABET), has identified technology use skills, technology competency, multi-tasking and the ability to identify, formulate and solve engineering problem as part of the key themes in their assessment of skill trend.

#### *Benefits of Ubiquitous Technology Utilisation*

##### i) Promoting Flexibility in Learning

In higher learning, the use of u-tech as a learning tool could provide authentic learning opportunities for students, especially for engineering and technical students who need clear and explicit examples or stages in connecting electronic circuits, without the chance of doing it hands-on (Beetham & Sharpe, 2013). A study conducted among engineering educators and students showed that with technology, engineering educators were able to draw on the applications to simulate real-world environments and create actual arenas for experiments for their students. With technology too, their students could carry out 'bona fide' tasks as real workers, explore new environments, meet people of different cultures and employ a variety of tools to gather information and solve problems (Rodríguez, Granados & Muñoz, 2013).

##### ii) Promoting Engagement in Learning

Student engagement is used to 'depict students' willingness to engage in routine learning activities, such as attending class, submitting required assignments and following teachers' directive' (Manuguerra & Petocz, 2011). Several alternatives have been demonstrated to promote students engagement. Educators can intensify students' engagement by persuading their students to become more active participants in learning by providing collaborative opportunities for educational research, planning, teaching and evaluation (Martin et al., 2013).

##### iii) Promoting Collaborative Learning

Collaborative learning refers to the environment in which engage learners in a task where each individual depends on and is accountable to each other. These include both face-to-face conversations and computer discussions such as online forums and chat rooms via videoconferencing (Moore, 2013). Generally, collaborative learning is about working together where knowledge can be generated by sharing experiences and taking on symmetry roles (Wali et al., 2014). Collaboration represents a virtue in the online world. Rather than working on a one-to-one basis, technology enables students to collaborate with one another and work with a range of interactive and instructional resources.

##### iv) Promoting Personalised Learning

In the 21st century, students learn best when lessons are tailored to their individual interests, strengths and challenges (Arshad & Scott-Ladd, 2010). A study conducted in Malaysia by Mokhtar and Huoy (2013) found that with wireless classrooms and electronic instruction let students study at their own pace. Personalisation makes learning more adaptive and timely and this frees educators from the usual tasks such as marking papers manually and gives them more time to serve as instructional coaches for students. Personalised learning with u-tech puts learners at the centre of the education process. Here, students' activities are customised based on what they need to learn where learning can be received either one-on-one or in small groups. At the same time, with the use of technology, educators are able to track their students' progress and give feedback at real-time.

##### v) Promoting Speed in Information Accessibility

A continuous flow of information among users is often hailed as the important feature of u-tech (Gupta, 2013). For example, when using u-tech, the students are provided with numerous channels of input and output, thereby augmenting their efficiency in learning. According to Hwang et al. (2008), with technology, there are five combinations of interaction occurring namely learner-content, learner-teacher, learner-learner, learner-interface and learner-community. Students can access databases, contact other students, send messages to lecturers, work within the interface of the technology and systems provided, connect to community-wide discussion areas or connect to social network system like Facebook® and Twitter to keep them up-to-date with the latest news or to amass information.

##### vi) Promoting 21st Century Skills

In Malaysia, in regard to a review of the relationship between technology and 21st century skills, Fadzil and Abdol Latif (2011) reported that with the utilisation of new technology, students were able to produce high-calibre work with a range of technology providing opportunities for creativity. The researchers found that students utilised u-tech to exhibit creative thinking, increase knowledge and develop innovative products.

## *Technology Competency*

BrckaLorenz, Haeger, Nailos and Rabourn (2013) refer to technology competency as the ability to handle a wide range of computer applications for various purposes which can be achieved through the process of learning, acquisition of knowledge and development of skills in using technology. In the context of engineering and technical education, technology competency is interpreted as the perceived skills, abilities, knowledge and other characteristics displayed by students (Passow, 2012). Technology competency is also considered as the most important skill that should be acquired by the engineering graduates before they enter the workforce. This is important, because the students are expected to deal with and be involved in technical skills while in the workforce, which require them to handle and utilise a wide array of technologies and machines (Male, Bush & Chapman, 2010). According to ISTE understanding of the technology competency pattern can also be based on the standards developed, which is NETS.S. The NETS.S serves as a set of standard in nurturing the practice of enhancing certain skills with the utilisation of technology in school up to university level as well as assisting students to promote 21<sup>st</sup> century skills.

A study conducted among engineering students in India by Goel (2006) concluded that technology competency had influenced the use of technology. He discovered that most undergraduates had excellent competency in using technology and this had influenced them to use the technology for learning. However, from the study, Goel found that most students used technology only for lower cognitive thinking level such as for specific subjects and as a general tool; the technology was not being used to its fullest capability. The use of technology for higher cognitive thinking at the level of analysis, synthesis, and evaluation was still lacking due the limited opportunities and exposure given to the students.

## **2. Problem Statements**

Although many attempts have been made to identify undergraduates' U-Tech usage in higher education around the world, there is mostly superficial literature in this area (Abdullah, Wan Mohd Amin, Masor, Mohammad & Amirdin, 2011). In most studies that have been conducted, many have merely focused on the lecturers' and students' ICT literacy, rather than the use of U-Tech (Ahmad & Bakhtiari, 2007). In fact, there is little information available on how U-Tech is being used among technical undergraduates. Moreover, the field also lacks data to actually determine the level of U-Tech usage among the undergraduates and their competency level. Hence, this study fills the gap in the existing literature by determining the level of U-Tech usage and U-Tech competency level among undergraduates in one Malaysian Technical University Networks (MTUN). It also determined the undergraduates' U-Tech usage according to the National Educational Technology Standard for Students (NET.S).

## **3. Objectives**

The study attempts to achieve the following objectives:

1. To identify the level of U-Tech usage among technical undergraduates.
2. To examine the competency level of technical undergraduates in the use of U-Tech.
3. To determine whether there is any significant relationship between technical undergraduates' use of U-Tech and competency level.

## **4. Methodology**

This research deployed a survey method using a questionnaire to investigate the level of U-Tech usage among engineering students and their competency level. The questionnaire consisted of Section A (eight items on socio-demographic information), Section B (42 items on U-Tech usage and 42 items on ICT competency). The instrument was validated by a panel of experts and pilot tested. Based on the pilot study the obtained reliability was 0.96 for U-Tech usage and 0.97 for U-Tech competency. Data were analyzed descriptively (mean, percentage, frequency and standard deviation), and inferentially (Pearson correlation) using SPSS version 17. All items in the section B were measured on a five-point Likert scale.

## **5. Findings**

### *Demographic Information*

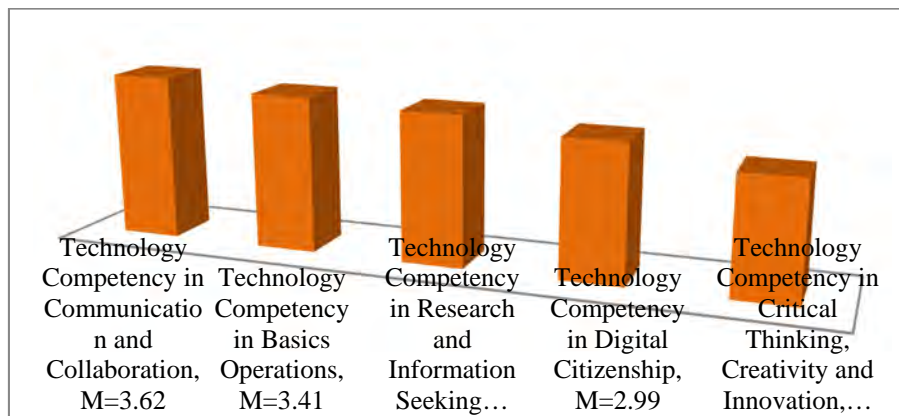
A total of 400 undergraduates from four universities participated in this study. Most undergraduates were from UTeM (n=175, 44%), followed by UTHM (n=154, 38%) and UniMAP (n=42, 11%). The least number of undergraduates was from UMP (n=29, 7%). The gender distribution was almost equal among undergraduates;

male (n=208, 52%) and female (n=192, 48%). The age of undergraduates varied from 22 to 25 years old. Many of the undergraduates were around 23 years (n=165, 41%). Those, of 22 years (n=113, 28%). Undergraduates of age 24 (n=79, 20%) and the fewest undergraduates were at the age of 25 (n=43, 11%).

#### *Undergraduates' Level of U-Tech Usage*

Results revealed that the overall level of u-tech utilisation was moderate. A majority of undergraduates (n=229, 58%) perceived their utilisation level as moderate, 168 (41%) undergraduates high with a maximum score of 223, and 3 (1%) undergraduates perceived their utilisation level as low with a minimum score of 98. From 229 (58%) undergraduates who perceived their utilisation level as moderate, 110 (28%) were males and 119 (30%) were females. From 168 (41%) undergraduates who perceived their utilisation as high, 95 (24%) were males and 73 (17%) were females. Finally, 3 (1%) undergraduates who perceived their utilisation as low, were all males.

#### **Patterns in Competency in Using Ubiquitous Technology According to Categories**



The highest competency in using u-tech was as a communication and collaboration tool (M=3.62, SD=.95), followed by basic operation tool (M=3.41, SD=.920), research and information seeking tool (M=3.28, SD=.95) and digital citizenship tool (M=2.99, SD=.93). Competency in using u-tech as a critical thinking, creativity and innovation tool was perceived as the lowest competency (M=2.57, SD=.99).

#### *Relationship between technical undergraduates' U-Tech usage and competency level*

The Pearson's correlation coefficient was used to examine the relationship between the undergraduates' use of U-Tech and their competency level. The correlation results between the research variables. Results revealed that, there was a significant and positive relationship ( $r = 0.335$ ;  $p < 0.01$ ) between the undergraduates' use of U-Tech and their competency level. The results indicated that undergraduates who used U-Tech very often have higher competency than those that never or occasionally used them. In other words, undergraduates who have high competency level tend to use U-Tech more frequently than the others.

#### **Correlation Analysis between Relationships of technical undergraduates of U-Tech usage and U-Tech Competency Level**

|                   |                     | U-Tech usage | U-Tech competency |
|-------------------|---------------------|--------------|-------------------|
| U-Tech_usage      | Pearson Correlation | 1            | .335**            |
|                   | N                   | 400          | 400               |
| U-Tech competency | Pearson Correlation | .335**       | 1                 |
|                   | N                   | 148          | 148               |

\*\* . Correlation is significant at the 0.01 level (2-tailed).

## 6. Discussion and Conclusion

The study also shows that there is a significant and positive correlation ( $r = 0.335$ ,  $p < .01$ ) between undergraduates' U-Tech usage with their competency level. Hence, it is assumed that when undergraduates have high competency, there is a relative advantage in using U-Tech fully, perhaps for the higher level of thinking, such as in expressing complex concepts. This finding is consistent with those of Abdullah Abdullah, Wan Mohd Amin, Mansor, Mohammad Noor and Amirudin (2011) and Ahmad, Abdul Karim, Din and Albakri (2013) in which competency was the most influential factor related to technology use. Both studies reported that many users were in agreement that having sufficient technology competency and skills were primary importance in the successful and effective utilisation of technology.

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# Seamless Flipped Classroom Using SCROLL in CALL Class

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**Abstract:** In this paper we have explored flipped classroom. How we can encourage students to learn outside-class is a key issue in flipped classroom. In our previous study it was found that our system called SCROLL (System for Capturing and Reminding Of Learning Log) contributed to the students' increased involvement in outside-class learning. SCROLL is expected to play an important role in its effective implementation of flipped classroom. A pilot evaluation was conducted to examine the effectiveness of our proposed learning scenario using SCROLL and SNS(Social Networking System). The result showed that it enhanced the students' outside-class learning, though more examination is necessary to conclude its contribution since there are other factors which contributed to boosting up outside learning time. Timing of posting outside-class task was also examined and the period of two weeks was found to be appropriate.

**Keywords:** flipped classroom, mobile assisted language learning, second language learning

## 1. Introduction

Growth of the Internet has enabled us to go beyond the interaction between individual learners and the system, and it realized collaborative learning that can occur simultaneously with group of learners connected to each other. Besides, New telecommunications technology such as Wi-Fi (wireless fidelity), Bluetooth, 3G and 4G (third and fourth generation), has enabled various kinds of portables devices (e.g. laptop or netbook computers, palmtop computers or PDA, mobile phones, smart phones, GPS devices, MP3 players, handheld electronic game devices). These technologies allow learners to learn anytime, anywhere, and provide them with multiple ways of learning throughout the day.

The progress of these technologies and realization of one device or more per learner have offered us a new learning environment called "flipped classroom". In flipped classroom, how we can encourage students to learn outside-class is a key issue. In our previous study, SCROLL contributed to the students' increased involvement in outside-class learning (Uosaki et al. 2013). Therefore we expected our system could play an important role in effective implementation of flipped classroom.

The rest of the paper consists of 4 sections: Theoretical backgrounds of our study were overviewed in Section 2. In Section 3, our developed system SCROLL is described. Section 4 includes the pilot evaluation experiments we have conducted to investigate how our system could contribute to the effective implementation of flipped classroom. Finally Section 5 concludes the study mentioning our future works.

## 2. Theoretical Backgrounds

### 2.1 Flipped classroom

Flipped classroom is a newly risen learning strategy and has gathered a lot of attention from researchers and educators of various fields in the recent years (Bergmann & Sams, 2012; Kiat & Kwong, 2014; Vaughan, 2014; Schmidt & Ralph, 2014). It is a kind of blended learning, where learning contents moved outside the classroom. According to Flipped Learning Network, ‘flipped classroom’ is defined as “a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter.” More simply it is often defined as “school work at home and home work at school”. Theoretically it might be possible to conduct flipped classroom without technology. One possibility is to deliver paper-based learning contents to the students for reading before class. But when the term, “flipped classroom” or “flipped learning” emerged, it was already a generalized idea to deliver video contents. Therefore flipped classroom can be realized with the help from technology.

As one of the advantages of flipped classroom, Bergmann et al. (2011) has listed that flipped classroom is “a means to INCREASE interaction and personalized contact time between students and teachers.” It is also expected that it can be a means to increase interaction not only between students and teachers but among students. Thus it enables us to realize a student-centered collaborative learning, which is reported as one of the most effective way of learning in second language learning class (Chen, 2003). It is a growing research area attracting the attention of scholars of learning technology all over the world. Since it is an emerging research area, a lot of issues are to be explored in order to prove its effectiveness and its efficacy.

## *2.2 Mobile Learning*

Mobile learning has generally been defined as learning with the use of mobile and wireless technologies. The concept for mobile learning was foreseen as early as 1970s with the Xerox Dynabook project which proposed a “self-contained knowledge manipulator in a portable package the size and shape of an ordinary notebook” (Sharples et al, 2009). It has been recognized as one of the natural directions toward which CALL (Computer-Assisted Language Learning) is heading (Chinnery, 2006; Stockwell, 2007). Thornton and Houser (2005) reported that the learners preferred mobile platform rather than PCs. Especially, mobile technologies have been expected to foster shifting from classroom-based learning to the one that is free from time and space boundaries. Since mobile technology is a fast-evolving, constantly advancing field, its infinite potential is inevitably expected to contribute to implementation of flipped classroom.

## *2.3 Motivations*

One of the motivations for introducing flipped classroom is to make use of class time for collaborative activities. In Uosaki and Ogata (2009), the survey result shows that the participants, university sophomores, felt it was the most useful to conduct an interview with international students among various activities in their communicative English class. In fact, it is regarded as one of the most effective ways of learning languages to mingle with those who speak that language. Since one of the authors’ L2 learning class consisted of international and Japanese students, it was an ideal situation for language learners. In order to make most use of class time with group discussion, group presentation or any kind of collaborative activities, flipped classroom was introduced.

The other motivation is that learning time of the second language at school is far from sufficient in Japan and there is a strong necessity to boost up outside-class learning time (Uosaki et al., 2013). In order to solve this problem, flipped classroom is expected to be one of the key contributors. Taking the above mentioned elements into account, we have designed a class where students can mingle with peers during class with lecture part at home such as introduction of new terms.

## **3. SCROLL**

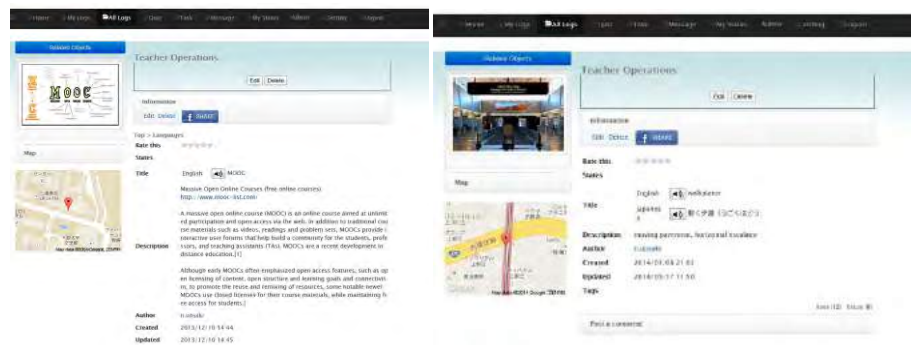
### 3.1 System Design

We have developed a system called SCROLL (System for Capturing and Reminding of Learning Log) that allows learners to log their learning experiences with photos, audios, videos, location, QR - code (Quick Response code), RFID (Radio - frequency identification) tag, and sensor data and so on , and share and reuse them with others (Ogata, et al., 2010). SCROLL is a client-server application. The server side runs on Linux OS. It runs on different platforms such as Android mobile phones, PCs, and other smart phones and tablets. Users register what they have learned, which we call “ubiquitous learning logs (ULLs)”, to the system and view ULLs uploaded by themselves and others. Then the system automatically generates quizzes to help learners to recall their past ULLs.

ULL recorders facilitate learners' recording of their ULLs to the server whenever and wherever they learn new objects. As shown in Figure 1, in order to add a ULL, they take its photo, attach different kinds of meta-data such as its meanings in different languages, comments, tags and location information. They can share their new ULLs with others and view ULLs uploaded by themselves and others. They can keep their ULLs private if they wish.



Figure 1. Add ULL on Android



(1) “MOOC” for previewing before class (2) “walkalator” for reviewing after class  
Figure 2. SCROLL Interface on the Web

It is expected that the sharing function that we can share ULLs with other learners instantly gives a great deal of support for implementation of flipped classroom. In this study, SCROLL was used for an instructor’s uploading terms to be learned for viewing before class (eg. “MOOC” in Figure 2(1)) and also terms which they learned during class for reviewing after class (eg. “walkalator” in Figure 2(2)). It was also encouraged learners to upload their own learning experiences, which is the system’s original purpose.

## 4. Evaluation

### 4.1 Subjects

Eleven university students in an international exchange class which was held weekly and conducted in English language at Osaka University participated in the evaluation. They were 5 international students (two from Netherland, two from Brazil, and one from Germany) and 6 Japanese students. They all reported they had Internet-connected PCs at home and were mobile phone owners.

### 4.2 Flipped classroom Design

The objectives of the subject class were 1) to improve their target language abilities and 2) to enhance mutual understanding of the culture of their mother countries and Japan. In order to make much of class time for discussion and other collaborative activities, as for lecture part such as learning new terminology, or briefings on how to use SCROLL, they were assigned to view contents on SCROLL before class, which are, in most traditional classes, supposed to be done during class. In addition, in order to encourage students’ outside-learning, they created their own Blogger site and were given home assignments of composing essays using their target language. Furthermore, in order to promote their

interaction outside-class, a Facebook group was created. The learning procedures are described in Figure 3.

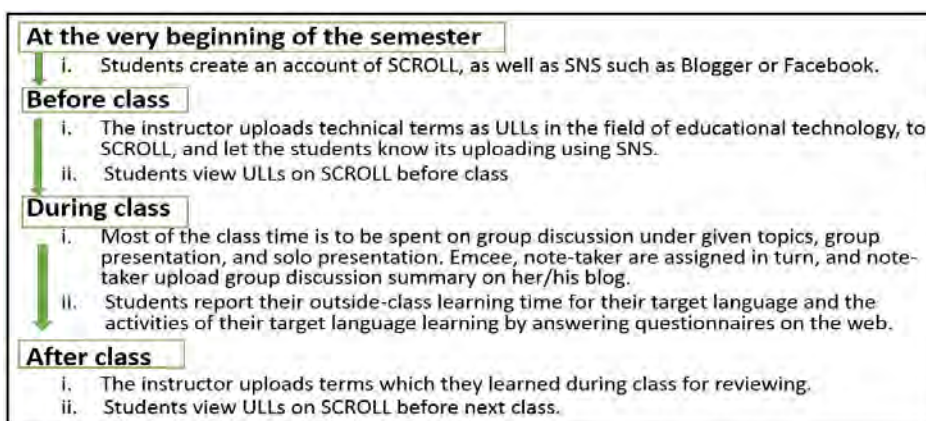


Figure 3. Learning Procedures

### 4.3 Results and Discussion

#### 4.3.1 The average outside-class learning time for the target language learning

As mentioned, since it is a key issue how we can encourage students to get involved in learning outside-class in flipped classroom, the participants were asked to report their outside-class learning time and what kind of activities were included on the questionnaire site created by Google Drive.

The average outside-class learning time for each student was shown in Table 1. The whole class average was 53.9 minutes per day.

Table 1: Average outside-class learning time for the target language learning (per day)

|                  |                    |
|------------------|--------------------|
| Student #1       | 116.9              |
| Student #2       | 75                 |
| Student #3       | 70.1               |
| Student #4       | 65.8               |
| Student #5       | 55.3               |
| Student #6       | 51.8               |
| Student #7       | 51.5               |
| Student #8       | 47.3               |
| Student #9       | 22.1               |
| Student #10      | 21.6               |
| Student #11      | 15.7               |
| <b>Mean (SD)</b> | <b>53.9 (27.6)</b> |

In our previous study, we had conducted an evaluation with university freshmen with/without SCROLL (Evaluation I) in order to find the answer to our hypothetical question: Does SCROLL contribute to the solution of lack of learning time? (Uosaki et al., 2013). Table 2 shows the average outside-class learning time for both groups: SCROLL group, 10.07 minute per day, without-SCROLL group, 6.6 minute per day. This indicates that the SCROLL group more committed to outside-class learning than without-SCROLL group, though the t-value (1.28) did not show its statistical significance.

Table 2: Average outside-class learning time in Evaluation I (per day) from (Uosaki et al., 2013)

|                | Outside-class Learning Time (min)Mean (SD) | <i>t</i> | Effect Size (d) |
|----------------|--|----------|-----------------|
| With SCROLL    | 10.07 (151)                                | 1.28*    | 0.37 (Small)    |
| Without SCROLL | 6.6 (115)                                  |          |                 |

\**p* = 0.11

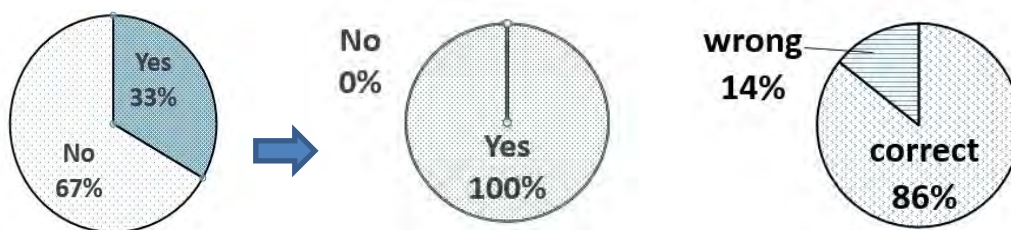
Compared with our previous study, outside-class learning time dramatically increased in this pilot study. Since one of the motivations for introducing flipped classroom was to boost up their outside-class learning time, the question was “How long did you study your target language outside class from date *X* – date *Y*?”, the same question asked in the previous one. There should be considered

various factors which contributed to boosting up outside learning time. The interview session was conducted for the hardest worker whose average outside-learning time for her target language was 116.8 per day. She said “I studied hard because I intended to take IELTS (International English Language Testing System). In her case, it seemed to be IELTS test that boosted up her outside-class learning time. Therefore it is too early to say flipped classroom was one of the contributors.

#### 4.3.2 Appropriate timing of posting an outside-class task

##### 1) One week Vs. two weeks

The students were assigned to view ULLs before class. Figure 4 shows the questionnaire results on whether they learned a new term, ‘flipped classroom’. The first questionnaire result shows only 33% answered ‘yes’ to the question whether they knew it. In fact the exact the same 33% said ‘yes’ to the question whether they viewed it. Next class, the instructor encouraged them to view it and the second questionnaire conducted one week later shows 100% of the students answered ‘yes’. It seemed it was unlikely for them to do their outside-class task during the first week. Their performance was highly improved after the teacher pushed them to view it. Therefore it is recommendable to give them at least two weeks to view ULLs as an outside-class task.



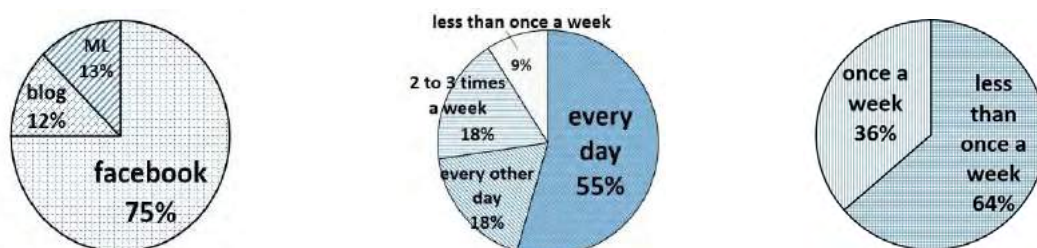
(1) 1<sup>st</sup> time (2) 2<sup>nd</sup> time (one week later)  
**Figure 4.** Do you know what 'flipped learning' means?

**Figure 5.** What does 'MOOC' stand for?

The students were assigned to view ‘MOOC’ uploaded to SCROLL as an assignment. The instructor gave them a reminder the next class and a multiple-choice quiz was conducted two weeks later. Figure. 5 shows its result. 86% gave a correct answer. The result also endorsed it was adequate to give them two weeks view an assignment content.

#### 4.3.3 SNS contribution to outside-class learning

Since SNS function of SCROLL is yet to be ready, all the students created their own blog including the teacher and became readers each other and a Facebook group and a mailing list were also created in order to encourage outside-class interaction. According to the survey, 75% of the students used Facebook as a means of getting messages from the teacher (Figure. 6(1)). 55% of the students viewed Facebook posts every day, while 64% of the students viewed blog posts less than once a week (Figure.6(2)(3)). Therefore blog sites did not work as a means of communication outside-class, while Facebook group functioned as a group forum and they interacted each other using their target language outside-class, which, we believe, one of the contributors to boosting up their outside-class learning time of their target language.



(1) Means of getting messages (2) FB viewing frequency (3) Blog viewing frequency  
**Figure 6.** SNS contributions

## 5. Conclusion and Future Works

In this study, we explored flipped classroom and conducted a pilot evaluation. It was found that outside class learning time increased in our proposed learning scenario, but still more examination was necessary to conclude its contribution. Timing of posting outside-class task was examined and found out that the period of two weeks is appropriate as far as this pilot is concerned. Full evaluation is scheduled to be conducted in the near future to examine whether these findings are replicated.

## Acknowledgements

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# Supporting E-Learning in Computer-poor Environments by Combining OER, Cloud Services and Mobile Learning

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**Abstract:** Research supervision is an important type of support for advanced students when engaged in study projects or in writing their final theses. One of the most common complaints from research students is erratic or infrequent contact with supervisors, who might be too busy with other responsibilities or are not present frequently enough. High proliferation of mobile phones (i.e. 'mobile-rich') but no computer prevalence (i.e. 'computer-poor') in African countries calls for using mobile technologies to address this challenge. However, limitations of mobile devices (such as usage cost, memory capacity and small screen) are some of the barriers for mobile learning adoption. In this paper, we combine mobile learning with OER and Cloud Computing Services to enhance supervisors' availability to their research students, who are in 'mobile-rich' but 'computer-poor' learning settings typical for African universities.

**Keywords:** Mobile learning, Cloud Computing, Open Educational Resources

## 1. Introduction

A case study conducted by Muyinda, Lubega, & Lynch (2008) in Makerere University observed that the face-to-face collaboration between supervisors and research students was inadequate. The students were frustrated by the 'non-availability' of their supervisors. This includes limited face to face interactions that required student to physically meet their supervisors in the campus premises.

By the end of 2012, Africa had a 73% SIM penetration (Connections divided by total population) and is estimated to reach 97% by 2017 (Kearney & GSMA, 2013). However, Computer Access is still very low in this region. A survey conducted by Calandro, Stork & Gillwald (2012) has revealed that in 10 African countries, only 30% of the population have access to computers, while twice as much (60%) have access to mobile phones.

Although, technical limitations and cost of using mobile phones hinder large scale adoption of mobile learning approaches (Isaacs, 2012), incorporating the use of open education resources (OER) and Cloud Computing services in mobile learning can be used to address these challenges.

This paper discusses how OER and Cloud Computing Services can be combined with mobile learning approaches to support research supervision processes in 'mobile-rich' but 'computer-poor' learning environments typical for African universities.

## 2. Related Work

### 2.1 Research Supervision Process

According to Hockey (1996), the supervision of students' project work is a complex social process that consists of strategies employed by supervisors for allowing research students to complete their research project successfully. Studies show this complexity to be further reinforced by the fact that the process itself is dynamic in nature. The strategies and tactics selected by supervisors and the way they are implemented depend on a number of factors within the research process that are fluid. There are three strategies which can be adopted (Spear, 2000). That is: i) *Strong Interaction*, which involves sharing of responsibilities in the running of an experiment, regular group meetings (usually after every



5 days) and continuous interaction (collaboration) between supervisor and student; ii) *Intermediate Interaction* is viewed as the most common strategy today, which requires the supervisor and student to agree on meeting frequency usually on weekly basis to discuss research progress; iii) *Weak Interaction* involves irregular and infrequent meetings with the supervisor, whose interval can be several months.

## 2.2 Mobile Learning

In recent years, there is increased attention in mobile learning by educators, companies, researchers and policy makers, which has resulted to variously definitions of mobile learning (Muyinda, Lubega, & Lynch, 2010). For the purpose of this study, we will adopt the definition by Parsons & Ryu(2006), which states that mobile learning is a form of electronic learning (E-learning) that use mobile devices.

The current forms of mobile learning can be classified into three categories based on their primary objectives(Mwendia & Buchem, 2014). These include: i) Context sensitive mobile learning, which aim at supporting learning by considering the learner's current context (such as activity, identity, and social relations); ii) Mixed modes of representation learning, which aims at improving the meaning of learning content by allowing learners to participate in a media-rich environment, for example, is using a mixture of video, audio and text to present the same learning content; and iii) Ambient learning, which aims at enabling anytime, anywhere and anyhow access to personalized and high quality E-learning material. This category is distinguished from other E-learning services by three main features: Firstly, Multi-modal Broadband Access enables learners to access different modes (e.g. text, audio and video clips) of online E-learning materials. Secondly, Content Management allows integration of existing knowledge catalogues and e-learning resources using meta-data language. Thirdly, Context Management enables capturing and using learners' context(e.g. personal profile, activities) to deliver relevant content (Paraskakis, 2005).

Although there is high proliferation of mobile phones in Africa, mobile learning is still in its infancy, partly because of limitations associated with mobile devices such as small screen, low storage capacity and communication costs(e.g. text messaging cost) (Isaacs, 2012).

## 2.3 Cloud Computing Services

Studies show that there are several definitions of Cloud Computing. In this paper, we will adopt the definition of Cloud Computing as a form of computing where largely scalable IT-enabled capabilities are provided as a service to external clients using Internet technologies(Plummer, Bittman, Austin, Cearley, & Smith, 2008). In the field of technology-enhanced learning(TEL), there are four categories of Cloud Computing Services that can be used to overcome certain limitations of mobile devices, server systems or desktop computers, especially to enhance accessibility and interoperability in technology-enhanced learning scenarios(Jansen, Bollen, Baloian, & Hoppe, 2013). These are:

- Cloud-based *Communication Services* can help to exchange information between learners in collaboration learning scenarios, for example, chat features in Facebook may be used to support group discussions.
- Cloud-based *Repository Services* can facilitate the integration of learning objects in the cloud, for example, storage services offered by Amazon Simple Storage Service (S3), Dropbox, Youtube, Instagram and Flickr.
- Cloud-based *Production Services* can facilitate the creation of new content and/or improve its quality, for instance, using web-based applications(e.g. 'Mindmeister') to create mind maps.
- Cloud-based *Processing Services* can help to process or analyze data, particularly large amount of data. A good example is the ' Amazon Elastic Map and reduce' service that can be used to analyze huge data set with minimal effort.

However, more research is needed to investigate benefits of combining these services based on their potential functions for education usage, especially in mobile learning scenarios.

## 2.4 Open Educational Resources (OER)

According to Butcher (2011), open educational resources (OER) refers to any learning resources such as course materials and multimedia applications, which have been constructed for teaching and

learning and are openly accessible for use by educators and learners, without requiring them to pay royalties or license fees. Cloud-based applications can be used to facilitate networking, sharing, communication, and the production and publishing of OER (Ally & Samaka, 2013). Some of the benefits for incorporating OER in mobile learning include:

- Improving quality of learning materials through peer review activities such as editing, adding and mixing (Park, 2013).
- Reducing communication cost by using free OER tools that supports free exchange of messages during collaboration without paying for access fees or licenses (UNESCO/COL, 2011).

### 3. Applications Scenario and Requirements Analysis

#### 3.1 Scenario

According to Spear (2000), intermediate interaction is the most common strategy that is used to implement research supervision process in universities. We therefore focus on this strategy by discussing an example scenario, which was observed at KCA University in Kenya as a case study for this research.

Bachelor of Information Technology (B.Sc. IT) is one of the degree programs offered by KCA University, which enrolls about 50 students per semester. The Research project unit, is one of the course units that are offered in the program requiring students to do a computer related project of their own choice. The project is progressively evaluated by an allocated supervisor (usually a lecturer) from the start to the last stage of the project. At each stage of research progress, there are two main activities. Learning activity involves receiving guidance from the supervisor through provision of learning materials and collaboration. Evaluation activity involves submission of deliverable and oral presentation to the supervisor, who provides feedback (i.e. marks, remarks) to the student. This process is progressively repeated until the final dissertation is submitted. In order to facilitate the project supervision process, mobile learning can be adopted in universities like KCA University.

#### 3.2 Value-Adding Functions on Mobile Devices

Value-adding functions provided by mobile devices competes with those offered by printed materials. These functions promote the shift from traditional Distance Education Learning (DSL) that utilizes printed materials, towards mobile learning. The following table illustrates these functions.

Table 1: Value-adding functions of mobile phones compared to printed materials.

| Mobile devices   | Printed materials   |
|--|---|
| Interactive support enables learners to communicate with others through feedback channels e.g. social media. | No collaboration (interaction) support due to the lack of feedback channels.    |
| Multi-modal support allows access to dynamic content such as video and audio clips.                          | Can only support access to static content such as text and images.              |
| Content in the same learning object can be updated dynamically through copy and paste features.              | Content cannot be dynamically updated. It only be replaced with increased cost. |

### 4. Proposed Learning Approach and System

The primary objective of ambient learning is to provide easy E-learning by supporting access to personalized and high quality content at anytime, anywhere and anyhow (Paraskakis, 2005). Among the three categories of mobile learning, this objective of ambient learning seem to be more appropriate for enhancing supervisors' availability to their research students. We therefore choose to adopt ambient learning as a form of mobile learning that can be used to support research supervision process in bachelor or master degree programs.

Ambient learning is described as combining requirements of learning paradigms and characteristics of ambient intelligence (e.g. embedded, context awareness, adaptation, anticipation) (Bick, Kummer, Pawlowski & Veith, 2007). Using this description, we propose a new form of ambient

learning that consists of ambient intelligence characteristics and combines mixed modes representations learning with context sensitive learning, which use mobile devices, cloud-based services and OER for learning support. The distinguishing components of our proposed architecture are:

- The Embedded Mobile Application helps to overcome display limitations of mobile devices by supporting context awareness (i.e. capturing learner's context ) and presenting personalized user interface for learners to choose preferred mode of representation (i.e. audio, video or text) (Bick, Kummer, Pawlowski & Veith, 2007).
- Cloud Computing Services help to overcome storage limitations of mobile devices (Jansen et al.2013- see above).
- The Content Manager searches and selects the most relevant online learning materials (videos, audios and text documents) from the cloud- based repositories by considering learners' context obtained through mobile application (Paraskakis, 2005).
- The Context Manager receives, evaluates and stores learners' context in the context database. Examples of context include learner's identity, education level, preferences and so on (ibid).
- Multimodal Mobile (MM) Broadband Access facilitates internet access to multiple modalities of representations such as audio, video and text modes at anytime, anywhere and anyhow using existing mobile broadband technologies such as wireless networks and internet enabled mobile phones (ibid).
- The Context Database stores learners' context (e.g. preferences, profile, learning stage, etc.) that is captured by mobile application. Therefore, the database is connected to the context manager.
- Open Educational Resources (OER) refers to freely available online learning materials (e.g. documents, video and audio clips) that are stored in Cloud-based Repositories (Butcher, 2011).

Figure 1 illustrates how these components are interconnected. It shows that learners can access personalized Cloud Computing Services ( i.e Communication, OER repository and Production services) using mobile devices and adaptation components (i.e the context manager, the content manager and the context database) that run on local web server to ensure data confidentiality.

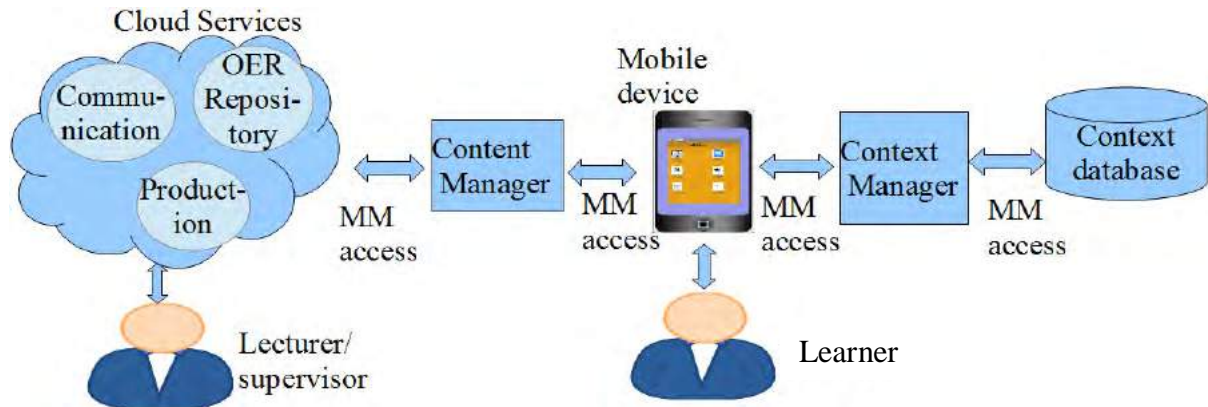


Figure1. Proposed system architecture.

## 5. Implementation

The effectiveness of the proposed learning approach needs to be evaluated before its adoption. To facilitate this, a prototype was developed during a stay of the first author at the University of Duisburg in Germany and later piloted at KCA University in Kenya starting from mid May 2014. The prototype consists of mobile application that runs on smart phones and a backend web server for hosting adaptation components (i.e. the context database, the context manager and the content manager). It also supports mobile access to Cloud Computing Services that are relevant to learners' individual context. Cloud-based applications connected to the prototype are: i) Google Docs for creating study guides and progress appraisals; ii) Facebook for collaboration support; and iii) Dropbox for managing OERs (i.e. storing, sharing, and deleting). Full implementation of the prototype is scheduled to start from January 2015 at KCA University and can be demonstrated using the following walk through example that includes screen captures of the prototype.

Example: Peter is a university student with a smart phone but has no personal computer at home. He has just registered for the research project unit through his phone and would like to start the learning process while at home during the weekend. Upon login, the mobile application his smart phone checks the context database and notices that no feedback has been posted so far. The application determines that Peter is a beginner and anticipates that next learning material is the proposal guide. The multi-modal access screen is then presented (as shown in Figure 2) so that Peter can choose his mode of access (e.g. video, text or audio). Peter chooses the audio mode, which will allow him to listen through headphones while he is cleaning the house. The application downloads MP3 files from OER repository (as shown in Figure 3) to allow the playing the audio file even when there is no internet connection (offline). After listening for 30 minutes, Peter decides to do a test for evaluating his proposal idea. Now he chooses the assessment option(as shown in Figure2). The application then presents the Progress Appraisal form, which contains diagnostics questions (for identifying knowledge gaps) and reflective questions (to help student evaluate himself) (as shown in Figure 4). Peter answers all the questions and submits them by pressing the submission button.

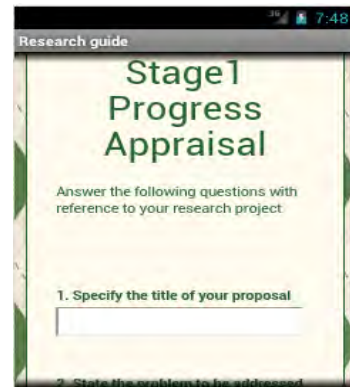
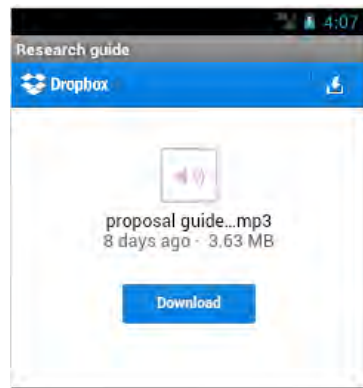
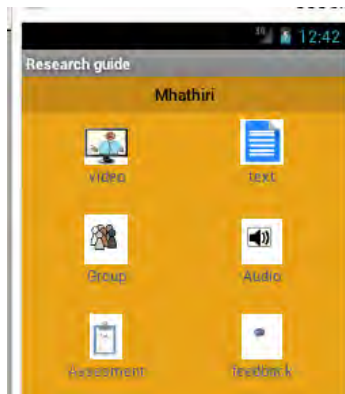


Figure 2. Main menu screen. Figure 3. Stage 1 content. Figure 4. Stage1 assessment.

Before closing the application, Peter presses the Group button(as shown in Figure 2), which displays Facebook page as shown in Figure5. He then writes a message to notify his supervisor that he has submitted stage1 progress appraisal. On receiving the notification, the supervisor uses his tablet to download the appraisal document in PDF format (as shown in Figure 6). He evaluates Peter's submitted work and posts feedback (i.e. marks and remarks) using his tablet as shown in Figure 7.

During the next learning session, Peter logs in and presses the Feedback button at the bottom of the Multi-modal access screen (as shown in Figure 2) .The mobile application searches for feedback posted by the supervisor in the database and presents it on the screen. This process continues for several days until Peter completes all the required learning stages.

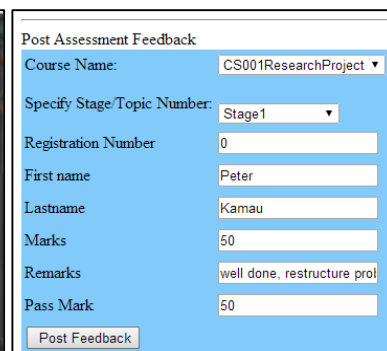
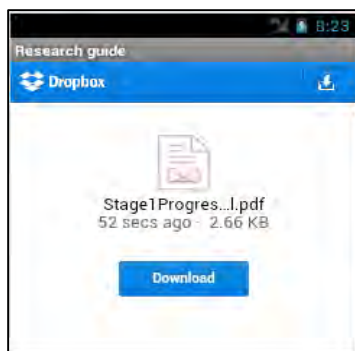


Figure 5:Facebook page Figure 6: Downloading Figure 7: Posting feedback

## 6. Conclusions and Further Work

This paper discussed the proliferation of mobile phones and non-prevalence of computers in African universities. Mobile phones can be used to reach large proportion of learners but they are associated

with limitations such as usage costs, small screen and limited storage capacity. Based on the digital status of African universities and the need to address limitations of mobile devices, a new learning approach has been proposed, which integrates mobile learning with open education resources (OER) and Cloud Computing services. In order to evaluate the approach, a mobile application has been developed to simulate how the new approach can be used for facilitating to access web based applications that offer Cloud Computing services. These include: Drop box, Google Docs and Facebook. Screen captures obtained from the simulator are included in this paper.

Further work is expected to focus on evaluating the effectiveness of the proposed approach. This can be done through conducting experiments in 'mobile-rich' but 'computer-poor' learning environments, especially concerning African universities. Additionally, there is need to explore other cloud-based applications that can support mobile learning scenarios.

## Acknowledgement

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# Applying POE framework in a simulation system for facilitating physics learning with Tablet PCs

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**Abstract:** This study attempts to propose a model integrating real videos into the development of simulations on iPads to support students' science learning about motions based on Predict, Observation and Explanation (POE) framework. Motion examples in videos embedded in the simulation were employed to assist students in contrasting stimulated phenomena and real-world cases for meaning making about force and motion. A preliminary study found that the students, who were given with the video clips, exhibited significantly higher frequencies of modeling (manipulating variables to simulate the movement) and replaying (watching the simulation) than those who were not given with the videos while dealing with complex motion. Such a result suggest that integrating video clips into the simulation could be helpful to stimulate students' involvements in reviewing and revising the simulation while exploring more complex concepts.

**Keywords:** Simulation, science learning, iPads, video, POE

## 1. Introduction

Many researchers (Rutten et al., 2012; Smetana & Bell, 2012) have suggested that computer simulations could be a potential option for facilitating science learning and instruction. Computer simulations can offer many advantages to support students' science learning by ways of making abstract concepts and tacit knowledge of science visible and concrete. Students can see and interact with representational models of natural phenomena that would be hard to observe in the real world to carry out scientific discovery learning (de Jong & van Joolingen, 1998). However, researchers asserted that simulations should be carefully regarded as abstract models by its nature different from the physical entity in the real world, even though computer simulations are useful to the concretization of scientific concepts and phenomena (Horowitz, 1999).

Such a difference raises the concerns about how to strengthen the connection between stimulated representations and real-world situations. If students are engaged in conceptualizing science phenomena in the natural world, they actually learn science from real experience of what they were engaged in (National Research Council, 2011). For this reason, computer simulations demonstrated with real-world examples may be helpful to bridge the gap between the conceptual world and reality, and then help them develop better understanding of scientific principles and phenomena conveyed by the stimulated models. Therefore, this study attempts to propose a model integrating real videos into the development of simulations on iPads to support students' science learning based on Predict, Observation and Explanation (POE) framework. Motion examples in videos embedded in the simulation were employed to assist students in contrasting stimulated phenomena and real-world cases for meaning making about force and motion. Students are expected to acquire better understanding about scientific concepts related to the subject of force and motion within the research context conducted in this study.

## 2. The POE framework to apply simulations with video clips on iPads

In this study, pictures, texts, simulations and videos were employed to construct a series of multiple representations in support of science learning about force and motion on iPads. In the prediction phase,

a descriptive question with an example illustration as shown in Figure 1 was offered to elicit students' idea of the particle movement being subject to the resultant of two different forces.

In the observation part, a simulation including a set of parameters (i.e., position, initial velocity, forces) was employed to demonstrate the effect of forces on the motion of a particle. Students were asked to choose a video clip that demonstrate a certain type of movement and simulate the movement by the use of the simulation system. Students were allowed to manipulate the given variables and observe the consequent movement of the particle as a way to validate their prediction made previously. The simulation system updates the value of the velocity to reflect the correct velocity of the particle's motion. The students were asked to construct at least two different combinations of the parameters in representative of the movement. The aim of combining hands-on simulation and example videos is to strengthen the connection between the stimulated and physical phenomena in support of students' knowledge transfer and integration.

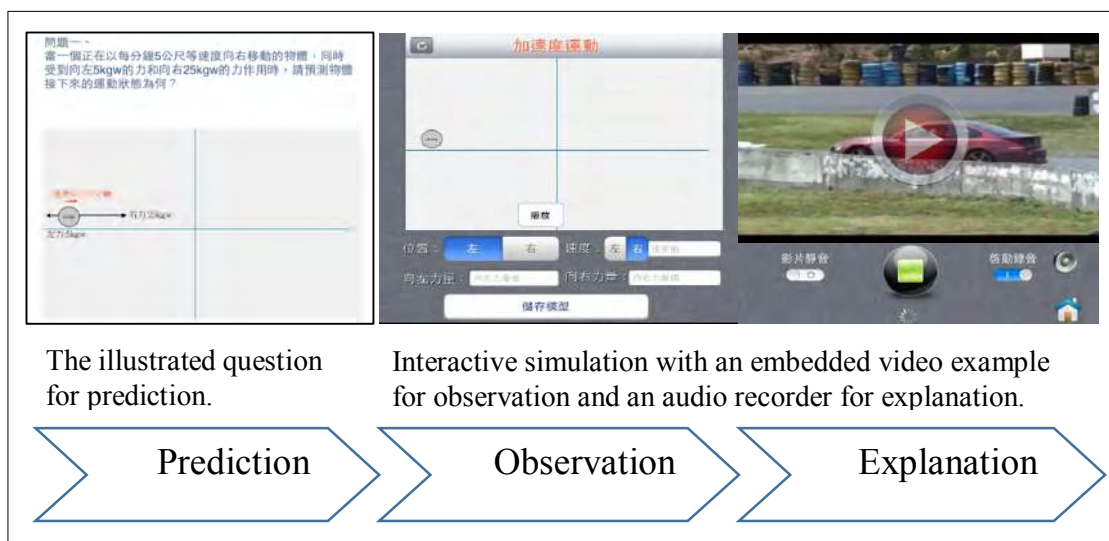


Figure 1. Interactive simulation with an embedded video example in a POE framework

Finally, a mechanism for voice recording is conducted to the explanation step that students are allowed to articulate their own explanations of what they observed and learned through the interaction with the simulation. The students are encouraged to describe the motion of an object by its position, direction of motion, and speed, as well as explicate how forces act on the object along a straight line and may cause changes in the speed or direction of the object's motion. The recorded explanations could be replayed and revised.

### 3. A Preliminary study

A preliminary study was conducted to understand whether video clips combined with the simulation is helpful to enhance science learning. Comparisons of activity log data between the control group (29 students given with simulation without video clip) and experimental group (28 students given with simulation with video clips) were made. The results indicate that the students in experimental group exhibited significantly higher frequencies of modeling (manipulating variables to simulate the movement) (2.92 versus 1.91,  $p < .05$ ) and replaying (watching the simulation) (8.83 versus 4.76,  $p < .05$ ) than those in control group while dealing with accelerated motion. There were no significant differences of modeling and replaying between the groups for the other two types of movements. The findings suggested that integrating video clips into the simulation could be helpful to stimulate students' involvements in reviewing and revising the simulation while exploring more complex concepts.

#### 4. Concluding remarks

Through the application of the well-designed simulations and supportive mechanisms students would be facilitated to construct their own understanding through interacting with simulations about conceptual knowledge. This study aimed to support students' science learning on the topic of force and motion through interacting with a set of simulations. The POE approach was adopted as explicit guidelines to design and develop the POE-based simulations of force and motion for a normal science course in a classroom setting. The mechanism of video clips and sound recording were utilized to support the students' observation and explanation of the POE-based simulations in experimental condition. This combination is on the strength that everyday physical events may held great potential for students' interpretation of the relationships between scientific principles and real-world situations. Students' own observation and explanation are viewed as a critical enabler for their active and productive learning about force and motion.

Comparisons of the students' interactions with simulations between the groups revealed that the students in experimental group exhibited more frequent interactions with simulations for a particle motion with acceleration. It could be suggested that integrating example video clips into simulations could be helpful to stimulate students' engagements with simulations, especially for exploring some difficult concepts such as acceleration. On the basis of these findings, employing the POE-based simulations along with the application of analogous video examples may offer students an alternative ways to assess the ideas coming up with their interactions with simulations.

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# Authoring Augmented Reality as Situated Multimedia

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**Abstract:** Augmented reality (AR) is an enabling technology for presenting information in relation to real objects or real environments. AR is *situated multimedia* or information that is positioned in authentic physical contexts. In this paper, we discuss how we address issues in creating AR content for educational settings. From the learning theory perspective, we explain that AR is a logical extension of multimedia learning theory. From the development perspective, we demonstrate how AR content can be created through our in situ authoring tool and our platform for handheld AR.

**Keywords:** augmented reality, authoring tool, multimedia learning, situated learning

## 1. Introduction

Augmented reality (AR) is an emerging technology for educational settings. Our review (Santos et al. 2014) provides a useful summary of AR prototypes applied to learning. Currently, researchers have varying definitions for AR, depending on which of its features are emphasized. We define augmented reality learning experiences based on Azuma's (1997) definition of AR – "3-D virtual objects are integrated into a 3-D real environment in real time". This is a conceptual definition that is independent from enabling technologies. The "objects" mentioned are more understood as inserting computer graphics and aligning it to a video feed of the real environment. However, Azuma et al. (2001) explained that AR can potentially apply to all senses.

Although there are many AR prototypes for learning, researchers do not usually use the most important feature of AR – showing an explicit relationship between the virtual learning content and real objects found in the natural environment. There are many definitions for AR. As a technology for education, we propose to define AR to be *situated multimedia*. In other words, AR is multimedia (text, sound, images, animations, etc.) that is displayed in relation to the real environment. Thereby, the real environment becomes the "authentic context" of learning that is characteristic of situated learning (Herrington & Oliver, 1995). From this formalization, we then discuss our implementation of authoring tools that teachers can use for creating such situated multimedia.

## 2. Extending Multimedia Learning Theory to Augmented Reality

Previous research works have described AR to offer contextual learning (Specht et al., 2011) and ubiquitous learning (Dede, 2011). Indeed, AR has several benefits because it applies situated cognition (Wu et al., 2013). In this paper, we take a step back and explain that AR is essentially multimedia. As such, multimedia learning theory applies. In this theory, multimedia refers to pictures and words. It assumes dual-channels, limited capacity, and active processing (Mayer, 2009). First, humans have two separate channels for perceiving visual and auditory information. Second, humans have a limited capacity of information that they can attend to. Lastly, learning only takes place if learners actively make sense of incoming information using their prior knowledge. AR visualization can reduce cognitive load, thereby, allowing students to allot more effort to actively processing

information. In a previous study (Fujimoto et al., 2012), we have shown that using AR visualization enables better memorization of abstract symbols. This result is consistent with the prediction of spatial and time contiguity principles of multimedia learning.

Multimedia learning is learning with *pictures* and *words* (both written and spoken). This theory applies to AR if we make the following logical substitutions: The real objects or the real environment is the *picture*. The virtual texts, symbols and pre-recorded sounds are the *words*. A *new picture* is created when real objects, real environment and the *original picture* are combined.

### 3. Authoring Augmented Reality Content

One of the difficulties for adapting situated multimedia is the lack of authoring tools to make educational content. Currently, several authoring tools exist. However, they do not address the needs of teachers for a simple but flexible tool for everyday use. Software libraries like the ARToolkit (Kato & Billinghurst, 1999), Vuforia<sup>1</sup> and PointCloud SDK<sup>2</sup> are authoring tools for programmers.

MacIntyre et al. (2004) and Hengel et al. (2009) developed desktop-based systems for non-programmers so that they can author AR content. On the other hand, Langlotz et al. (2012) created a system for handheld-based authoring. Although handhelds have less processing power than desktops, it has the key advantage of mobile authoring at any place in any time. Currently, Langlotz et al. (2012) draws basic 3D shapes and other features such as copying, deleting, etc.

#### 3.1 Simple In Situ Authoring for Teacher's Use

For the purposes of teachers, it is enough for them to download pictures from the internet, and then place it on a real environment. As such, we implemented an authoring tool that enables teachers to download a picture, and perform affine transformations. Our prototype uses the ARToolkit running on iPad 2 (dual-core A5, 512MB DDR2 RAM, 32GB, 601 grams, 9.7 in display, 1024-by-768 at 132 ppi).

Figure 1 shows the interface for our simple authoring tool for teachers and a sample use case. In this example, teachers can download any image from the internet. This image is converted into a texture on the screen. Using gestures like swipe, pinch, and so on, the teachers can modify the appearance of the image. In this example, it is desirable to scale and position the lungs correctly on the body.



Figure 1. Simple Authoring Tool (left); Sample Use of the Authoring Tool (right)

#### 3.2 Handheld AR Platform for Situated Multimedia

Currently, authoring tools focus on rendering fast and beautiful graphics on a real world scene. There are few authoring tools that emphasize on the use of sounds and text. For educational settings, teachers use a combination of image, sound and text to facilitate learning. As such, we developed a handheld AR platform for presenting images, sound and text onto real objects.

We implemented the whole platform on iOS7 running on iPad 2. Figure 2 shows the package diagram and a sample application for vocabulary learning. The main part of the platform is the Controller, which has access to learning contents. It receives the marker ID and camera view matrix

<sup>1</sup> <https://developer.vuforia.com/>

<sup>2</sup> <http://developer.pointcloud.io/sdk>

from the Tracker and uses these information to specify the behavior of the on-screen display. The Tracker was built using ARToolkit, and the Renderer was built on OpenGL ES 2.04. In the sample use case, students can learn the word “pindutin” (Filipino for “to push”) by animating a hand which pushes a real button. This is an example of situated multimedia because it shows explicitly the relationship of the animation with real objects such as a coffee maker found in the learner’s natural environment.

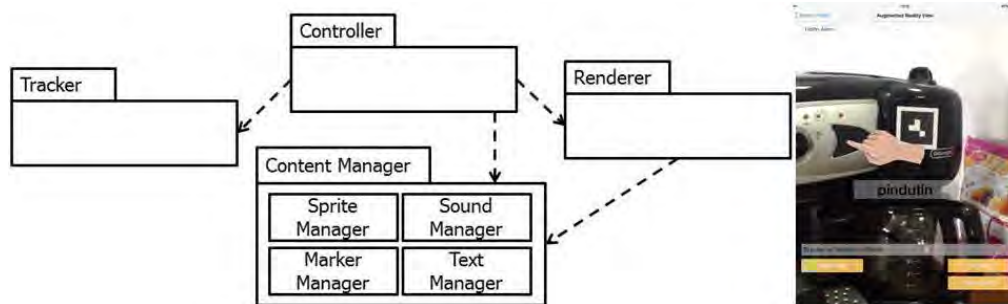


Figure 2. Package diagram of handheld AR platform (left); Sample Interface using the platform (right)

#### 4. Conclusion

We defined augmented reality as situated multimedia. For the first time, we point out that AR could be better understood and designed by applying multimedia learning theory. Aside from graphics, sound and text is also required for creating AR learning materials. As such, we implemented two prototypes for authoring situated multimedia content namely, in situ authoring and our handheld AR platform. Currently, we are conducting evaluations of the interface with teachers. Educators can benefit from this research because it will enable them to design educational content in authentic contexts.

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# Behavioral Analysis of Learners Using Smart Devices in an Indirect Learning System

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**Abstract:** The main method of learning carried out generally is still direct learning, that is, a method of learning that directly and actively focuses on the object of learning. We call indirect learning the learning of a subject matter indirectly as a result of having actively studied another subject matter. We have aimed to establish the information technology required to put indirect learning into practice. This research deals with the behavior of system users when they use smart devices and realize indirect learning in implementing a task. We report results based on analysis of notebooks and videos recorded at the time of learning.

**Keywords:** Indirect learning, smart devices, face-to-face communication, user analysis

## 1. Introduction

In his book, *The Last Lecture* (Pausch and Zaslow, 2008), Pausch said that when we learn something we should not learn it directly: instead he emphasized indirect learning in which learning proceeds indirectly by focusing on another object. However, even today, the type of learning normally carried out is direct learning. Until now proposals have also been made on indirect learning (Adler, 1993). Still, it has been difficult to make a quantitative evaluation of indirect learning itself, and there are almost no examples of the achievement of practical indirect learning. In this study, we introduced a face-to-face meeting support system (Ishitoya et al., 2012) for a small number of people. This system uses tablet devices and large displays as a practical indirect learning system that makes use of information technology. We report on indirect learning in task implementation in English language education.

## 2. Indirect Learning Systems using Smart Devices

### 2.1 System Overview

In indirect learning systems, as shown in the processes of indirect learning in Figure 1, it is necessary to carry out support for both individual indirect learning (through investigations, thought, and organization) and indirect learning within a group (through discussions and organization.) We developed and operated a face-to-face meeting support system. This system is composed of two parts. The first part, called the Time Machine Board (hereafter TMB), is a framework for recording the content of meetings. The second part, called iSticky, is client software for collecting content related to individual activities and inputting information into the TMB. TMB uses a large display as a computerized whiteboard, and iSticky is operated by a tablet device (iPad).

### 2.2 Use in Individual Learning

iSticky has two functions. One of them is to act as a log that records and controls individual daily learning activities. The other is link to an informationally expanded TMB and act as a user interface that presents part of the learning log on a large display. We assumed that the iSticky would be carried around by learners in their daily activities. The learning log recorded on an iSticky can be saved on an indirect learning cloud connected with a network.

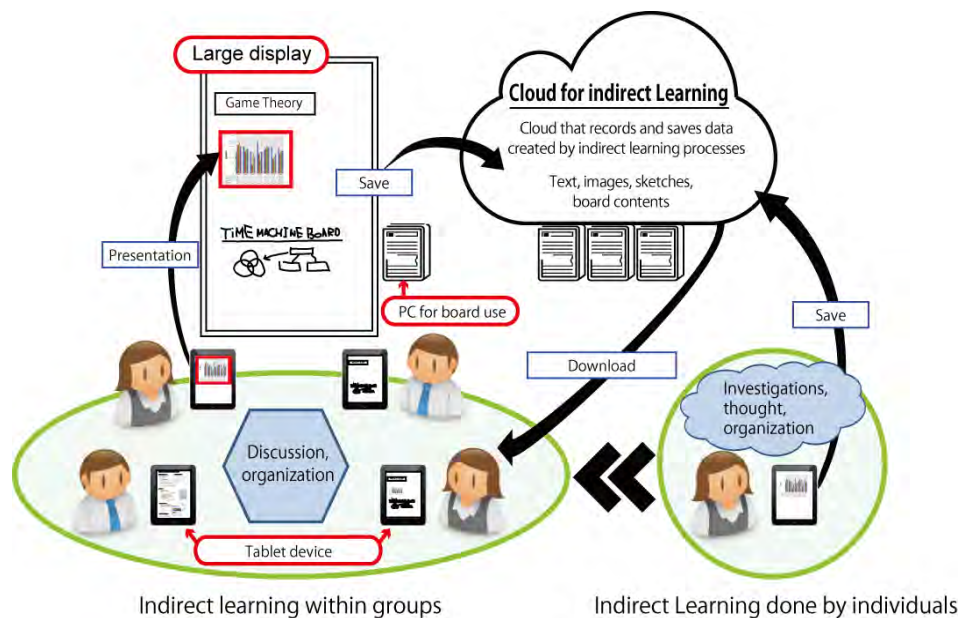


Figure 1. Indirect learning processes.

### 2.3 Use in Group Learning

There are some studies concerning the mixed use of mobile devices, shared displays, and cloud services (Liu et al., 2009; Jansen et al., 2013). In indirect learning carried out by small groups, students can hold discussions among themselves while they organize and present to other learners some of their ideas, thoughts, and results, which they investigated in their daily activities by using TMB and iSticky. The TMB is composed of a large display and a single PC. With iSticky, individual learning logs such as sketches, images, and text that are stored on a cloud for indirect learning can be transferred to a PC and presented on a large display. With the iSticky board tab, learners can confirm the content displayed on the TMB. They can copy part of the learning log onto the board tab, and by moving, enlarging, or reducing the elements on the board, they are able to manipulate the information presented on the TMB.

### 3. Collection of Indirect Learning Data

We used this system for indirect learning in which students carried out a task using graded readers, and we collected indirect learning data. The participants were ten second-year university students (9 males, 1 female). TOEFL ITP scores ranged from a high of 620 to a low of 450, with a mean of 510. We first divided the students into small groups of five members. Then we gave the students this indirect learning assignment: “Decide on a theme from any branch of knowledge that you like. Then create a poster that will communicate in an easily understandable way the history, the current situation, and the future of this branch of knowledge.” As material for the students to refer to when doing their assignment, we designated books from the Oxford University “A Very Short Introduction” series as graded readers. We divided implementation of the task into five phases: (i) selection of a theme and assignment of roles (ii) report on investigations (iii) design of posters (iv) presentations and (v) feedback meetings. We made use of an indirect learning support system in the discussions and operations of each phase.

### 4. Analysis of Indirect Learning Processes

We analyzed the recorded data of operations and of discussions of learners among themselves during indirect learning. We analyzed this data in terms of whether indirect learning systems based on TMB and iSticky were used or not. When these systems were not used, whiteboards and posters were used instead of a large display, and paper notebooks were used instead of tablet devices.

#### 4.1 Analysis of Notebooks and Posters

As a result of comparing the number of characters written in notebooks for each page in the extensive reading text, there was almost no difference between the iSticky and the notebooks, but the number of English words was 2.2 times greater in the iSticky than the notebooks. Furthermore, when the number of characters presented on the whiteboards was compared in terms of time, the rate was 2.9 times more for the TMB than for the whiteboard. Regarding the number of characters on the posters, the TMB had about 11% more, and the time required for making the poster was about 52% less. From the above, we found that when this system was used during a limited time period, it was able to present information efficiently. As a result, more time could be used for communication such as discussions.

#### 4.2 Use of Video Data to Analyze Verbal and Non-verbal Information

We used ELAN to provide annotations to the video data for indirect learning processes. Specifically, we wrote out the content of conversations as verbal information, and we analyzed and recorded eye direction and nodding as non-verbal information. Consequently, the number of characters included in statements per unit of time was about two times greater when smart devices were used. When smart devices were used instead of posters, listeners tended to nod more and have better eye contact with the speaker. The result was that in the discussions immediately after the presentations, we found that groups using the smart devices were asked more questions.

#### 4.3 Questionnaire Survey

Through the whole task of making a poster, we had the learners evaluate, then we found that groups using smart devices had higher evaluations on the understandability of the poster and on the degree of satisfaction with the discussion. We asked the students about any skills other than presentation skills they felt they obtained. Regardless of whether the students used or did not use the indirect learning system, they gave answers such as communication skills overall, ability to impart what I want to say, cooperation, and ability to summarize. Furthermore, students using the system said they improved their ability to create a consensus, their powers of comprehension, and their ability to discuss and debate.

### 5. Conclusion

We analyzed the behavior of system users when they realized indirect learning through implementation of a task with smart devices. As a result, we found that tablet devices were highly efficient in the presentation of information and more time could be used for communication activities such as discussions; furthermore, we learned that the degree of satisfaction in carrying out the task was higher for those using the system. On the other hand, we learned that there was a trade-off between the redundancy of tool operation and the re-usability of information.

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# Development of a Mobile Visualization Application for Constructivist Learning and Assessment in Science

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**Abstract:** In this paper we introduce a newly developed application for Android tablets that is designed based on the perspectives of constructivist learning and scientific modeling and representation. The purpose of this designed product is to facilitate visualization instruction and assessment in science class. We conducted an initial evaluation study for usability tests and investigated how case users from scientists, teachers, advanced learners and novice learners may use the tool to support their visualization of the concept of carbon cycling. Different patterns of use were identified for further research and tool development.

**Keywords:** Mobile technology, visualization, constructivism, science learning, assessment

## 1. Introduction

Visualization involves important practice for communities of scientists, engineers and many other professional experts (National Research Council [NRC], 2011). Visualization refers to processes of creating multiple representations, making meaning of and interacting with the representations (Gilbert, 2008). In light of education, students' ability to visualize or draw their ideas about certain phenomena and to use their visualizations to understand science concepts is important in terms of science education goals and 21st century knowledge and skills (NRC, 2012). Moreover, asking students to draw their ideas can be an effective teaching strategy since it follows the constructivist perspective that learning occurs when learners try to integrate existing and new information to form their own conceptual framework (Ainsworth, Prain, & Tytler, 2011; Linn, 2006).

There are numerous mobile applications available for the purpose of making digital drawings. However, while many applications allow drawing in general, we have not found any current mobile application that provides science content related functions and supports, which are important for students to make drawings efficiently and with scaffolds to benefit science learning (Quintana et al., 2004). For example, ChemSense (Schank & Kozma, 2002) and Chemation (Chang & Quintana, 2006; Chang, Quintana & Krajcik, 2010) provided built-in atom pallets and connection bonds for students to make digital drawings and animations to represent their ideas of chemical phenomena. Research has shown that students benefit from content specific functions to make their drawings to learn science (Chang & Quintana, 2006). However, neither application can operate on the Android system. Also, they only support students in making drawings of atoms and molecules, representing ideas at the particulate level. In this study we describe our efforts to develop a new mobile application for Android tablets, DrawScience, that allows students to visualize their ideas, not only at the particulate level, but also at the symbolic, systematic, and macroscopic levels, as these levels of representation are all essential elements for visualization of science phenomena and concepts. Currently DrawScience is designed as a formative assessment tool that can be seamlessly integrated in science class to make students' ideas explicit and accessible, and for teachers to learn from students' ideas to improve teaching and learning. Future research includes possibilities of automatic scoring of

visualizations, real-time feedback for the making of visualizations, and collaborative construction of visualizations to spur discussion during the poster presentation.

## 2. The Mobile Application: DrawScience

The design of the application is based on the constructivist perspective that students' existing ideas are building blocks for their later learning (Linn, 2006). The interface is divided into three main areas (Figure 1, left) to allow students expressing their ideas: question, drawing and animation. During class, teachers can use an e-learning platform to type in their question for students; students respond to the question by using the features in the application to construct visualizations to make their thinking visible. The design of the four modes (Figure 1, middle) is based on the perspective of scientific modeling and representation that indicates four types of representation that are essential in science teaching and learning: particulate, symbolic, systematic, and macroscopic (Gilbert, 2008; Lehrer & Schauble, 2006). The four modes including the free drawing, textual, particulate, and link modes, enable users to draw the four types of representations in their visualization. In addition, users can use the animation function to create flipbook-style animations to represent a dynamic process in their visualization.



**Figure 1.** Screenshots of DrawScience: Left: the interface includes three major areas - question, drawing, animation; Middle: four modes - free drawing, textual, particulate, and link modes Right: an example drawing made using DrawScience

## 3. Evaluation of the Application

We interviewed a total of 16 participants to investigate how they used the tool to visualize their understanding of the concept of carbon cycling. We chose to focus on the topic of carbon cycling since it involves important science concepts within biology and across other subject areas such as earth and environmental sciences. Also, visualizing the carbon cycle involves the use of dynamic and multiple representations at particulate, symbolic, textual, systematic and macroscopic levels. We interviewed four cases from each of the distinct groups, biologists, biology teachers, 12<sup>th</sup>-grade students (who had already learned carbon cycling) and 10<sup>th</sup>-grade students (who had not yet learned carbon cycling), aiming to test the maximum variety of possible patterns of uses with the visualization tool. Each interview lasted about two hours, and consisted of five major questions asking the participants to make a total of five drawings or animations to show their ideas related to carbon cycling.



Overall the interview results indicate that all participants were able to construct their visualizations and animations of carbon cycling using DrawScience, while participants from different groups seemed to show different patterns of use. To further discern the patterns, we developed a coding framework to analyze the quality of the participants' visualizations (Table 1). We identified four aspects of visualizations emergent from the data, and developed detailed scoring rubrics to rate the participants' drawing in the four aspects: the use of animation, multiple representation, scientific concept and visualization strategy. We found that both the biologist and biology teacher groups scored higher than the students in representing more scientifically appropriate propositions and relationships of the concepts in their visualizations. The biology teachers seemed best at using multiple representations, probably due to their expertise in teaching in which multiple representations are often needed to help students learn the concepts. Interestingly, the students seemed as good as the scientists in terms of using visualization strategies. All participants created three to four frames to formulate an animation showing the directionality and continuity of a dynamic process of plant growth.

Table 1: A coding framework to analyze the quality of the participants' visualizations in four aspects.

| Aspect                          | Definition   |
|---------------------------------|--|
| Use of animation                | Participant created multi-frame animation to show the directionality and continuity of a dynamic process.                  |
| Use of multiple representations | Participant used the modes in the tool to create textual, symbolic, macroscopic, and particulate levels of representation. |
| Use of scientific concepts      | Participant represented scientific concepts appropriately including propositions and relationships of concepts.            |
| Use of visualization strategies | Participants used visualization strategies including use of color, zoom-in and zoom-out, and animation techniques.         |

#### 4. Concluding Remarks

The results of the initial evaluation study indicate that for science learners the design of the visualization tool needs to embed supports in the aspects of appropriately using scientific concepts and multiple representations; for teachers, a reminder to use visualization strategies and for scientists, a reminder to use multiple representations might help. However this tendency of patterns we observed needs further tests with a larger sample size. Nevertheless the application enables scientific visualizations and we are working on providing automatic scoring, real-time feedback, and collaborative construction functions.

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# Educational Affordances of Smart Learning Applications in Science Education

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**Abstract:** Science educators have made efforts to design and use educational applications of smart devices for meaningful learning. For the design of *smart learning* environments, it is crucial to understand the affordances of educational applications as well as their limitations. This study analyzed 40 applications according to their educational affordances: information acquisition, inquiry, modeling, and collaboration. Characteristics of smart learning applications were described along with specific examples. More efforts are needed to design smart learning applications for collaboration and to overcome the limitations of existing applications.

**Keywords:** Educational affordance, smart device, application, science education

## 1. Introduction

A growing number of educators have paid attention to the use of smart devices that promote ubiquitous learning in formal and informal settings. In South Korea, the government has encouraged Self-directed, Motivated, Adaptive, Resource-enriched, and Technology-embedded learning (i.e., SMART learning). In addition, global enterprises like Apple, Google, and Samsung have invested a lot in the development of educational applications for smartphones and tablet PCs. For the design of meaningful learning with smart devices, it is necessary to understand educational affordances of smart learning applications. Educational affordances indicate the properties of an artifact that enable a particular action for learning and teaching (Gibson, 1977; Tan et al., 2012). Some educational applications are more likely to facilitate constructive or collaborative learning activities than others that focus on delivering new information and knowledge. It is crucial for educators to select and use smart learning applications that have educational affordances closely related to learning objectives. Thus, this study intends to explore educational affordances of smart learning applications in science education.

## 2. Meaningful Learning in Science Education

Science educators recently emphasized inquiry, modeling, and collaborative learning for meaningful learning rather than knowing scientific information and facts. In inquiry-based learning, students are engaged in creating hypotheses, conducting experiments, and explaining collected evidence. These activities help students to develop an in-depth understanding of scientific principles and scientific literacy in authentic contexts. Students who participate in scientific inquiry are likely to be motivated through authentic activities and develop positive attitudes toward science (Ahmed & Parsons, 2013). In addition, modeling is an essential practice in science education because a lot of scientific knowledge consists of models of scientific phenomena. Student-constructed models explicitly show what students understand and what misconceptions they have. Through iterative modeling activities, students can explain causal relationships behind observed scientific phenomena qualitatively as well as quantitatively (Louca et al., 2011). The inquiry and modeling activities are often conducted in a small group because collaborative discourse helps students to perceive multiple aspects of a scientific phenomenon and develop argumentation skills to support their hypothesis with evidence and scientific knowledge. Students can develop more valid explanations by integrating diverse ideas and challenging

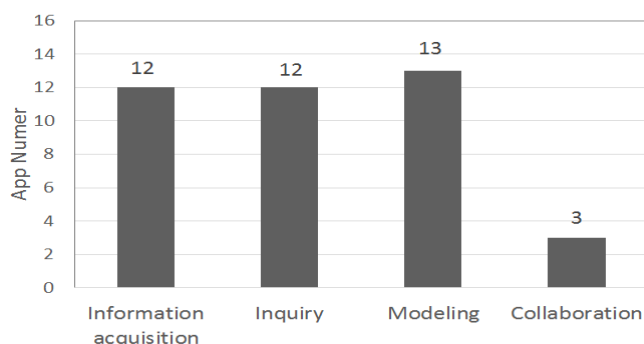
each other. Thus, in science education, smart learning applications should have affordances to enable inquiry, modeling, and collaboration activities for meaningful learning.

### 3. Methods

Science education applications, which work in smartphones and tablet PCs using Android as an operation system, were searched in “Google Play Store” in October 2013. Initially 163 applications were identified with keywords of chemistry, biology, physics, earth science, and science education. Two graduate students in science education and one secondary school teacher collaborated to exclude redundant applications and select applications that were closely related to K-12 science education on the basis of Korea National Science Curriculum. As a result, 40 applications were selected for analysis. Through constant comparison and discussion, the three researchers grouped the smart learning applications into *information acquisition*, *inquiry*, *modeling*, and *collaboration* according to their educational affordances. They analyzed which learning activity was closely related to the properties of a smart learning application. The data analysis process was constantly monitored and coached by two professors in the college of education.

### 4. Findings

According to educational affordances, the 40 applications of science education were categorized into information acquisition, inquiry, modeling and collaboration as shown in Figure 1. Smart learning applications for inquiry and modeling were as many as those for information acquisition. However, the number of applications to promote collaboration was much smaller than others. More attention should be paid to develop smart learning applications to enable students to share their different viewpoints and collaboratively build knowledge



**Figure 1.** Number of smart learning applications according to educational affordances

Applications of information acquisition enabled students to memorize facts and concepts included in the science education curriculum and to have access to educational resources in the Internet. The applications included the content of a textbook, which allowed students to prepare and review lessons anywhere and at anytime. For instance, the application of “Periodic Table Quiz” helped students to memorize the location of atoms through simple quizzes. However, this kind of applications had limitations in supporting higher-order thinking skills and social competencies.

Inquiry applications enabled students to collect and analyze data with smart devices in and out of school. Students were able to record audio and visual information and to measure the angle, length, height, or temperature of an object. The applications were helpful in observing scientific phenomena and collecting data for scientific inquiry in real world contexts. For instance, the application of “Smart Measure” enabled students to easily measure the distance and height of a target in a smartphone screen by trigonometry. However, we could not find an application that supported a whole process of scientific inquiry (e.g., prediction, observation, and explanation).

Modeling applications visualized scientific concepts and objects (e.g., molecular structure) that could not be observed in everyday lives. The applications allowed students to explore a 3D model from

multiple directions and to interact with the model through the touch screen of a smart device. The application of “3D Brain,” for example, enabled students to explore the function of each brain region by rotating and zooming around a 3D brain model. Despite the benefits of the applications, they had limitations in encouraging students to iteratively create and modify their own models of scientific phenomena.

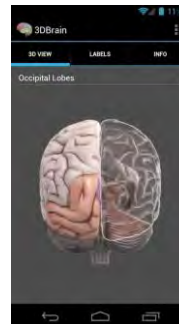
Information Acquisition:  
Periodic Table Quiz



Inquiry:  
Smart Measure



Modeling:  
3D Brain



Collaboration:  
ISS Detector



Figure 2. Examples of smart learning applications

Lastly, collaboration applications encouraged students to collaboratively collect data and share their opinions on findings. The applications can support not only discussion in a classroom but also online discussion among students in different schools and regions. For instance, the application of “ISS detector” allowed students not only to get information of the international space station and iridium flares but also to share their insights through social network service (SNS). Despite the potential of smart devices for collaborative learning, there were few science education applications that focus on collaboration. More efforts are needed to apply smart devices for collaborative argumentation and knowledge building in science education.

## 5. Conclusion

Smart learning applications have diverse affordances to facilitate meaningful learning in science education. This study explored educational affordances of the applications in terms of information acquisition, inquiry, modeling, and collaboration. More attention should be paid to the development of smart learning applications that support meaningful learning in science education. Particularly, more smart learning applications are needed to enable students to share their viewpoints of a scientific phenomenon and collaboratively carry out a scientific task. In addition, future research is suggested to investigate educational affordances of smart learning applications in other sources (e.g., Apple Store) and domains. It is also necessary to carry out developmental studies to overcome the limitations of smart learning applications and to optimize educational affordances of smart devices. The study of educational affordances will contribute to the design of meaningful learning environments that help students to develop key competencies necessary in the 21st century.

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# Evaluation of Using a Tablet Device for a School Trip

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**Abstract:** A tablet device can help solve various problems such as shortening the time of pre- and post-learning activities and remedying the problem of unavailability of a personal computer room. Therefore, this research examines how a tablet device can be effectively used for various learning phases in a school trip. The results show that the use of a tablet device is helpful during the pre-learning phase of a "Famous-place Investigation" and in the use of data obtained in this phase and information sharing during the experiential activities. In addition, this study reveals that the use of a tablet device to present an augmented reality poster is effective.

**Keywords:** Tablet Device, School Trip, Augmented Reality, Practical Class

## 1. Introduction

When planning a school trip, various problems may emerge such as securing the time required for pre- and post-learning activities. Moreover, to deepen the learning experience, in many cases, personal computers (PCs) are used for collecting information. However, availability of a PC room may be limited, especially in larger schools.

On the other hand, information and communications technology (ICT) have been utilized for learning activities, such as a school trip, to secure safety and improve the learning effect (Kasahara et al., 2013, Sato et al., 2010). Thus, a tablet device is an example of how ICT equipment has been increasingly put to practical use in schools (Hasegawa et al., 2010), and from the perspective of mobility and user interface, such a device has been deemed effective in various applications (Savilla, 2010).

By utilizing the functions of a tablet device, experiential learning activities at a selected location on a school trip as well as pre- and post-learning activities can be accomplished by a single device. For example, if the Internet is available, then information regarding the location or attraction can be obtained using a tablet device as a pre-learning activity, even if a PC room is not available. In addition, by saving such data on a tablet device and utilizing the information during the visit, work can become more efficient, especially under the time restraints of the pre-learning phase. With regard to post-learning activities, the still images and animations obtained from the location can be saved on the device and used for subsequent presentations. Therefore, in this study, a tablet device was employed for a school trip during the pre-learning phase, the experiential activities at the location, and the post-learning phase in order to evaluate its overall effectiveness for such educational activities.

## 2. Method

### 2.1 Use of a Tablet Device

A tablet device (Apple iPad2) was used on a school trip for second-year students at a junior high school. Moreover, as shown in Fig. 1, the tablet device was used during the pre-learning phase, the experiential activities at the location, and the post-learning phase. In the pre-learning phase, the famous place that was selected for visiting, the traffic schedule, and the map were investigated; this digital data was saved

on the tablet device. In the experiential activities, the tablet device was used for viewing the aforementioned digital data, information sharing with other groups, creating the activity report (using a TV phone), and producing the still images and animation used in the presentation for the post-learning phase. In this final phase, an augmented reality (AR) poster was produced as a learning tool and the photographs taken by the students of each group were attached to the sightseeing map and printed in A1 size. In this case, if the tablet device is held up by making the photograph into an AR marker, then the animation recorded during the experiential activities will be displayed on the marker.

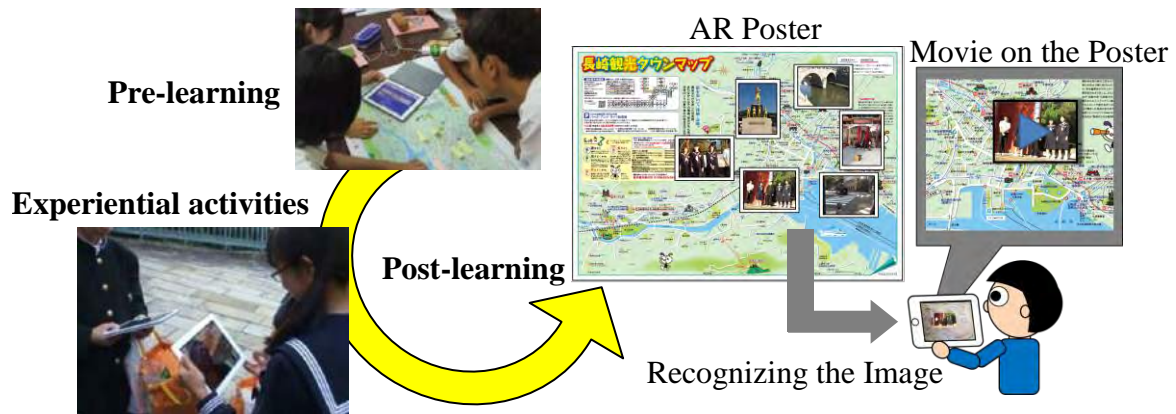


Figure 1. Use of a Tablet Device

## 2.2 Subjective Assessment by Survey

Evaluation of the use of a tablet device was obtained from the 99 students who participated in the pre-learning and experiential activities. The question items regarding interest and usefulness of the pre-learning activities included "Theme Arrangement," "Famous-place Investigation," and "Presentation." Moreover, the question items concerning the experiential activities were "Usefulness of Famous-place Data," "Interest in Photographs by Other Groups," "Usefulness of Map Data," "Interest in the TV Phone," and "Interest in the Report." The question items regarding the AR poster included "Interest (AR poster was interesting)," "Usefulness (AR poster is useful for presentation)," and "Motivation (I would like to produce AR poster next time also)." Finally, evaluations were performed by 188 students (comprising first and third graders who have not previously participated in a school trip), 19 teachers, and 76 parents.

## 3. Results and Discussion

Regarding the use of the tablet device in the pre-learning and experiential activities, students responded by selecting either "strongly agree," "agree," "disagree," or "strongly disagree" for each question. The point scores were 4, 3, 2, and 1, respectively. The mean value of the points in each category was then calculated and analyzed using analysis of variance (ANOVA). In addition, multiple comparisons were made using the Holm method.

Figure 2 presents the results of the evaluation for the pre-learning activities. Regarding interest, "Famous-place Investigation" received the highest evaluation, which was followed by "Theme Arrangement" and "Presentation" ( $F(2,190) = 31.87, p < .01/MSe = 0.30, p < .05$ ). Moreover, regarding usefulness, "Famous-place Investigation" obtained the highest evaluation, which was followed by "Presentation" and "Theme Arrangement" ( $F(2,190) = 15.64, p < .01/MSe = 0.35, p < .05$ ). Thus, the findings show that using a tablet device was useful for these activities.

Figure 3 shows the results of the evaluation concerning the experiential activities. "Usefulness of Famous-place Data," "Interest in Photographs by Other Groups," and "Usefulness of Map Data" obtained a higher evaluation than "Interest in the Report" ( $F(4,208) = 5.30, p < .01/MSe = 0.51, p < .05$ ). Therefore, the data obtained by the pre-learning activities and information sharing with the others was useful for these activities.

Figure 4 reveals the results of the evaluation of the AR poster. According to the responses, the participants were not concerned with the subject's attributes, and at least 90% answered in the affirmative for all questions. Therefore, using a tablet device to present the AR poster was useful.

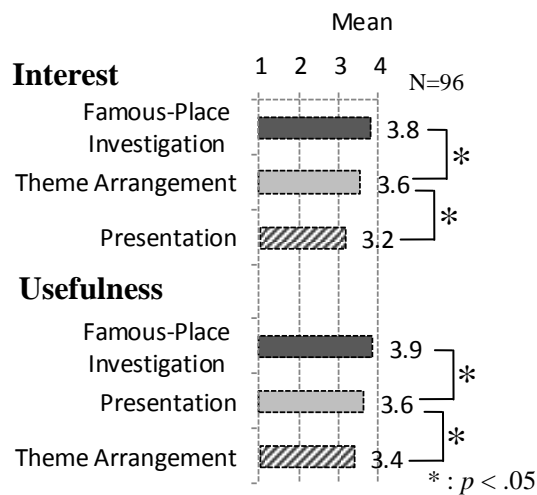


Figure 2. Results of the pre-learning activities

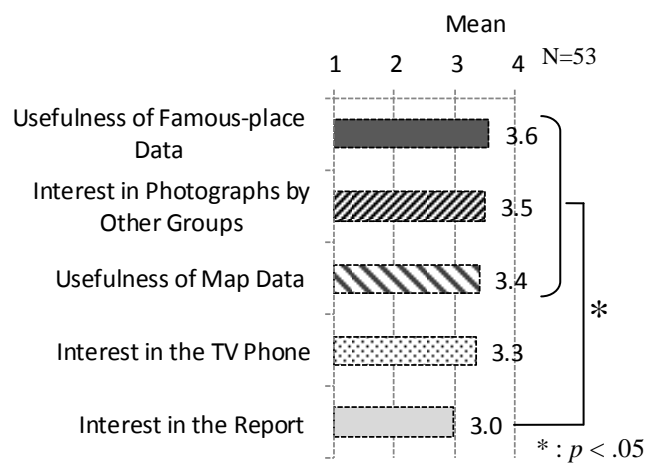


Figure 3. Results of the experiential activities

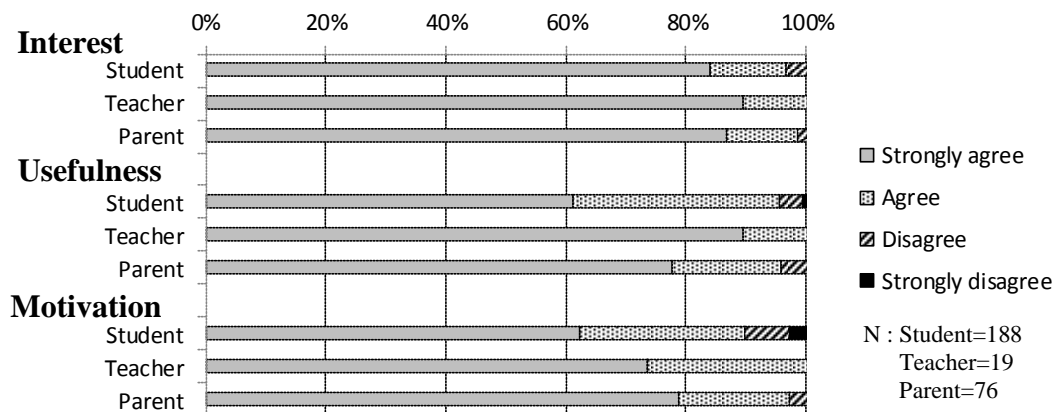


Figure 4. Results of the post-learning activities

#### 4. Conclusion

This study evaluated the usefulness and practicality of a tablet device for a school trip during the pre-learning, experiential activities, and post-learning phases. The results of the evaluation show that using a tablet device during the pre-learning phase of a "Famous-place Investigation" was useful and that the data obtained during this phase and information sharing with others was also useful during the experiential activities. Furthermore, the results reveal that the use of a tablet device to present the AR poster was effective. Although the findings of this study show the effectiveness of such a device for the various learning phases of school trips, further investigation should be conducted regarding its learning effect and usefulness in other situations.

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# Features of Creating Flash Card Materials for Reflecting on Learned Contents

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**Abstract:** It is important that reflecting on contents learned during a class is done at the end of each class. However, it is difficult for many to invest in the human cost in time to prepare for such reflection time. This research suggests creating flash card materials using pictures that teachers have taken during class to reflect on different elements of the class. This study introduces the Skitch application tool as a useful application for providing reflection scenes of the class to students belonging to the Graduate School of Education. The tool was evaluated according to its availability during class and from the perspectives of “learning content,” “notes,” and “creativity” in a descriptive questionnaire. Results revealed that Skitch is a tool that can utilize flash card materials created at an earlier time in the class. The study also reveals features of creating and using flash card materials taken during class.

**Keywords:** ICT, Reflection, Flash Card Material, Materials development, Skitch

## 1. Introduction

It has become possible to reflect on the contents of a class using different types of multimedia, such as video, with advances in Information Communication Technology (ICT). However, there are issues about Reflection of class use video by Many cost about human and time (KONNO et al. 2009). Empirical research into the use of ICT to reflect on class material focuses on using video(MURAKAMI et al. 2010). Such research has neglected the use of other types of technology in the class. It is important that students reflect on the contents of the class before they forget the class. Therefore, reflecting on class content must be done quickly at the end of every class. Thus, using materials such as flash card materials (FCMs) by taking pictures of scenes during the class by the teacher is a valid form of content reflection. Takahashi (2011) defines FCMs as digital material used to repeatedly present questions quickly as a “Flash Card.” There are also several different types of activity associated with the use of FCM, such as 1) Reading the word written, 2) Giving the name of a picture, figure or symbol, 3) Answering a quiz with three choices, 4) Giving a “yes” or “no” answer, 5) Filling in the blank. Therefore, it can be said that FCMs are still a tool used most frequently in questioning. However, sometimes the target of questioning is unclear because of the large amount of information that can be contained in one still image, particularly if the FCM is a photo which has inserted a shape such as an arrow to clearly depict the target in question. In doing so, it can create FCMs for reflecting scenes from the class. If necessary, it is also possible to take pictures and insert a shape such as an arrow during class. Therefore, advantages are in reducing planning time as much as possible, and ease of operation.

This study focuses on the Skitch application, which has a reputation for speed and simplicity of photo manipulation. Because, Skitch is one of tools which can shoot and modify easily and quickly. This study reveals the possibility of creating practical FCMs in Skitch. In addition, it reveals the features of creating scenes as FCMs with Skitch.



## 2. Survey-1 : Whether the practical use of Flash Card Materials

### 2.1 Survey Methods about Whether the practical use of Flash Card Materials

Figure 1 demonstrates that Flow about FCMs by Skitch for Reflection to Learning Contents. The time taken in creating FCMs in Skitch was investigated, as well as the possibility of practically creating FCMs by Skitch in Survey-1. A questionnaire survey was conducted in which 19 teachers of elementary schools were assessed for the duration taken to create FCMs using Skitch in class. Questions in the survey included the maximum allowable time for the creation of FCMs (Stoppable time). This questionnaire is in a description format. The duration taken to create several different images in Skitch was measured: 1) The duration to take a photo, 2) The duration needed to take a picture and add an arrow, 3) The duration to take a picture and add a mosaic, 4) The duration to take a picture, add an arrow and mosaic. Participants in this part of the study were graduate students of 16. The experiment consisted of taking and editing photographs of four character idiomatic compounds that were written onto a whiteboard. Equipment used in the experiment included a tablet PC with Windows8 installed. The creation time of a flash card was calculated as being the time between pushing the shutter button in Skitch and pushing the save button.

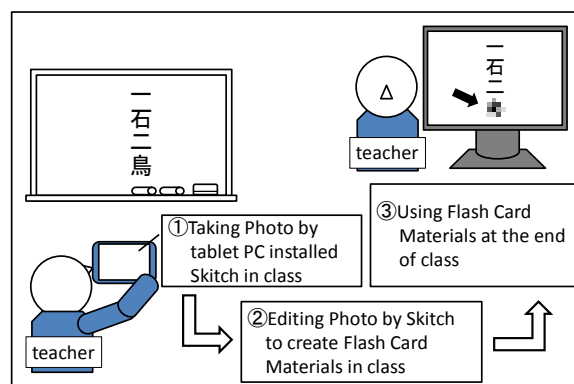


Figure 1 : Flow about Flash Card Materials by Skitch for reflection to learning contents

### 2.2 Survey Results about Whether the practical use of Flash Card Materials

Figure 2 show the relationship between the number of people and length of stoppable time which teachers think. Results into the average speed of creating a flash card was 112.1 seconds (SD: 70.6). The maximum amount of time taken was 300 seconds, whereas the quickest time was 30 seconds. Results into the amount of time to create an FCM in Skitch were as follows: 1) The average time of taking a picture was only 10.6 seconds (SD: 2.8), 2) The average time of taking a picture and adding an arrow was 13.7 seconds (SD: 3.5), 3) The average time of taking a picture and adding a mosaic was 13.6 seconds (SD: 3.7), 4) The average time of taking a picture, adding an arrow and mosaic was 14.7 seconds (SD: 3.8). In addition, the maximum time taken to create a picture in variable 4 (taking a picture, adding an arrow and mosaic) was 26.0 seconds 2,3,4 in four pattern was creating works of FCMs due to works including to edit ware 2,3,4 in four pattern. The average time across all four variables for creating FCMs was 14.0 seconds. Therefore, the time it takes to create an FCM in Skitch is an average of 14.0 seconds, with a maximum of 26.0 seconds. However, this does not consider the time spent on set up and troubleshooting before and after the pictures are taken.

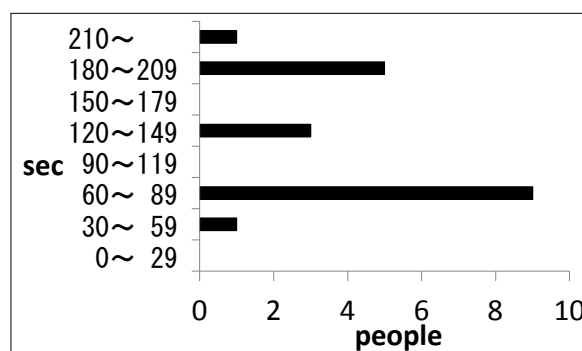


Figure 2 : Relationship of the number of people and stoppable time

## 3. Survey-2 : Feature for creating scene of Flash Card Materials by Skitch

### 3.1 Survey Methods about Feature for creating scene of Flash Card Materials by Skitch

A survey was conducted to reveal the features of creating FCMs on Skitch in Survey-2. This questionnaire is in a description format. This survey's participants were the same graduate students who participated in the investigation in Survey-1. There were 17 questions included in this data because one question was added regarding the subject of the survey. The contents of this questionnaire survey included questions such as; 1) "What do you think about the types of lesson contents that can be used?," 2) "What do you think about the notes provided when the flash cards were created?," and 3) "What do you think about the notes provided when editing?." Furthermore, the questionnaire was organized to categorize the information obtained in the questionnaire.

### 3.2 Survey Results about Feature for creating scene of Flash Card Materials by Skitch

The survey was conducted in the form of a questionnaire following the description format found in Survey-2, and the results were categorized in the same manner. For example, in question 1) "What do you think about the type of lesson contents that can be used?," results were classified into three groups; "passive," "active," and "experience." There were many answers about knowledge acquisition in "passive." There were many answers about sharing, thinking, and behavior in students in "active." Specifically, examples included "Work of a child," "Content of a notebook," "Scene of activities," and so on. There were many answers regarding the difficulties of preparing materials beforehand in "experience." Questionnaire results about the question 2) "What do you think about the notes provided when the flash cards were created?" were classified as "subject," "how to copy," "content," and "other." Answers included comments on accessibility and also on concerns about the privacy rights of portraits including children. There were many answers about the manner in which the camera-works, as well as answers clarifying the purpose and object. Questionnaire results about question 3) "What do you think about the notes provided when editing?" were classified into "focus," "design," and "amount." There were many answers about adding marks to objects under "focus." In "design" answers mostly included comments on the simplicity and ease of viewable colors, as well as many answers about what many mark as unnecessary in "amount."

## 4. Conclusion and Discussion

Survey-1 is not sufficient to reveal the average time it takes to prepare flash cards because preparation time for teachers largely differs among individual. However, as previously mentioned, the average time for creating FCMs on Skitch was 14 seconds, with a maximum creation time on Skitch of 26 seconds. On the other hand, the average preparation time was 112.1 seconds, and the minimum time was 30 seconds. Therefore, it is considered that almost all teachers at elementary school can create FCMs on Skitch during class.

Survey-2 revealed more qualitative data about creating FCMs on Skitch. The results showed the following; A Skitch application tool can be adapted to feature "passive," "active," and "experiential" class content, covering reasons as to why some teachers may want to use FCMs on Skitch. Traditional FCMs are created in advance by teachers. Therefore, Traditional FCMs cannot be used in class for "active" and "experiential" learning, which has not been a previously predicted progression of the class. On this basis, it is suggested that FCMs by Skitch are more effective in class for providing a review of "active" and "experiential" type materials, which would be difficult to provide by means of traditional FCMs. In considering the classifications of features such as "subject," "how to copy," and "content" notes when creating FCMs on Skitch, these features were considered to be the same as traditional FCMs regarding "content." However, it is important to note the differences which were revealed concerning the "subject" and "how to copy" when taking pictures. In particular, if participants raised concerns about the publicity rights and privacy rights of the "subject." When considering features such as "focusing," "design," and "amount" in editing FCMs by Skitch, results revealed similar results for Traditional FCMs regarding the same topics. However, Traditional FCMs are easy to see in the original form because they are created from a blank, whereas FCMs on Skitch can be difficult so as to find a target for, because they are created from photos. In conclusion, it is important to be clear about the target and not to include too much additional information in each picture. Therefore, it is necessary that the expression should be easy-to-understand and one which keeps additional information to a minimum when creating FCMs on Skitch.

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# Research on Learning Support Using a Digital Pen

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**Abstract:** This study proposes that digital pens may contribute to increased learner autonomy amongst university students who are struggling academically – specifically within the realm of mathematics. The researchers distributed digital pens to a low proficiency mathematics class to determine if the devices could meaningfully contribute to improved motivation to learn, academic performance, and autonomy.

**Keywords:** Learning Supports, Digital Pens, Learning Situation

## 1. Introduction

Due to declining birthrates, Japanese universities have loosened their admission policies, a change reflected in the national university entrance examinations, which have decreased in difficulty. Consequently, students with both high and low academic abilities are now attending many Japanese universities. However, the poor academic performance exhibited by many of these new students has been problematic. To remedy this, universities instated a GPA system and also developed college orientation programs, which include placement tests and remedial classes. Chitose Institute of Science and Technology offers such a program, established to prepare prospective university students a year prior to their studies. While Web Based Learning is a component of the program, its implementation could be refined to more adequately address each pupil's unique educational needs. To accomplish this, educators must first familiarize themselves with those needs, and provision appropriate guidance based on that knowledge. Therefore, this study proposes the use of digital pens in conjunction with web applications to gain a more refined understanding of learners' unique learning habits, both inside and outside of the classroom. The researchers tested this idea by distributing digital pens to a group of low-proficiency mathematics students enrolled in the aforementioned orientation program; the data collected were then analyzed to determine the device's effect on the participants' motivation to learn, academic performance, and development of autonomous learning.

## 2. Application

The authors were permitted to collect data captured during the participants' home studies of mathematics using the digital pens mentioned earlier. To document the students' progress throughout the study, the Deji Note Learning Management System was used. This data were extracted as the students transitioned from the first to second semester, and subsequently between two different topics. Using Deji Note, the researchers identified the beginning and end of each student's home studies on a weekly basis. Furthermore, these statistics were used to calculate the rate at which changes in the participants' motivation, academic performance, and autonomy occurred. The system also allows one to view recreations of a user's pen strokes (see Figure 1), and can be retrieved at any time. In the screenshot that follows, the plotted graph illustrates the learner's transition between activity and rest: the vertical axis denotes that the learner has begun writing, while the horizontal axis indicates rest. The plotted graph corresponds with the series of vertical lines to its left. Here, the black lines indicate activity while the absence of lines indicates rest. By analyzing these graphs, one can obtain a chronological overview of the user's motivation, performance, and autonomy in relation to time, and consequently, course content.

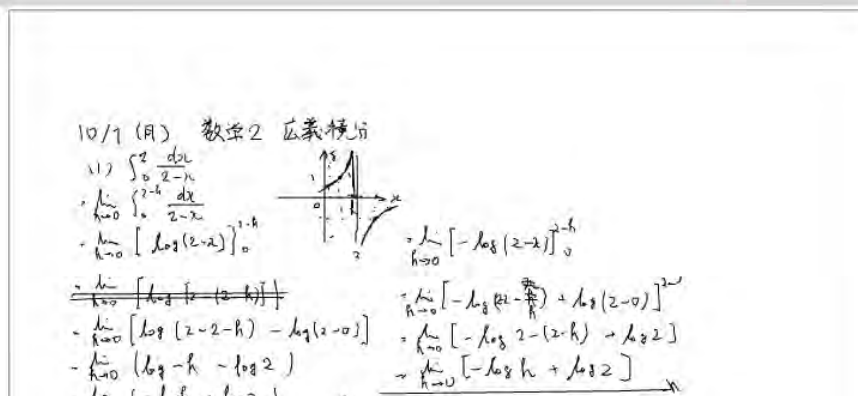
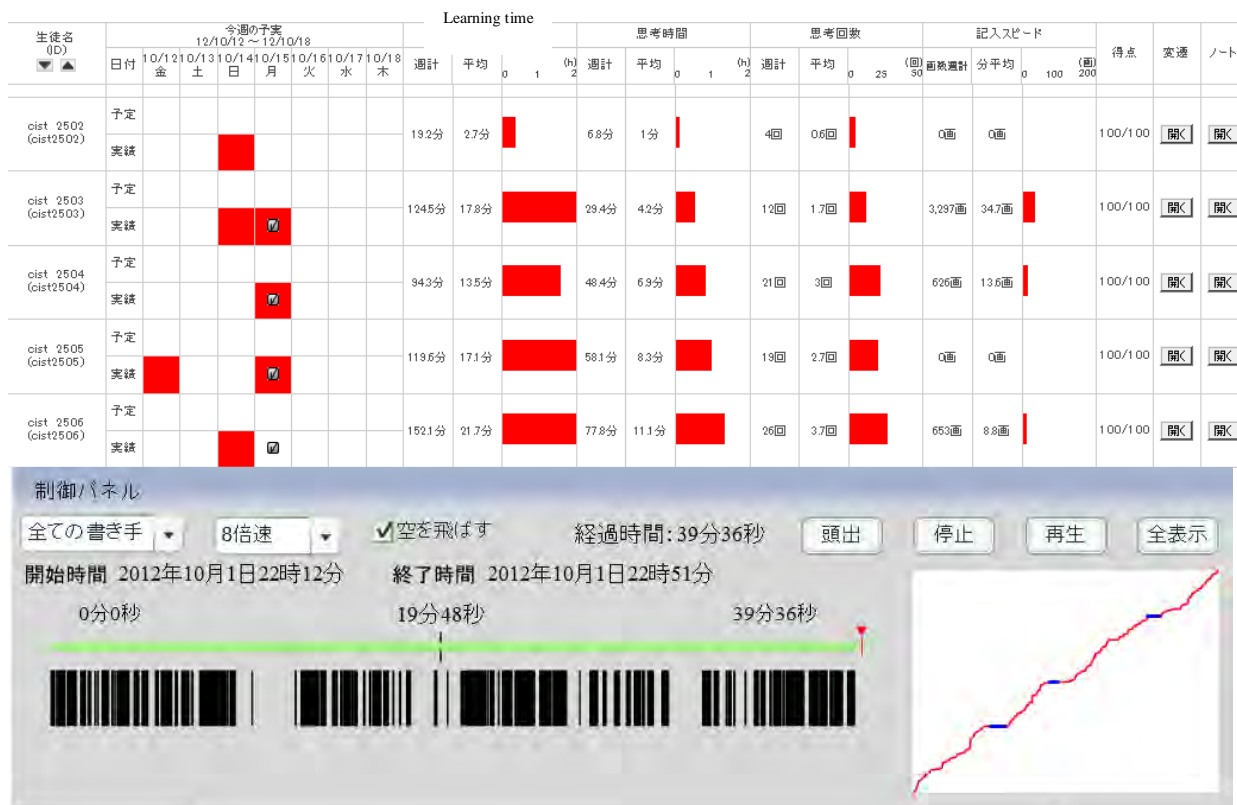


Figure 1. Deji Note Learning Management System

### 3. Case Study

In this case study, we carry out the learning using the digital pens to students. The study's participants comprised sixteen students attending orientation, all of which lacked mathematics proficiency. We lent a digital pen and notebook dedicated to them. We were used to them to self-study in the home. We were about a month the case study period. We were conducting learning situation of them by Deji Note System. Teachers had taught to students using the learning situation from the system once a week. By comparing participants' test results from before and after the pens were distributed, the authors could reliably gauge whether the devices exhibited a positive effect on students' motivation and academic performance. In addition to the quantitative data above, qualitative data were also collected in the form of interviews and questionnaires. Table 1 shows the learning status and test results. The average score of before test and after test of students who do not use the digital pen was 66 points and 70.7 points. Table 1 shows user's learning time (minutes), the number of pages of notes for the learning, test results before using the digital pen and test results after using it. The result of interviews and questionnaires, all the users have responded that learning time is increased compared to before using the digital pen. The percentage of students who responded motivation is improved by utilizing the digital pen was 85.7%. In the results of interviews, there was opinion that felt being monitored, a sense of crisis to learning. In addition, there was also the answer to the motivation of learning that was increased.

Table 1: A learning situation of students.

| User    | Learning time (minutes) | The number of pages of notes for the learning | Before test score | After test score |
|---------|-------------------------|---|-------------------|------------------|
| 1       | 361                     | 14  | 36                | 54               |
| 2       | 192                     | 12  | 12                | 40               |
| 3       | 277                     | 10  | 17                | 31               |
| 4       | 332                     | 19  | 34                | 47               |
| 5       | 347                     | 14  | 6                 | 38               |
| 6       | 397                     | 27  | 32                | 71               |
| 7       | 250                     | 12  | 31                | 62               |
| 8       | 2943                    | 197   | 32                | 82               |
| 9       | 354                     | 17  | 33                | 69               |
| 10      | 69                      | 2   | 32                | 27               |
| 11      | 563                     | 38  | 34                | 52               |
| 12      | 146                     | 8   | 14                | 41               |
| 13      | 832                     | 24  | 33                | 66               |
| 14      | 352                     | 21  | 27                | 73               |
| 15      | 271                     | 22  | 13                | 38               |
| 16      | 275                     | 12  | 31                | 42               |
| Average | 497.5                   | 28.1  | 26.1              | 52.1             |

#### 4. Consideration

Test scores of fifteen students out of sixteen were improved. Student of No.10 that test scores fell, learning time had the lowest. The difference between the students who use the pen and the students who do not use it is narrowed to 18 points from 40 points. From the above, the effect of learning by the digital pen available suggests. For contribution to the motivation, students of more than 80% answered motivation were improved. In addition, there was a similar opinion from the interview results. From the above, it has resulted in suggesting that their motivation is improved. While respondents admitted that their motivation had improved as the course progressed, this cause is not said to be due to only the digital pen. Because teachers had done learning support to students using the learning situation from the system once a week. Normally, in the university class, it is not performed tutoring such in most cases, we think to be necessary in the future to compare with the case of performing learning general teaching supports without using data from the digital pen. From the above, to students of low academic ability in particular, we can be considered that there is effective using the digital pen and learning supports using that data. To be specific, it is possible to give a sense of crisis training students and can grow attitudes autonomous. In the future, research of extending the learning period is required. In addition, there is a need for students of low academic ability layer other than, for example, conduct a demonstration evaluation to high academic achievement layer. It is considered that possible to improve motivation for learning is important. In the future, it will be necessary to consider the learning design more effective as well as aim to continue the fixing of study habits autonomous of the digital pen.

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# Smart Phone based Data Collecting System for Analyzing Learning Behaviors

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**Abstract:** Nowadays, it is a hot topic to analyze the huge amount of data in the world. This issue also exists in the learning during students' life. The learning data are collected only to record students' learning status. As a result, most learning data are not used to improve the quality of learning for students. In this paper, we propose an order made education system, which can recommend students to select the courses they want to learn. In order to analyze students' learning behaviors, we collect students' learning data by using mobile devices.

**Keywords:** Data Mining, Analyzing Learning Behaviors, Big Data, Mobile learning

## 1. Introduction

Sensor networks have been widely used to detect certain aspects of the contexts of our daily lives, which embed computation and communication components into the environment (Peng et al., 2009).

By 2020, Ministry of Education, Culture, Sports, Science and Technology (MEXT) is scheduled to change all the textbooks for elementary, middle, and high schools into digital textbooks in Japan<sup>1</sup>. Using the digital textbooks, all the learning history can be collected; meanwhile this will create a huge amount of data. Therefore, how to analyze the huge amount of data has been a hot topic, especially in the students' daily learning life. However, most of learning data collection is not aiming at giving students suitable reminders about students' learning status.

We carry out a BYOPC (Bring Your Own PC) program in Kyushu University, which encourage all students to use their own PCs in the University campus. We have set sensors in the university campus to collect and analyze the students' behavior and accumulate various educational data; moreover, this year we are planning to offer digital textbooks for the freshman of our university. All of these learning logs can be used for demonstrating students' learning behaviors. However, most of the system analysis does not focus on giving suggestion of students' learning status.

In this paper, by using mobile devices, sensor technologies, and digital textbooks, we propose a system to collect students' learning data and give students suitable reminders by analyzing students' learning behaviors. The system also provides recommendation and navigation for students to use their available space and free time effectively.

## 2. Related Work

### 2.1 Analysis of learning behaviors

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<sup>1</sup> <http://www.mext.go.jp/>

Nowadays, many of studies are focusing to analyze student web-based learning behaviors. For example, Hwang et al. (2008) proposed to use Meta-Analyzer to assist the teachers to analyze student web-searching behaviors while they are using search engines for problem solving. Tsai et al. (2011) explored the correlates among teachers' epistemological beliefs concerning Internet environments, their web search strategies and search outcomes.

We can use our system to analyze students' learning behaviors and make students to remind their their learning status.

## 2.2 Open Educational Resources

Open educational resources (OERs), such as OCW, Moocs, have been widely documented recently. Learners can freely access these learning resources anytime and anywhere. Compared with OERs, traditional educational resources, such as books, textbooks, or their learning contents cannot easily be accessed in online. There are many difficulties in verifying the educational effectiveness with the traditional educational resources and supporting group learning.

Although there are various types of traditional learning resources, there is no research about measurement of the educational effects with those traditional learning resources.

## 3. System Overview

Students can use the various educational resources in many kinds of e-learning systems, and their learning history will be recorded by those systems.

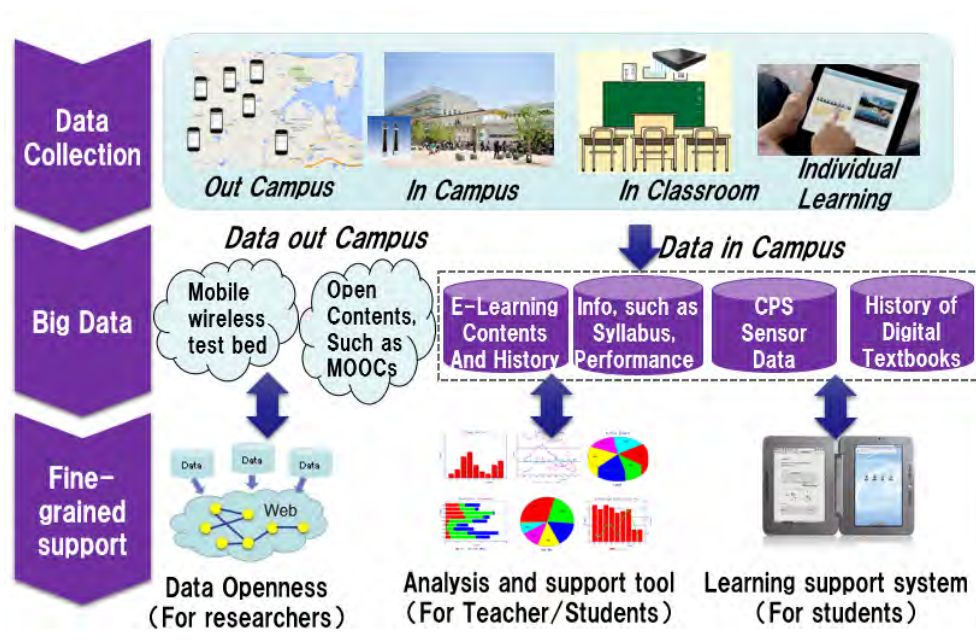


Fig 1. System overview.

As shown in the Fig. 1, many kinds of sensors are set in the campus of Kyushu University, in order to measure and visualize the learning effectiveness; our mobile system is used to collect and analyze various kinds of learning logs. Based on the analyzing results, the system provides recommendation and navigation for the users.

As for the experiment, we use not only the static data such as learning history and performance, but also the activity log such as the operation log of digital textbooks obtained from the camera or video sensors arranged on campus.

## 4. Scenario



Fig. 2 Underline



Fig3. Comment



Fig.4 Full text search

Mr. X is Japanese and he is studying Chinese in the classroom by using the digital textbooks. He can underline the important parts (Fig. 2), write his comment (Fig. 3), and carry out a full text search (Fig. 4). If he have some questions about Chinese language and need somebody to help him, he memorizes questions with the digital textbook. Then, the system searches a helper for him automatically; the system discovers some helpers who are good at Chinese finally. By using the data of the GPS sensor, the system recommends a closest helper Mr. Y who is in the 3<sup>rd</sup> floor of the same building for Mr. X. Then Mr. X can get help from Mr. Y.

## 5. Conclusion and Future Works

Mobile, wireless communication and ubiquitous computing technologies can provide learners and educators with active and adaptive support.

With the sensor technologies, learning systems can detect students' learning behaviors in the real world. Hence, educators and students can conduct more active and adaptive learning activities (Hwang, 2006).

In the paper, we proposed a mobile system with sensor network and digital textbooks. We can collect the educational data with this system in Kyushu University and give students suitable suggestions and supports by analyzing students' learning behaviors.

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