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Implementing Analytic Mechanics Learning Based on Multiple Representations on GeoGebra Software: In Forwardness to Face the Industrial Revolution 4.0 (Mr-Geo.4ir)

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Abstract

Analytic mechanics is a course that requires a media to be able to improve students' concept understanding. To face the industrial revolution 4.0 era, the education that can establish creative, innovative, and competitive generations is importantly needed. Objectives - This study examines the analytic mechanics learning based on multiple representations (MR) using GeoGebra software in forwardness to face the industrial revolution 4.0 (MR-Geo.4IR). This study involved 21 third semester students from one of the private universities in Jakarta. The instrument used was GeoGebra software to analyse images and graphics in an analytic mechanics concept in an MR-based concept module and student-worksheet. Methods - This study used quantitative and qualitative descriptive methods to determine the achievement of students on MR-based analytic mechanics learning using GeoGebra software on gravity and central force (GCF), particle system dynamics (PSD), rigid object rotation (ROR), and three-dimensional rigid object rotation (3DROR) materials. Findings - The results of this study found that the average score percentage of MR-based concept module from 3 respondents is 14.29% in “very high” category, from 17 respondents is 85.71% in “high” category, and from 1 respondent is 0.05% in “moderate” category. Based on student-worksheet assessment results, it is found that the average score percentage for each material from 21 respondents is 62% in “moderate” category for GCF, 77.10% in “high” category for PSD, 83.33% in “very high” category for ROR, and 78.95% in “high” category for 3DROR. It can be concluded that MR-based analytic mechanics learning using GeoGebra software in concept module and student-worksheet filling can improve concept understanding mastery in GCF, PSD, ROR, and 3DROR materials. Research Limitations - Limitation of this study is that this study only involved one class with a small number of students from merely one university. So that the results are not potential enough to represent the overall situation. This can be a way to conduct further research with more study materials. Originality - This study is the first study that scrutinize MR-based mechanics lectures using GeoGebra software in analysing verbal, images, graphics, and mathematics.

Keywords: Geogebra, analytic mechanics, multiple representations, industrial revolution 4.0

Introduction

Nowadays we have been entering the industrial revolution 4.0. era where technology has become basis of human’s life. Everything becomes infinite and unlimited due to the development of internet and digital technology. This era has influenced many life aspects in the economic, political, cultural, artistic, and even the world of education. The progress of a

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country on catching up is very dependent on these three factors namely education, the institutions quality, and the availability of infrastructure [1].

In this industrial revolution 4.0 era, the education world is required to follow the technology development which is growing rapidly [2], [3]. Education world also has to utilize information and communication technology (ICT) as advanced facilities to expedite the learning process. Indonesian Minister of Education and Culture assesses that aspects of Indonesian education need to revise the curriculum by adding five competencies owned by students. These five competencies are considered to be very necessary so that humans can be able to compete in the industrial revolution 4.0 era. The five competencies are: 1) The critical thinking ability; 2) Creativity and innovative skill; 3) Good communication skill; 4) Cooperation ability; and 5) High self-confidence. To deal with current development in this 4.0 revolution era, the education and culture practitioners also must be alert in adjusting themselves to various existing developments. School reforms, capacity enhancement, teacher’s professionalism, a dynamic curriculum, reliable facilities and infrastructures, and the up-to-date learning technology are needed in order to readily face the era of the Industrial Revolution 4.0 [4].

To deal with problems in humans’ daily life, physics and mathematics are very important subjects that can be used to solve those problems especially mathematics [5]. There are some views about the relationship between physics and mathematics. First, mathematics can be used as a tool to easily reveal the laws of physics. Second, physics is a subject where mathematical structures are suitable to describe the regularity patterns of natural phenomena. So, physics can be realized as an attempt to discover mathematical reality as a model that represents physical reality. Mathematics is considered as a framework for theoretical physics. The reality teaches us that the more perfect a theory in physics, the more sophisticated mathematics is needed to become a framework for that theory [6], [7].

The lack of ability to master basic mathematics and physics concepts has made it difficult for students to understand the mechanics concept material. So that through GeoGebra software, this software is expected to overcome difficulties in the process of understanding abstract mechanics concepts, especially verbal, images, graphics, and mathematics concepts that are often found in mechanics material. GeoGebra is a software to teach mathematics, especially geometry and algebra [8]. GeoGebra is a math learning application program that is quite sophisticated. The software is freely available and it supports various mathematical topics.

Physics learning is a part of science that deals with real or even abstract natural phenomena. The physics learning materials that are considered abstract and difficult are gravity and central force (GCF), particle system dynamics (PSD), rigid body rotation (ROR) and three-dimensional rigid body rotation (3DROR). It is because in the learning implementation, students are not much involved in the process of constructing concepts in their mind. Students are not entangled to discuss and ask many things, either. Students only hear and repeat the expected answers [9]. Multiple representations (MR) based learning uses GeoGebra software as an alternative to embody Physics Learning 4.0. MR is a combination of two or more representations, for example verbal representations in the form of text with one or more types of visualization [10]. The description of MR-based learning using GeoGebra software above shows the alignment of the learning approach with the five competencies in the industrial revolution 4.0 (4IR) education. This learning approach specifically develops 4Cs skills (critical

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thinking, creativity, collaborating, and communicating skills), innovation, and the ability to design processes on mechanics concept to solve verbal, images, graphics, and mathematics problems. Therefore, MR-based learning using GeoGebra software can be an alternative to actualize the education concept in the 4IR era.

Literature Review

This study aims to examine the analytic mechanics learning based on multiple representations (MR) using GeoGebra software in forwardness to face the industrial revolution 4.0 (MR-Geo.4IR). Universities in Indonesia are demanded to be capable to anticipate the rapid development of technology that occurred in the 4IR era. Now society is in the 4IR era which obviously can be seen from the rampant development of cyber-physical systems. Most of human activities has been controlled by machine and technology. This event is known as the internet of things (IoT) or Internet of People (IoP). Indonesian government certainly sees this opportunity and is considered to potentially contribute in creating more jobs and new investments based on technology. So, a roadmap was established under the name "Making Indonesia 4.0", where the Indonesian government opened up jobs where workers master the digital technology. Living the life in the 4IR era is a challenge that must be quickly and accurately responded. This era will also disrupt various human activities, including activities in the fields of science and technology and higher education. It is marked by the beginning globalization of education era. However, this education globalization still arises positive impact that the connectivity between countries and nations, especially in the field of education, will increase. The development of science and technology is now causing new changes for the world, especially in the industrial world (the industrialization era), where it requires competent workforces who are capable to adapt to digital technology.

The expected formal institution to produce competent and expert workforces in science and technology matters is the Higher Education or college [11]. Simply, industry 4.0 principles 4.0 can be described as follows in Figure 1.

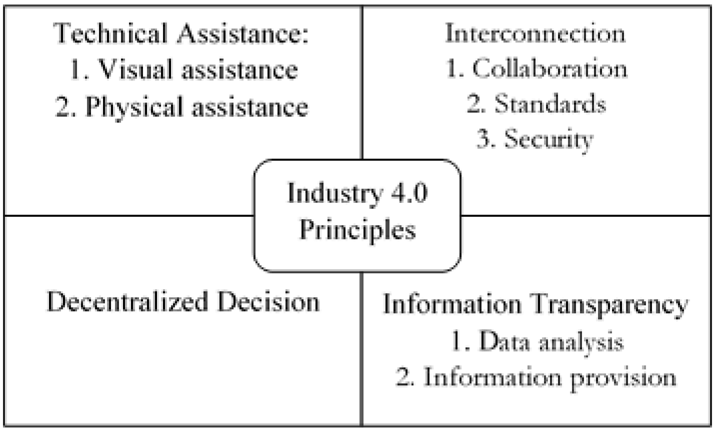

Figure 1

Industry 4.0 principles [12]

[12] added that there are four industry 4.0 principles designs. First, interconnection which is the ability of machines, devices, sensors, and people to connect and communicate with each

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other through the Internet of Things (IoT) or the Internet of People (IoP). This principle requires collaboration, security, and standards. Second, information transparency which is the information systems capability to create virtual copies of the physical world by enriching digital models with sensor data, including data analysis and information provision. Third, technical assistance which includes; (a) an assistance system ability to support people by consciously combining and evaluating information to make the right decisions and solve urgent problems in a short time; (b) the system ability to support humans by performing various unpleasant, tiring, and unsafe tasks; and (c) visual and physical assistance. Fourth, decentralized decision which is the ability of virtual physical systems to make self-decisions and carry out tasks as effectively as possible.

The Higher Education is expected to generate graduates who have work skills on mastering science and technology, dynamic mindset, and the ability to adapt. These skills are required in coping with the situation of shifting human workforces towards digitization. This is such a challenge that needs to be responded by students and graduates. This challenge has to be surmounted by increasing alumni competences, especially mastering computer technology skill, communication skill, the ability to collaborate well, and the ability to keep learning and be adaptive to environmental changes. The graduates are expected to have creativity and good personality, also be innovative and adaptive. Thus, the pre-service physics teachers are also required to master digital technology which will be able to transfer physics material to students.

The Higher Education produces pre-service physics teachers as prospective professional educators who are able to prepare prospective educators to have jobs with special expertise requirements. The professional education graduates will get a professional degree. So, the industrial revolution 4.0 can only be faced with higher education system that keep up with the changes that happen along the time. This higher education system fosters creativity, critical thinking, and innovation. The 4IR era will impact new professions or occupations based on a combination of digital technology including the Internet of Thing (IoT); artificial intelligence; new material; big data; robotics: augmented reality; computation; 3D printing additives manufacturer; nanotech and biotech; genetic editing and e-learning to emerge. Then how is the role of lecturers in the 4IR era? Like it or not, lecturers must have strong competency abilities. They need to have soft skills such as critical thinking, creativity, communicating, and collaborating. Lecturers can be considered as role models, who spread enthusiasm and inspiration. This role cannot be replaced by any technology. It is important for lecturers to have educational competencies, competencies in research, and competencies in the business world [13]. One of the main steps that must be taken by universities is to improve campus data management. Information also must be conveyed properly, both for educators and students. A reliable information system will increase competitiveness of competitors and bring up attractiveness to prospective students.

Blended learning is one of the learning solutions in the 4IR era. There are several definitions of blended learning, according to several experts. Blended learning is a combination of online-based learning with face-to-face learning in class [14]. According to [14] and [15], blended learning is a method that combines face-to-face learning in class with online learning. Blended learning is a combination of physical learning in the classroom with virtual environment [16].

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Learning activity based on blended learning is a combination of old and new literacy, which includes human, technology, and data literacies.

The curriculum design and education methods also must be able to adapt to the evolving business climate. The education services and industrial business also has a very fast a competitive development in technology and information field. Physics learning is a part of science that discusses and explores a lot about nature and its phenomena, from the real to the abstract one. Analytic mechanics course includes gravity and central force, particle system dynamics, rigid body mechanics, and three-dimensional rigid body motion learning materials [17]. Learning innovation carried out in the development of digital information technology is by utilizing information technology facilities that are developing rapidly in the 4IR era to improve the learning quality [18]. Furthermore, educational innovation in learning methods includes the formulation of the teaching materials organization. Besides that, the strategy of activities delivery and management by paying attention to students' purpose, obstacles, and characteristics is also needed. Hence, the effective, efficient, and attractive learning outcomes can be obtained [19].

Physics is a branch of natural sciences subject. Physics is the heart of ICT's development that has fundamentally changed human life. Based on global and historical views, physics provides more dynamic methods in solving humans' complex life problems [20]. In fact, it has been found that many students who have difficulty in following physics lecture are not interested in the course itself. Students have no understanding after lecture is finished. So, lecturers as educators are required to present meaningful lectures. In this way, students will be fascinated in learning the taught lectures. Students will learn more effectively and efficiently when they are active in processing information with multiple representations [21]–[24]. Students as adult and independent learners can make multiple representations into conceptual understanding by processing information more effectively and efficiently so that satisfying learning outcomes can be achieved.

Physics learning is the process of making students study physics and lecturers carry out physics learning tasks in the classroom. Physics learning can be considered successful if it is possible to cause students to actively study physics inside and outside classroom [25]. Learning is a process that is designed in such a way so that students can experience learning process. One of the lecturer's main tasks is to deliver students to do the learning process. In order to make learning physics take place properly and in accordance with the learning process, the components involved in learning activity must be related to the physics learning concept. Lecturers can build a learning design so that the learning activity can be directed towards achieving the expected competencies. Students must actively follow the lectures and lecturers must provide adequate learning media and also can bridge the achievement of learning objectives. Learning media can be a tool that can stimulate students' thoughts, feelings, concerns, and interests. It can also motivate students in such a way so that the learning materials can be conveyed properly [26]. Students, as learners who can think maturely and independently, must be able to use learning media correctly. Learning media is a driving tool which functions as a media to show human interactions in reality, still or moving images, written text, and recorded sound that is very helpful for students in learning process. Learning media are various types of components in the environment around students that can stimulate

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them to learn. The beginning of learning media is indeed as a teaching assistance for teachers, which can be in the form of visual tools such as pictures, models, objects, and other tools that can provide concrete experiences for students. There is also the Virtual Lab, which combines moving and still images, text, and it also allows sound or audio in it [27]. Virtual Lab can be defined as a series of computer programs that can visualize abstract phenomena or complicated abstract concepts carried out in the laboratory. This way, lecturers can use virtual lab to increase students' learning activities in an effort to develop the skills needed in problem solving.

In accordance with the Ministry of Education and Culture Regulation Number 65 of 2013 concerning about learning process standards, it states that one of the learning principles used is the ICT utilization to improve the efficiency and effectiveness of learning. It also states that computers, as a very rapidly developed technology, should be used in learning. Computer technology is an invention that allows us to present several or all forms of response, so that learning activities will be more optimal [28]. Utilization of computers in education, especially in learning activities, is actually a chain of the history of learning technology. MR-based analytic mechanics learning will use virtual lab with GeoGebra software. This software is such a math application program that can be used freely without violating copyright. GeoGebra is a math learning application program that is quite sophisticated, that supports various mathematic topics and is freely available. GeoGebra can be used on a number of relatively simple topics to quite complex material such as matrix, vectors, trigonometry, statistics, calculus, and three-dimensional geometry [29], [30]. That is why GeoGebra software is widely used in learning physics in analytic mechanics lectures, which have many abstract concepts in it, including analyzing graph and images concepts. The learning outcome in this study are GeoGebra software in analytic mechanics lectures. Lectures using GeoGebra software are conducted in gravity and central force (GCF), particle system dynamics (PSD), rigid body rotation (ROR) and three-dimensional rigid body rotation (3DROR) materials in the third semester. The results of this study can later be used by lecturers in conducting physics learning and other subjects.

In physics learning, physics representation is interpreted as broad forms that are used to comprehend and convey physics concepts [31]. Physics as a subject requires comprehension and ability of using multiple representations for the studied concepts, so that students can master physics subject. However, students' inability to use multiple representations in understanding physics concepts seems to be an obstacle to their understanding [32]. Representation forms that are widely used in physics learning include verbal, diagrams (pictures, motion maps, and path diagrams), and mathematical [33]. The use of those various forms is called multiple representations [34]. The mathematical form is also called quantitative representation, while verbal, diagrams, and pictures forms are called qualitative representations. Multiple representation (MR) means to represent the same concept with different formats, including verbal, pictures, graphics, and mathematics formats [35].

In other words, the ability to master physics concepts is closely related to how to use various scientific languages in learning physics, such as words (oral and writing), visuals (pictures, graphics, and simulations), symbols and equations, gestures, role play, presentations, and other forms. This will enable students to study physics through developing intelligent thinking skill. This is called the multi representation approach or multi-mode representation [36]. The learning environment by using multiple representations has three main functions. First, MR

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can be used to obtain additional information to support or complement the existing cognitive processes. Second, MR is used to limit the interpretation that might occur. Third, MR is used to motivate students to build deeper understanding [37]. [37] also proved that MR play three main roles, namely complementing one another, explaining interpretations of an unusual representation, and helping students form a deeper comprehension about the studied topic. Cognitive process for improving students' comprehension meant in this study are interpreting, exemplifying, classifying, summarizing, concluding, comparing, and explaining [38]–[40]. Understanding activity is a process of thinking to observe phenomena or events. The ideas can be delivered either in oral or written form, and either visually or symbolically. The concept is the main principle that underlies all the results of abstract human thought about things, events, facts that explain many experiences. Concept understanding is the process of interpreting, modelling, classifying, comparing, explaining, and concluding about objects, events, situations, or characteristic features that are unique and represented in each culture for a sign or symbol in physics.

The use of MR will be able to develop the representation ability of physics students. The representation ability is the competence to interpret and apply various representations to understand and solve physics problems appropriately [41]. Students' representation ability will help them to understand and solve analytic mechanics problems in various analytic mechanics materials.

Method

This study used a mixed method with quantitative and qualitative triangulation. To find out the achievement of MR-based analytic mechanics learning, GeoGebra software is used. Learning activities are conducted on GCF, PSD, ROR, and 3DROR materials. The subjects in this study were students from a private university in Jakarta, Indonesia (Figure 2). The sample consisted of 21 students, majoring in physics education in the third semester. The instrument used in this study consisted of MR-based content module and student-worksheet, which contains 5 to 10 questions in accordance with the designed indicators and lectures' objectives on MR-Geo learning. This instrument will reveal the percentage of students' concept mastery from the MR-based content modules filling and answers in students-worksheet. The result of this study will reveal the level of concept understanding, concept misunderstanding, and the achievement of GeoGebra software utilization to actualize the 4IR for physics education.

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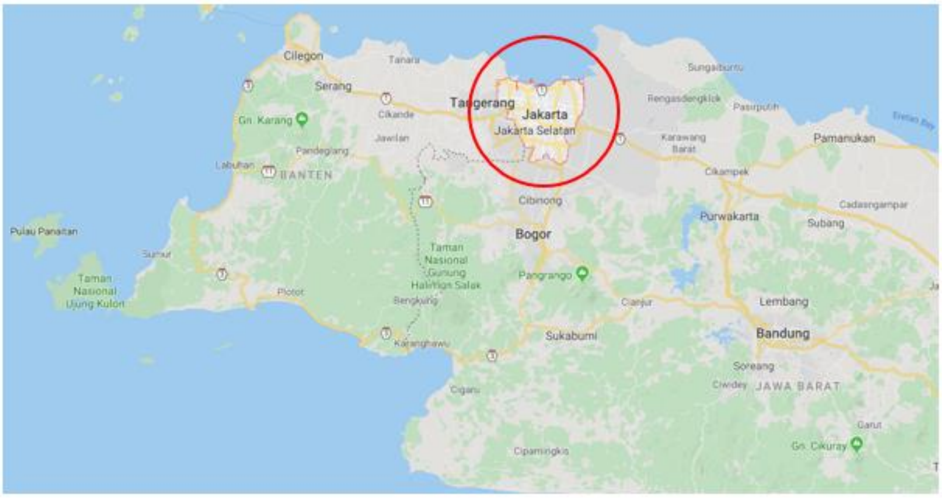

Figure 2 :*Map of Jakarta City(Source: https://www.google.com/maps/jakarta)*

Results and Discussion

The results of students' answers, obtained through mechanics content modules filling and MR-based student-worksheet answers, are shown in several forms, namely verbal skill, mathematical, graphics, and images. Figure 3 shows students' ability to verbally represent gravity concept, represent it in an image and mathematically. Figure 4 shows students' ability to make graphics using GeoGebra software on GCF material on the coordinate graph to calculate the gravitational field on the spherical shell. And then Figure 4 shows students' ability to make three-dimensional images on the effective potential concept for the laws of force and on radial motion.

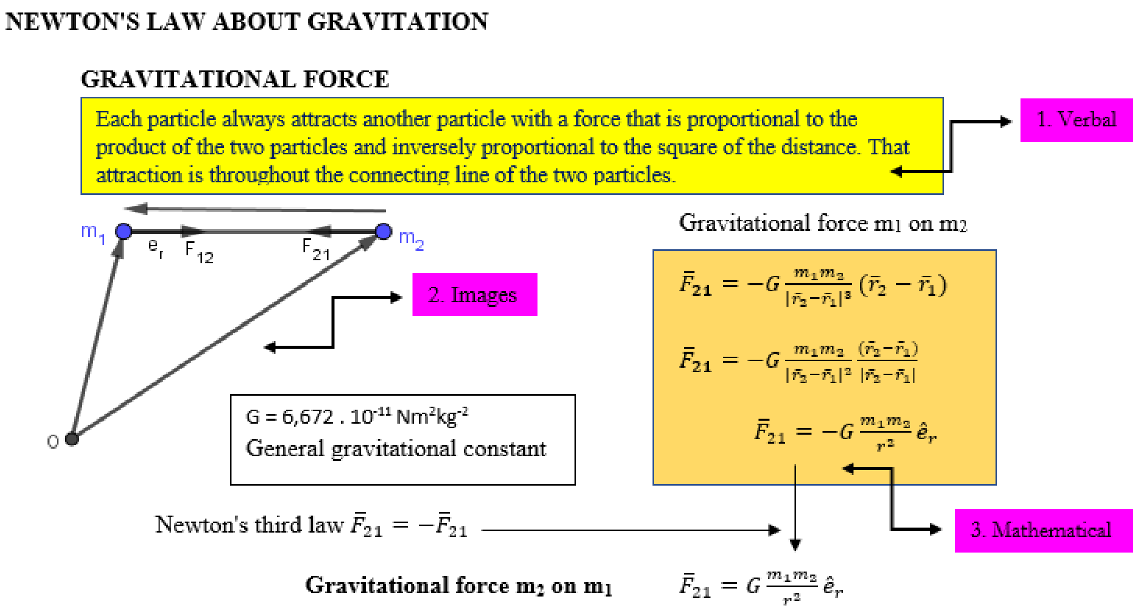

Figure 3 : *Multiple representations: Verbal (1), Images (2), and Mathematical (3)*

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Figure 3 shows students' ability to represent the concept of gravity verbally (1): each particle always attracts another particle with a force that is proportional to the product of the two particles and inversely proportional to the square of the distance. After being presented in the form of images (2) from the gravity concept, where m1 particle attracts m2 particle with a large tensile force F12 and F21 with the square and the pull force along the connecting lines of the two particles. And the third representation is in mathematical form, namely: $\bar{F}_{21} = G\frac{m_1 m_2}{r^2}\hat{e}_r$.

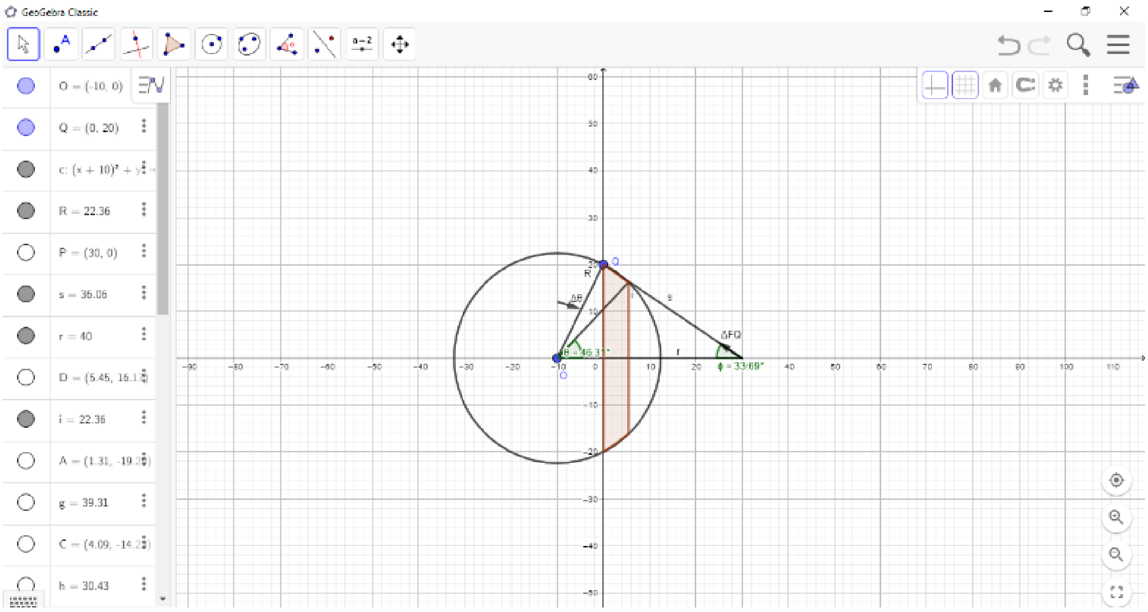

Figure 4
Graphics representation using GeoGebra software

Figure 4 shows students' ability to represent graphs. The results of MR-based mechanics lectures development proved that students were able to make graphs using GeoGebra software in coordinate graphs to calculate the gravitational field on the spherical shell. Students have gained the basic knowledge to use GeoGebra software so that students can easily analyze graphs from mathematical equation formulas.

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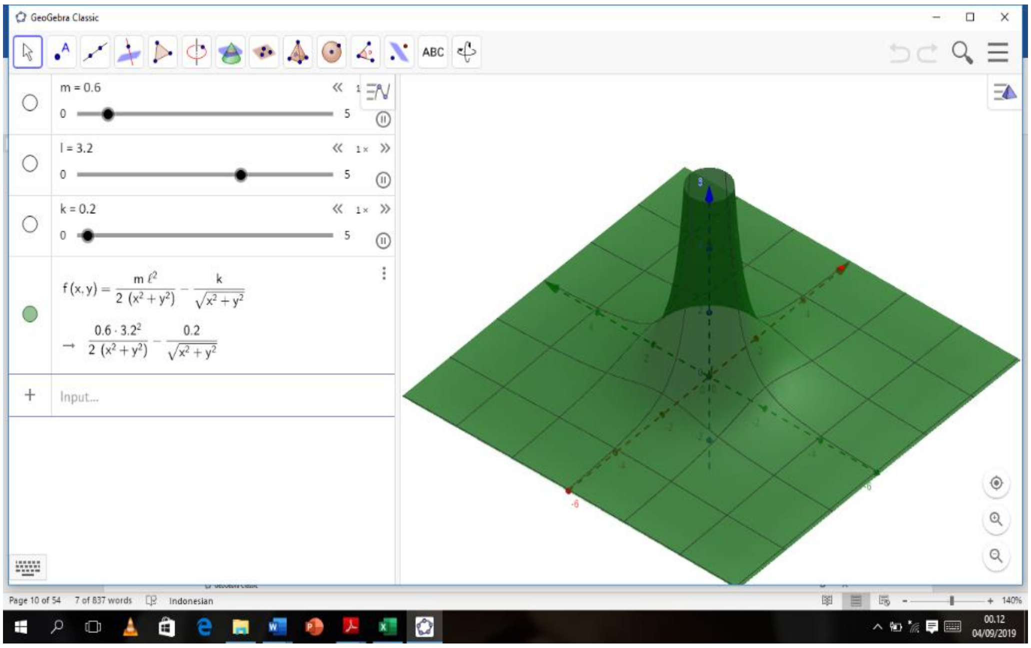

Figure 5
Images and graphs representations using 3D GeoGebra software.

Figure 5 shows the results of students' ability to make three-dimensional images with GeoGebra software on the effective potential concept for the law of force and radial motion.

The results of the overall percentage score on students' concept understanding in GCF, PSD, ROR, and 3DROR mechanics materials based on multiple representations can be observed in Figure 6 below.

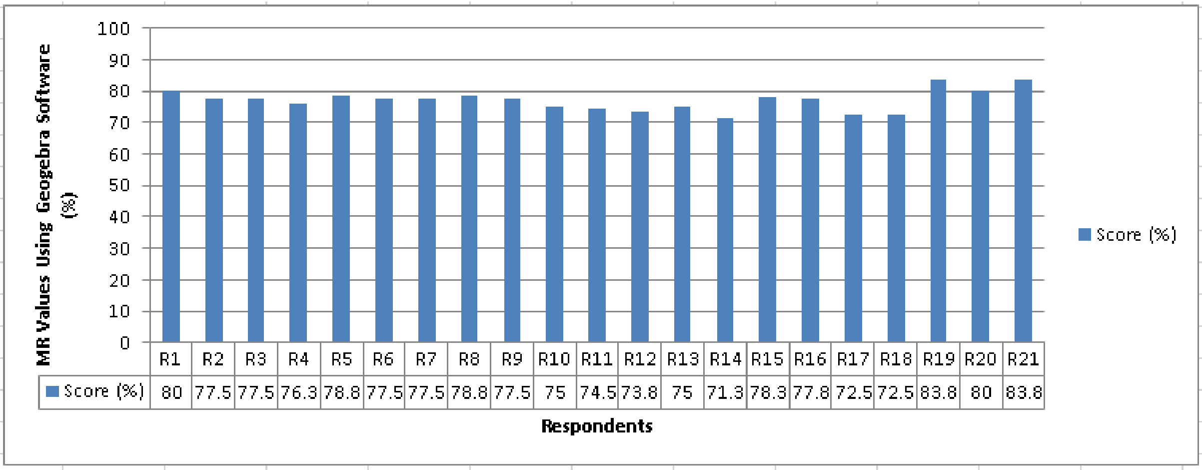

Figure 6
The percentage graphics of students' concepts understanding results on MR-based analytic mechanics module using GeoGebra software

In Figure 6, from 21 students it can be seen that the concept understanding of 3 respondents is at 14.29% in "very high" category, 17 respondents at 85.71% in "high" category, and 1

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respondent at 0.05% in “moderate” category. Based on these results, it can be concluded that the MR-based analytic mechanics learning using GeoGebra software can improve the concept understanding mastery in the GCF, PSD, ROR, and 3DROR materials modules.

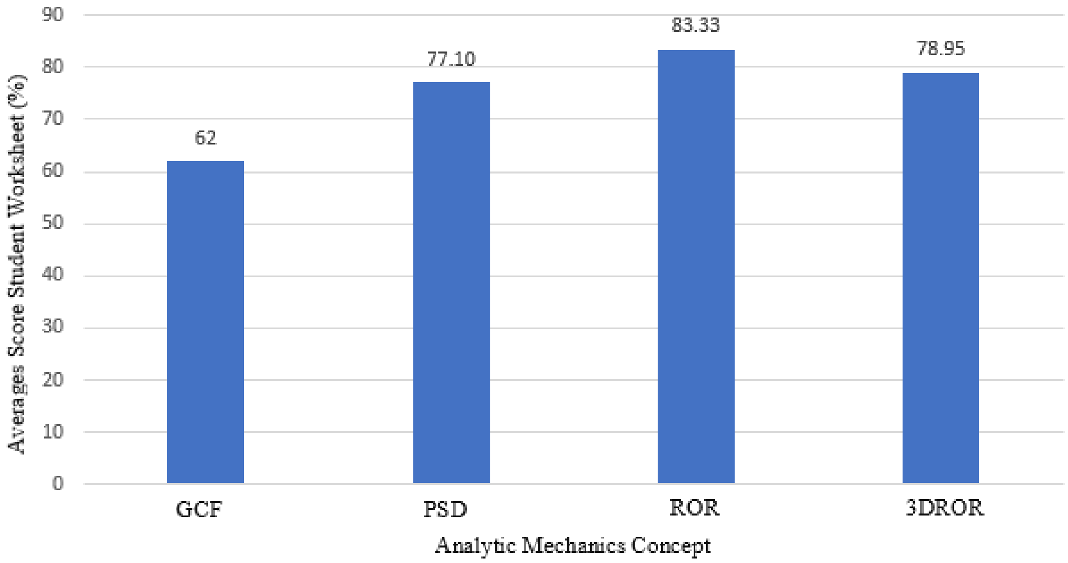

Figure 7
The percentage graphics of MR-based analytic mechanics student-worksheet results.

From the graphs in Figure 7 above, the average percentage of student-worksheet results in each material from 21 respondents are obtained. The average percentage of GCF material is 62% in “medium” category, PSD material is 77.10% in “high” category, ROR material is 83.33% in “very high” category, and 3DROR material is 78.95% in “high” category. It can be concluded that MR-based analytical mechanics learning using GeoGebra software in completing student-worksheet can improve the concept understanding mastery in GCF, PSD, ROR, and 3DROR materials. It can be seen in the PSD material, 83.33% is obtained in a very high percentage compared to other materials. This happened because when this material is given, students already have the basic concepts of basic physics course that have been obtained at the beginning of the semester. In the GCF material, a smaller percentage of 60% is obtained. This happened because when this material is given, students experience confusion to comprehend abstract concepts of gravity and central forces, when they made three-dimensional image analysis. Students were still confused when operating GeoGebra software. Based on these findings, it can be said that students actually have their own ability to understand some of the concepts of analytic mechanics. But unfortunately, the concepts that they master are still relatively weak and the mastery of GeoGebra software is also weak due to student weaknesses in mathematics. However, students’ limited condition does not undermine the efforts of researchers to conduct treatment in the analytic mechanics learning process with MR-based approach. Using GeoGebra software can help students to overcome the difficulties in analyzing abstract concepts, especially in the analysis of graphs and images. So, the results of this study will be an alternative to embody the education concept of the 4IR era in physics learning.

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Conclusions

The data found in this study shows that the MR-based analytic mechanics learning using GeoGebra software has been achieved. It can be seen from the students' concept understanding in the analytical mechanics module, which is in "high" category. Based on the findings data on student-worksheet answers, it was concluded that high students' mastery of concepts was achieved, which led to a high level of analytic mechanics concepts mastery as well. This study has produced quite complete data, and is very supportive to welcome the education concept in entering the industrial revolution 4.0 (4IR) era. For the future researchers, this study can be developed more broadly by reviewing students' learning styles in a wider group. Therefore, the data collection process is not limited so that the data accuracy and strength levels can be higher and the used software can be better.

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Dr. Tri Isti Hartini, M.Pd - Implementing Analytic Mechanics Learning Based on Multiple Representations on GeoGebra Software: In Forwardness to Face the Industrial Revolution 4.0 (Mr-Geo.4ir)

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Implementing Analytic Mechanics Learning Based on Multiple Representations on GeoGebra Software: In Forwardness to Face the Industrial Revolution 4.0 (Mr-Geo.4ir)

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Abstract

Analytic mechanics is a course that requires a media to be able to improve students' concept understanding. To face the industrial revolution 4.0 era, the education that can establish creative, innovative, and competitive generations is importantly needed. Objectives - This study examines the analytic mechanics learning based on multiple representations (MR) using GeoGebra software in forwardness to face the industrial revolution 4.0 (MR-Geo.4IR). This study involved 21 third semester students from one of the private universities in Jakarta. The instrument used was GeoGebra software to analyse images and graphics in an analytic mechanics concept in an MR-based concept module and student-worksheet. Methods - This study used quantitative and qualitative descriptive methods to determine the achievement of students on MR-based analytic mechanics learning using GeoGebra software on gravity and central force (GCF), particle system dynamics (PSD), rigid object rotation (ROR), and three-dimensional rigid object rotation (3DROR) materials. Findings - The results of this study found that the average score percentage of MR-based concept module from 3 respondents is 14.29% in "very high" category, from 17 respondents is 85.71% in "high" category, and from 1 respondent is 0.05% in "moderate" category. Based on student-worksheet assessment results, it is found that the average score percentage for each material from 21 respondents is 62% in "moderate" category for GCF, 77.10% in "high" category for PSD, 83.33% in "very high" category for ROR, and 78.95% in "high" category for 3DROR. It can be concluded that MR-based analytic mechanics learning using GeoGebra software in concept module and student-worksheet filling can improve concept understanding mastery in GCF, PSD, ROR, and 3DROR materials. Research Limitations - Limitation of this study is that this study only involved one class with a small number of students from merely one university. So that the results are not potential enough to represent the overall situation. This can be a way to conduct further research with more study materials. Originality - This study is the first study that scrutinize MR-based mechanics lectures using GeoGebra software in analysing verbal, images, graphics, and mathematics.

Keywords: Geogebra, analytic mechanics, multiple representations, industrial revolution 4.0

Introduction

Nowadays we have been entering the industrial revolution 4.0. era where technology has become basis of human's life. Everything becomes infinite and unlimited due to the development of internet and digital technology. This era has influenced many life aspects in the economic, political, cultural, artistic, and even the world of education. The progress of a

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country on catching up is very dependent on these three factors namely education, the institution quality, and the availability of infrastructure [1].

In this industrial revolution 4.0 era, the education world is required to follow the technology development which is growing rapidly [2], [3]. Education world also has to utilize information and communication technology (ICT) as advanced facilities to expedite the learning process. Indonesian Minister of Education and Culture assesses that aspects of Indonesian education need to revise the curriculum by adding five competencies owned by students. These five competencies are considered to be very necessary so that humans can be able to compete in the industrial revolution 4.0 era. The five competencies are: 1) The critical thinking ability; 2) Creativity and innovative skill; 3) Good communication skill; 4) Cooperation ability; and 5) High self-confidence. To deal with current development in this 4.0 revolution era, the education and culture practitioners also must be alert in adjusting themselves to various existing developments. School reforms, capacity enhancement, teacher's professionalism, a dynamic curriculum, reliable facilities and infrastructures, and the up-to-date learning technology are needed in order to readily face the era of the Industrial Revolution 4.0 [4].

To deal with problems in humans' daily life, physics and mathematics are very important subjects that can be used to solve those problems especially mathematics [5]. There are some views about the relationship between physics and mathematics. First, mathematics can be used as a tool to easily reveal the laws of physics. Second, physics is a subject where mathematical structures are suitable to describe the regularity patterns of natural phenomena. So, physics can be realized as an attempt to discover mathematical reality as a model that represents physical reality. Mathematics is considered as a framework for theoretical physics. The reality teaches us that the more perfect a theory in physics, the more sophisticated mathematics is needed to become a framework for that theory [6], [7].

The lack of ability to master basic mathematics and physics concepts has made it difficult for students to understand the mechanics concept material. So that through GeoGebra software, this software is expected to overcome difficulties in the process of understanding abstract mechanics concepts, especially verbal, images, graphics, and mathematics concepts that are often found in mechanics material. GeoGebra is a software to teach mathematics, especially geometry and algebra [8]. GeoGebra is a math learning application program that is quite sophisticated. The software is freely available and it supports various mathematical topics.

Physics learning is a part of science that deals with real or even abstract natural phenomena. The physics learning materials that are considered abstract and difficult are gravity and central force (GCF), particle system dynamics (PSD), rigid body rotation (ROR) and three-dimensional rigid body rotation (3DROR). It is because in the learning implementation, students are not much involved in the process of constructing concepts in their mind. Students are not entangled to discuss and ask many things, either. Students only hear and repeat the expected answers [9]. Multiple representations (MR) based learning uses GeoGebra software as an alternative to embody Physics Learning 4.0. MR is a combination of two or more representations, for example verbal representations in the form of text with one or more types of visualization [10]. The description of MR-based learning using GeoGebra software above shows the alignment of the learning approach with the five competencies in the industrial revolution 4.0 (4IR) education. This learning approach specifically develops 4Cs skills (critical

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thinking, creativity, collaborating, and communicating skills), innovation, and the ability to design processes on mechanics concept to solve verbal, images, graphics, and mathematics problems. Therefore, MR-based learning using GeoGebra software can be an alternative to actualize the education concept in the 4IR era.

Literature Review

This study aims to examine the analytic mechanics learning based on multiple representations (MR) using GeoGebra software in forwardness to face the industrial revolution 4.0 (MR-Geo.4IR). Universities in Indonesia are demanded to be capable to anticipate the rapid development of technology that occurred in the 4IR era. Now society is in the 4IR era which obviously can be seen from the rampant development of cyber-physical systems. Most of human activities has been controlled by machine and technology. This event is known as the internet of things (IoT) or Internet of People (IoP). Indonesian government certainly sees this opportunity and is considered to potentially contribute in creating more jobs and new investments based on technology. So, a roadmap was established under the name "Making Indonesia 4.0", where the Indonesian government opened up jobs where workers master the digital technology. Living the life in the 4IR era is a challenge that must be quickly and accurately responded. This era will also disrupt various human activities, including activities in the fields of science and technology and higher education. It is marked by the beginning globalization of education era. However, this education globalization still arises positive impact that the connectivity between countries and nations, especially in the field of education, will increase. The development of science and technology is now causing new changes for the world, especially in the industrial world (the industrialization era), where it requires competent workforces who are capable to adapt to digital technology.

The expected formal institution to produce competent and expert workforces in science and technology matters is the Higher Education or college [11]. Simply, industry 4.0 principles 4.0 can be described as follows in Figure 1.

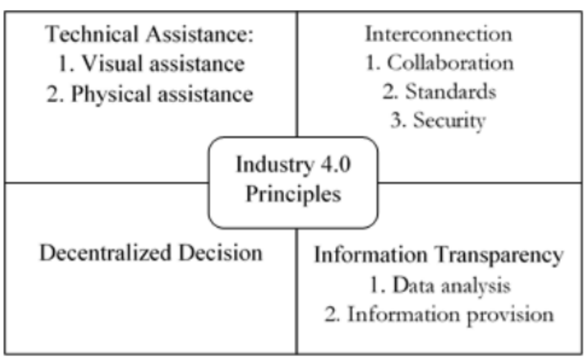

Figure 1

Industry 4.0 principles [12]

[12] added that there are four industry 4.0 principles designs. First, interconnection which is the ability of machines, devices, sensors, and people to connect and communicate with each

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other through the Internet of Things (IoT) or the Internet of People (IoP). This principle requires collaboration, security, and standards. Second, information transparency which is the information systems capability to create virtual copies of the physical world by enriching digital models with sensor data, including data analysis and information provision. Third, technical assistance which includes; (a) an assistance system ability to support people by consciously combining and evaluating information to make the right decisions and solve urgent problems in a short time; (b) the system ability to support humans by performing various unpleasant, tiring, and unsafe tasks; and (c) visual and physical assistance. Fourth, decentralized decision which is the ability of virtual physical systems to make self-decisions and carry out tasks as effectively as possible.

The Higher Education is expected to generate graduates who have work skills on mastering science and technology, dynamic mindset, and the ability to adapt. These skills are required in coping with the situation of shifting human workforces towards digitization. This is such a challenge that needs to be responded by students and graduates. This challenge has to be surmounted by increasing alumni competences, especially mastering computer technology skill, communication skill, the ability to collaborate well, and the ability to keep learning and be adaptive to environmental changes. The graduates are expected to have creativity and good personality, also be innovative and adaptive. Thus, the pre-service physics teachers are also required to master digital technology which will be able to transfer physics material to students.

The Higher Education produces pre-service physics teachers as prospective professional educators who are able to prepare prospective educators to have jobs with special expertise requirements. The professional education graduates will get a professional degree. So, the industrial revolution 4.0 can only be faced with higher education system that keep up with the changes that happen along the time. This higher education system fosters creativity, critical thinking, and innovation. The 4IR era will impact new professions or occupations based on a combination of digital technology including the Internet of Thing (IoT); artificial intelligence; new material; big data; robotics: augmented reality; computation; 3D printing additives manufacturer; nanotech and biotech; genetic editing and e-learning to emerge. Then how is the role of lecturers in the 4IR era? Like it or not, lecturers must have strong competency abilities. They need to have soft skills such as critical thinking, creativity, communicating, and collaborating. Lecturers can be considered as role models, who spread enthusiasm and inspiration. This role cannot be replaced by any technology. It is important for lecturers to have educational competencies, competencies in research, and competencies in the business world [13]. One of the main steps that must be taken by universities is to improve campus data management. Information also must be conveyed properly, both for educators and students. A reliable information system will increase competitiveness of competitors and bring up attractiveness to prospective students.

Blended learning is one of the learning solutions in the 4IR era. There are several definitions of blended learning, according to several experts. Blended learning is a combination of online-based learning with face-to-face learning in class [14]. According to [14] and [15], blended learning is a method that combines face-to-face learning in class with online learning. Blended learning is a combination of physical learning in the classroom with virtual environment [16].

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Learning activity based on blended learning is a combination of old and new literacy, which includes human, technology, and data literacies.

The curriculum design and education methods also must be able to adapt to the evolving business climate. The education services and industrial business also has a very fast a competitive development in technology and information field. Physics learning is a part of science that discusses and explores a lot about nature and its phenomena, from the real to the abstract one. Analytic mechanics course includes gravity and central force, particle system dynamics, rigid body mechanics, and three-dimensional rigid body motion learning materials [17]. Learning innovation carried out in the development of digital information technology is by utilizing information technology facilities that are developing rapidly in the 4IR era to improve the learning quality [18]. Furthermore, educational innovation in learning methods includes the formulation of the teaching materials organization. Besides that, the strategy of activities delivery and management by paying attention to students' purpose, obstacles, and characteristics is also needed. Hence, the effective, efficient, and attractive learning outcomes can be obtained [19].

Physics is a branch of natural sciences subject. Physics is the heart of ICT's development that has fundamentally changed human life. Based on global and historical views, physics provides more dynamic methods in solving humans' complex life problems [20]. In fact, it has been found that many students who have difficulty in following physics lecture are not interested in the course itself. Students have no understanding after lecture is finished. So, lecturers as educators are required to present meaningful lectures. In this way, students will be fascinated in learning the taught lectures. Students will learn more effectively and efficiently when they are active in processing information with multiple representations [21]–[24]. Students as adult and independent learners can make multiple representations into conceptual understanding by processing information more effectively and efficiently so that satisfying learning outcomes can be achieved.

Physics learning is the process of making students study physics and lecturers carry out physics learning tasks in the classroom. Physics learning can be considered successful if it is possible to cause students to actively study physics inside and outside classroom [25]. Learning is a process that is designed in such a way so that students can experience learning process. One of the lecturer's main tasks is to deliver students to do the learning process. In order to make learning physics take place properly and in accordance with the learning process, the components involved in learning activity must be related to the physics learning concept. Lecturers can build a learning design so that the learning activity can be directed towards achieving the expected competencies. Students must actively follow the lectures and lecturers must provide adequate learning media and also can bridge the achievement of learning objectives. Learning media can be a tool that can stimulate students' thoughts, feelings, concerns, and interests. It can also motivate students in such a way so that the learning materials can be conveyed properly [26]. Students, as learners who can think maturely and independently, must be able to use learning media correctly. Learning media is a driving tool which functions as a media to show human interactions in reality, still or moving images, written text, and recorded sound that is very helpful for students in learning process. Learning media are various types of components in the environment around students that can stimulate

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them to learn. The beginning of learning media is indeed as a teaching assistance for teachers, which can be in the form of visual tools such as pictures, models, objects, and other tools that can provide concrete experiences for students. There is also the Virtual Lab, which combines moving and still images, text, and it also allows sound or audio in it [27]. Virtual Lab can be defined as a series of computer programs that can visualize abstract phenomena or complicated abstract concepts carried out in the laboratory. This way, lecturers can use virtual lab to increase students' learning activities in an effort to develop the skills needed in problem solving.

In accordance with the Ministry of Education and Culture Regulation Number 65 of 2013 concerning about learning process standards, it states that one of the learning principles used is the ICT utilization to improve the efficiency and effectiveness of learning. It also states that computers, as a very rapidly developed technology, should be used in learning. Computer technology is an invention that allows us to present several or all forms of response, so that learning activities will be more optimal [28]. Utilization of computers in education, especially in learning activities, is actually a chain of the history of learning technology. MR-based analytic mechanics learning will use virtual lab with GeoGebra software. This software is such a math application program that can be used freely without violating copyright. GeoGebra is a math learning application program that is quite sophisticated, that supports various mathematic topics and is freely available. GeoGebra can be used on a number of relatively simple topics to quite complex material such as matrix, vectors, trigonometry, statistics, calculus, and three-dimensional geometry [29], [30]. That is why GeoGebra software is widely used in learning physics in analytic mechanics lectures, which have many abstract concepts in it, including analyzing graph and images concepts. The learning outcome in this study are GeoGebra software in analytic mechanics lectures. Lectures using GeoGebra software are conducted in gravity and central force (GCF), particle system dynamics (PSD), rigid body rotation (ROR) and three-dimensional rigid body rotation (3DROR) materials in the third semester. The results of this study can later be used by lecturers in conducting physics learning and other subjects.

In physics learning, physics representation is interpreted as broad forms that are used to comprehend and convey physics concepts [31]. Physics as a subject requires comprehension and ability of using multiple representations for the studied concepts, so that students can master physics subject. However, students' inability to use multiple representations in understanding physics concepts seems to be an obstacle to their understanding [32]. Representation forms that are widely used in physics learning include verbal, diagrams (pictures, motion maps, and path diagrams), and mathematical [33]. The use of those various forms is called multiple representations [34]. The mathematical form is also called quantitative representation, while verbal, diagrams, and pictures forms are called qualitative representations. Multiple representation (MR) means to represent the same concept with different formats, including verbal, pictures, graphics, and mathematics formats [35].

In other words, the ability to master physics concepts is closely related to how to use various scientific languages in learning physics, such as words (oral and writing), visuals (pictures, graphics, and simulations), symbols and equations, gestures, role play, presentations, and other forms. This will enable students to study physics through developing intelligent thinking skill. This is called the multi representation approach or multi-mode representation [36]. The learning environment by using multiple representations has three main functions. First, MR

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can be used to obtain additional information to support or complement the existing cognitive processes. Second, MR is used to limit the interpretation that might occur. Third, MR is used to motivate students to build deeper understanding [37]. [37] also proved that MR play three main roles, namely complementing one another, explaining interpretations of an unusual representation, and helping students form a deeper comprehension about the studied topic. Cognitive process for improving students' comprehension meant in this study are interpreting, exemplifying, classifying, summarizing, concluding, comparing, and explaining [38]–[40]. Understanding activity is a process of thinking to observe phenomena or events. The ideas can be delivered either in oral or written form, and either visually or symbolically. The concept is the main principle that underlies all the results of abstract human thought about things, events, facts that explain many experiences. Concept understanding is the process of interpreting, modelling, classifying, comparing, explaining, and concluding about objects, events, situations, or characteristic features that are unique and represented in each culture for a sign or symbol in physics.

The use of MR will be able to develop the representation ability of physics students. The representation ability is the competence to interpret and apply various representations to understand and solve physics problems appropriately [41]. Students' representation ability will help them to understand and solve analytic mechanics problems in various analytic mechanics materials.

Method

This study used a mixed method with quantitative and qualitative triangulation. To find out the achievement of MR-based analytic mechanics learning, GeoGebra software is used. Learning activities are conducted on GCF, PSD, ROR, and 3DROR materials. The subjects in this study were students from a private university in Jakarta, Indonesia (Figure 2). The sample consisted of 21 students, majoring in physics education in the third semester. The instrument used in this study consisted of MR-based content module and student-worksheet, which contains 5 to 10 questions in accordance with the designed indicators and lectures' objectives on MR-Geo learning. This instrument will reveal the percentage of students' concept mastery from the MR-based content modules filling and answers in students-worksheet. The result of this study will reveal the level of concept understanding, concept misunderstanding, and the achievement of GeoGebra software utilization to actualize the 4IR for physics education.

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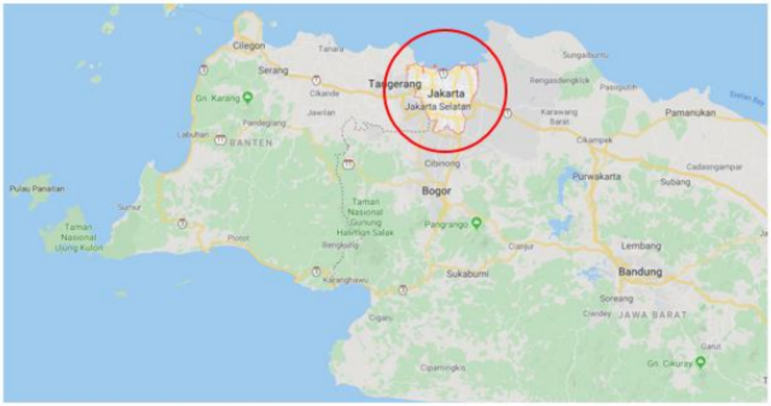

Figure 2 :*Map of Jakarta City(Source: https://www.google.com/maps/jakarta)*

Results and Discussion

The results of students' answers, obtained through mechanics content modules filling and MR-based student-worksheet answers, are shown in several forms, namely verbal skill, mathematical, graphics, and images. Figure 3 shows students' ability to verbally represent gravity concept, represent it in an image and mathematically. Figure 4 shows students' ability to make graphics using GeoGebra software on GCF material on the coordinate graph to calculate the gravitational field on the spherical shell. And then Figure 4 shows students' ability to make three-dimensional images on the effective potential concept for the laws of force and on radial motion.

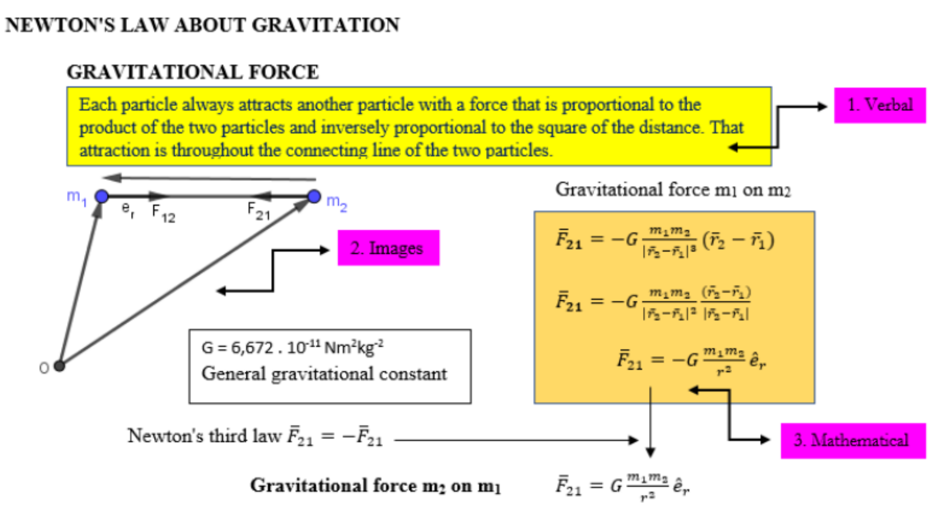

Figure 3 : *Multiple representations: Verbal (1), Images (2), and Mathematical (3)*

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Figure 3 shows students' ability to represent the concept of gravity verbally (1): each particle always attracts another particle with a force that is proportional to the product of the two particles and inversely proportional to the square of the distance. After being presented in the form of images (2) from the gravity concept, where m1 particle attracts m2 particle with a large tensile force F12 and F21 with the square and the pull force along the connecting lines of the two particles. And the third representation is in mathematical form, namely: $\bar{F}_{21} = G\frac{m_1 m_2}{r^2}\hat{e}_r$.

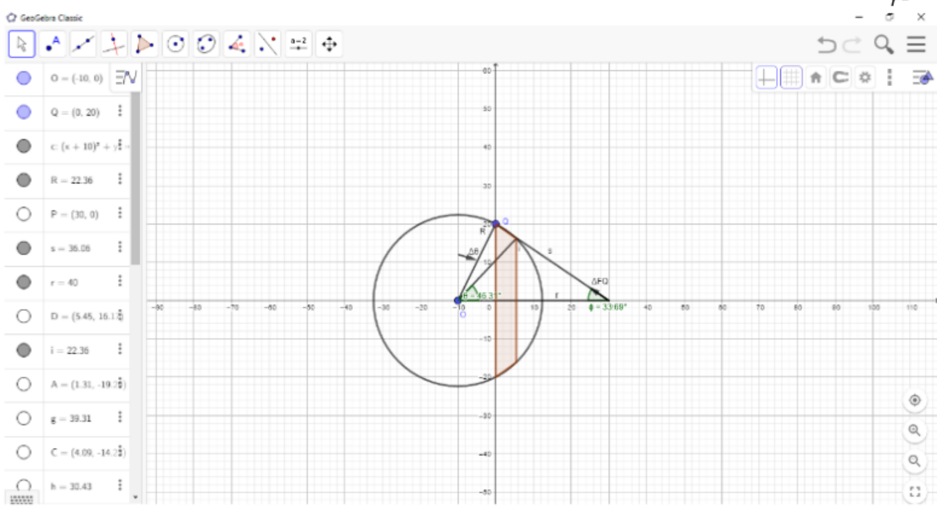

Figure 4
Graphics representation using GeoGebra software

Figure 4 shows students' ability to represent graphs. The results of MR-based mechanics lectures development proved that students were able to make graphs using GeoGebra software in coordinate graphs to calculate the gravitational field on the spherical shell. Students have gained the basic knowledge to use GeoGebra software so that students can easily analyze graphs from mathematical equation formulas.

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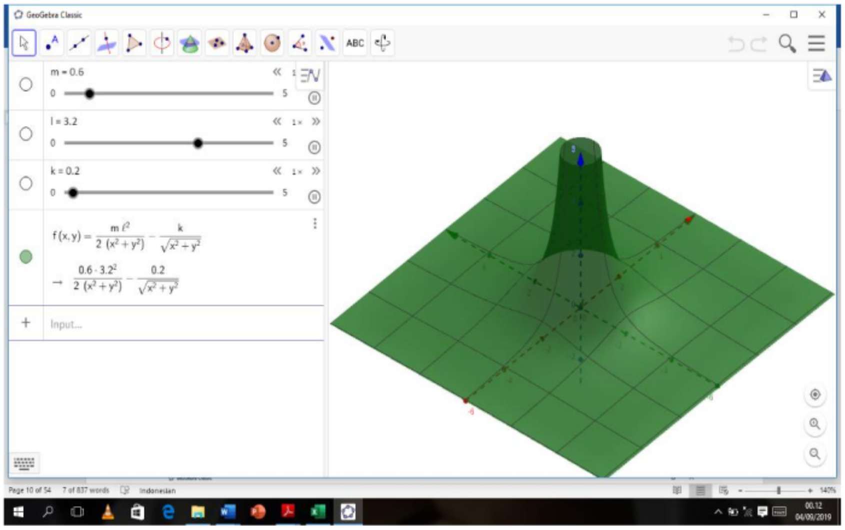

Figure 5

Images and graphs representations using 3D GeoGebra software.

Figure 5 shows the results of students' ability to make three-dimensional images with GeoGebra software on the effective potential concept for the law of force and radial motion.

The results of the overall percentage score on students' concept understanding in GCF, PSD, ROR, and 3DROR mechanics materials based on multiple representations can be observed in Figure 6 below.

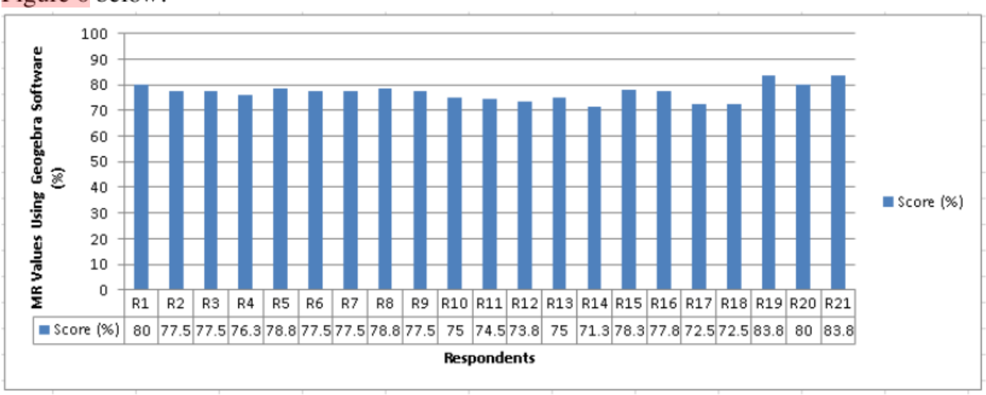

Figure 6

The percentage graphics of students' concepts understanding results on MR-based analytic mechanics module using GeoGebra software

In Figure 6, from 21 students it can be seen that the concept understanding of 3 respondents is at 14.29% in "very high" category, 17 respondents at 85.71% in "high" category, and 1

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respondent at 0.05% in "moderate" category. Based on these results, it can be concluded that the MR-based analytic mechanics learning using GeoGebra software can improve the concept understanding mastery in the GCF, PSD, ROR, and 3DROR materials modules.

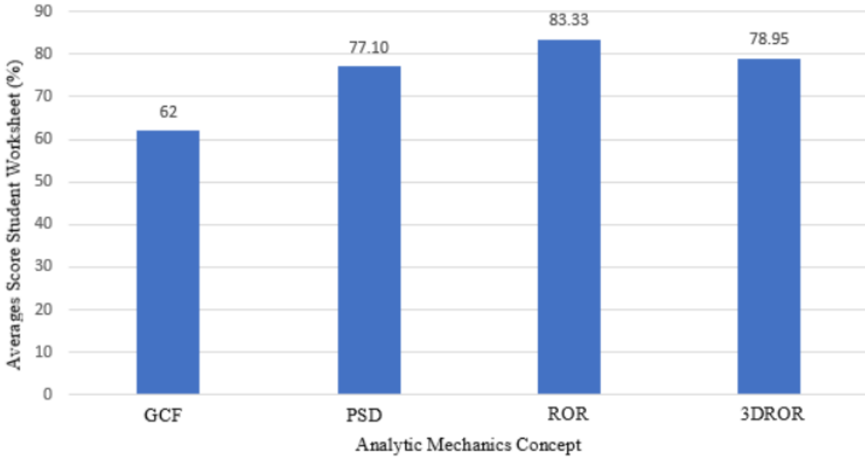

Figure 7
The percentage graphics of MR-based analytic mechanics student-worksheet results.

From the graphs in Figure 7 above, the average percentage of student-worksheet results in each material from 21 respondents are obtained. The average percentage of GCF material is 62% in "medium" category, PSD material is 77.10% in "high" category, ROR material is 83.33% in "very high" category, and 3DROR material is 78.95% in "high" category. It can be concluded that MR-based analytical mechanics learning using GeoGebra software in completing student-worksheet can improve the concept understanding mastery in GCF, PSD, ROR, and 3DROR materials. It can be seen in the PSD material, 83.33% is obtained in a very high percentage compared to other materials. This happened because when this material is given, students already have the basic concepts of basic physics course that have been obtained at the beginning of the semester. In the GCF material, a smaller percentage of 60% is obtained. This happened because when this material is given, students experience confusion to comprehend abstract concepts of gravity and central forces, when they made three-dimensional image analysis. Students were still confused when operating GeoGebra software. Based on these findings, it can be said that students actually have their own ability to understand some of the concepts of analytic mechanics. But unfortunately, the concepts that they master are still relatively weak and the mastery of GeoGebra software is also weak due to student weaknesses in mathematics. However, students' limited condition does not undermine the efforts of researchers to conduct treatment in the analytic mechanics learning process with MR-based approach. Using GeoGebra software can help students to overcome the difficulties in analyzing abstract concepts, especially in the analysis of graphs and images. So, the results of this study will be an alternative to embody the education concept of the 4IR era in physics learning.

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Conclusions

The data found in this study shows that the MR-based analytic mechanics learning using GeoGebra software has been achieved. It can be seen from the students' concept understanding in the analytical mechanics module, which is in "high" category. Based on the findings data on student-worksheet answers, it was concluded that high students' mastery of concepts was achieved, which led to a high level of analytic mechanics concepts mastery as well. This study has produced quite complete data, and is very supportive to welcome the education concept in entering the industrial revolution 4.0 (4IR) era. For the future researchers, this study can be developed more broadly by reviewing students' learning styles in a wider group. Therefore, the data collection process is not limited so that the data accuracy and strength levels can be higher and the used software can be better.

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