JHICE Journal
VOLUME 03 NO 01 2023, pp 10-18
ISSN: Online 2809-6916
DOI : https://doi.org/10.24036/jhice/vol1-iss01/48

INTERNATIONAL JOURNAL OF HIGH INFORMATION, COMPUTERIZATION, ENGINEERING AND APPLIED SCIENCE

Article

Trends in Science Education Research on Computational Thinking-STEM Using NVIVO : Literature Review

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Abstract— Science learning in the 21st Century is marked by the improvement and development of students' skills in thinking, acting, and living in the world; 21st-century skills can be developed using various methods, approaches, and learning models. The STEM and Computational Thinking (CT) approach can be a tool for teachers and students in achieving learning goals in the digital era. This paper aims to review the results of research related to CT-STEM in science learning. The research method is carried out by applying the PRISMA protocol. Articles imported from publish or perish come from international journals with a publication range of 2018-2021 then screening is carried out so that ten articles are obtained that are eligible for qualitative testing. After that, coding was carried out using NVIVO 12. The trend of the type of research used by some researchers was a correlative survey, elementary school students were mostly chosen as research subjects, while the most widely used research instruments were computational thinking skills and perception of STEM skills, while for data analysis, The most frequently used are content analysis and descriptive statistics. In addition, there are two articles that combine the CT-STEM approach with learning models, namely: inquiry and PBjL. Regarding the research results, it can be recommended for further research to develop products in the form of learning tools to be able to apply CT-STEM in science learning, especially in Indonesia.

Keywords— ***Problem solving, Critical Thinking, CT-STEM, Inquiry, PjBL***

Manuscript received 31 January 2022; revised 20 June 2023; Accepted: 15 August, Published 21 August 2023.

I. INTRODUCTION

Computational thinking, which is helpful in the future and needs to be taught to students so that they can adapt to the demands of the digital world, such as IoT (Internet of Things), Artificial Intelligence (AI), and Big Data, is required in the twenty-first century is critical thinking and problem solving, creativity, collaboration, and communication skills. In addition, learning in the digital era is based online [1][2][3] Computational Thinking (CT) is a method of problem-solving, system design, and human behavior analysis that uses core computing concepts.

CT is also a problem-solving process that includes problem formulation, logical organization of data analysis, data representation through abstraction, identifying and automating solutions through algorithmic thinking, analyzing and implementing, possible solutions, and generalizing, according to the International Society for Technology in Education (ISTE). They also transfer problem-solving techniques [1]. CT is expected to play a critical role in practically every sector of research and profession in the near future, hence it must be included into education [2] CT has a lengthy history in computer science, according to [3], extending back to the 1950s and 1960s when it was known as the "Thinking Algorithm." According to a research from the Royal Academy of Engineering, students aged 14–19 must comprehend the concepts of computational programming, design, problem-solving, usability, communication, and hardware.

CT is a skill that allows you to use computer science techniques to understand your surroundings better. CT is based on seven big ideas: 1) computing is a creative human activity, 2) abstraction reduces information and details to focus on concepts relevant to understanding and solving problems, 3) data and information facilitate the creation of knowledge, 4) algorithms are a tool for developing and expressing solutions to computational problems, 5) programming is a creative process that produces computational artifacts, and 6) digital devices, systems, and networks are all examples of computational artifacts. (College Board and National Science Foundation (NSF)); social sciences, humanities, arts, medicine, engineering, and business [4] .

Moursund claims that CT is a cognitive tool in his paper [4]. There are five important principles in CT, according to [5]: 1) When dealing with vast and complex problems that must be broken down into smaller and more numerous ones in order to be solved, decomposition is required [6], 2) Isolation [2] defines the ability to determine in-depth about the importance of a problem and what needs to be ignored as "the ability to decide in detail. About the importance of a problem and what needs to be disregarded." 3) Algorithm design is the abstraction of step-by-step problem-solving techniques. Take some input and turn it into something useful [2], 4) The ability to answer problems based on previously solved problems is known as a generalization [7].

In the United States, computer science (CS) has become a policy in STEM (Science, Technology, Engineering, and Mathematics) education since the turn of the century. CT is regarded as the foundation of STEM (Henderson, Cortina, Hazzan, & Wing, 2007; [4]). According to Sussman, CT is "closely connected" to mathematics in STEM, but "not identical"; "Rep. a Work. Scope Nat. Comput. Think.," (2010) both participate in abstraction and reasoning using simplified models, and both have a fundamental language structure. CT can be seen as a complement to, and synthesis of mathematical and engineering thought [2].

Educators can use CT in all STEM subjects; data practices in STEM include data production, data gathering, data manipulation, data visualization, and data analysis, according to [8]When students are collecting data, for example, they can utilize the concept of decomposition to identify all of the components and processes that are required to collect data that is appropriate for addressing a research topic. Then when students create data, they can utilize algorithmic thinking by structuring studies by arranging the components and processes found during decomposition in a logical manner so that the data can be replicated [12].

This paper has the urgency that previous studies discuss research related to computational thinking and STEM in science learning so that research trends have been found and can be a reference for future researchers. Referenced articles are imported from Publish or Perish, published from 2018–2021, and various categories are used as the basis for content analysis.

II. METHODE

The steps of this paper's literature review follow the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) research protocol: 1) By entering keywords, articles with publication years 2018–2021 are discovered and imported from Publish or Perish (computational thinking, STEM, science learning). We found 106 articles that were relevant to this subject.

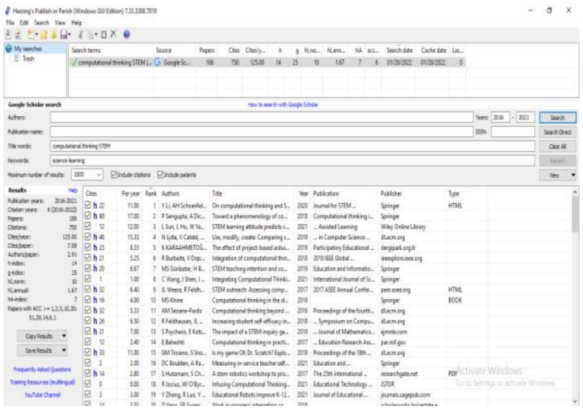

Figure 1. Imported data from publish or perish

2) The identified articles are vetted by removing those that do not satisfy the criteria, such as those from proceedings where the study topic is too broad and has no bearing on learning, particularly science. Thirty-four articles were vetted, and 72 articles were issued. 3) Eligibility is then determined to see if the article is feasible, with just 14 articles found worthy and four articles published in full text because they do not match the criteria. 4) we chose only ten articles for the qualitative synthesis based on the feasibility findings.

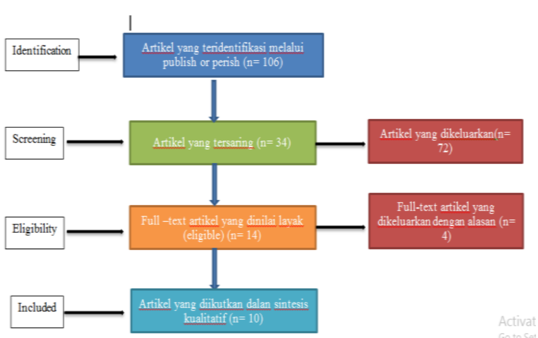

Figure 2. PRISMA Research Protocol Flow Diagram

Furthermore, the articles that we included in the qualitative synthesis were analyzed using the NVIVO 12 software so that the data coding was obtained as follows:

Table 1. Coding Process Using NVIVO 12

Nodes	Files	References
Data analysis	10	12
CHAID analysis	1	1
Factor analysis	1	1
Content analysis	3	3
Likert Instruments	1	1
SEM	2	2
Descriptive statistics	3	3
Non-parametric test	1	1
Data Collection Instrument	10	14
Bebras CT	1	1
Computational thinking skill level & Perceptions of STEM skill level	4	4
Audio files	1	1
Questionnaire	1	1
Video recording	1	1
STEM learning attitude scale	2	2
Computational thinking test	2	2
Interview	3	3
Types of research	10	10
descriptive	1	1
Mix Methods	1	1
Development	1	1
Quasi-experimental	1	1
Case study	1	1
Correlational survey	4	4
Quantitative survey	1	1
Learning model	2	2
Inquiry	1	1
PjBL	1	1
Research subject	10	10
Pre-service teacher	3	3
Teacher		
Guru	1	1
SD	5	5
SMP	1	1

III. RESULT AND DISCUSSION

As many as three research articles on CT and STEM in scientific learning can be discovered in journals published in 2020 and 2021, respectively. Problems on a global or local scale can lead to research issues. Computational thinking in problem-solving is the current topic of discussion. Typing "computational thinking research" into Google returns 55.900.000 results, while "computational thinking research and STEM" returns more than 6.960.000 results. This massive volume of data demonstrates that the topic of CT and STEM is exploding. The number of studies on this issue has increased by 83.3 percent, indicating that research interest in this area is growing [10].

However, as shown in Figure 1, there are only ten articles that integrate CT and STEM in science learning, which is consistent with [10] research. Only six items explicitly address the connection between CT and STEM. According to [14], incorporating CT into STEM is a new issue that is critical to students' 21st-century skills preparation. The graph in Figure 3 below shows the distribution by author and institution of origin. This shows that the authors who research CT-STEM come from different institutions. However, some are from the same country, namely Turkey [12][13][14][15], and the USA [16][17][18] in addition to those from Thailand [19] and China [20] and Athens [21].

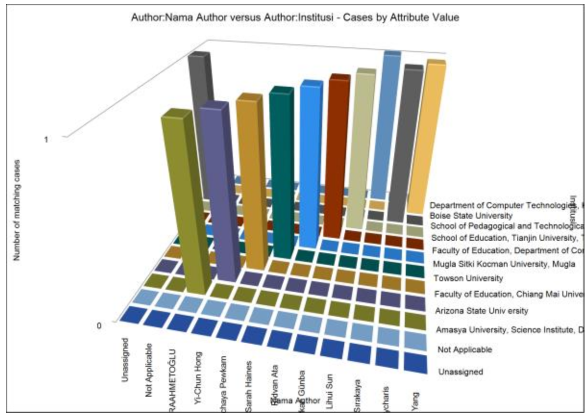

Figure 3. Distribution of Author and Institutional Identity

Based on the search results from several imported data sources utilizing the QSR NVivo 12 software's Phrase Frequency Query tool, the word 'STEM' has the highest frequency of appearing across all research data sources, followed by the words 'computational thinking, 'students,' and 'education.' The word cloud of the 30 most common words used in the research data source is shown in Figure 4.

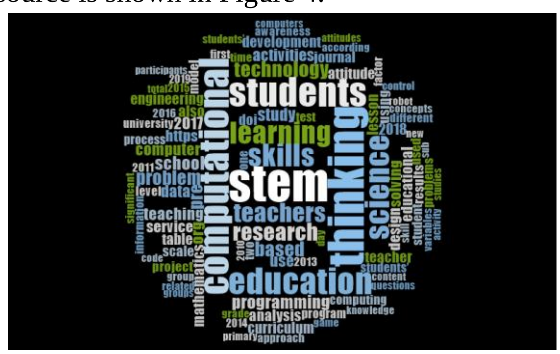

Figure 4. Word Cloud of 30 Dominant Words Used in Research Data Sources

Previous researchers in CT and STEM studies have employed seven different study approaches. On the other hand, the correlational survey method is more extensively utilized. The goal of this study was to look into the relationship between computational thinking and students' STEM skills. According to [13] research, prospective teachers' STEM awareness is insufficient, and their computing abilities are lacking. The most critical link between math elements and CT skills [20]. CT is essential for problem-solving in all fields, including STEM

[22][23][4][24][14]. STEM awareness is moderately influenced by computational thinking skills, media and technology, and attitudes. To implement STEM, at least two methodologies are used. The first is to take a comprehensive approach. At least in learning to teach two fields in one topic, this technique is built on four basic disciplines (Science, Technology, Engineering, and Mathematics) [25].

The four disciplines are taught individually in both traditional STEM methodologies, and these areas are approached separately. According to this strategy, including the four core disciplines into one activity might be challenging; the most significant is allowing pupils to study the four STEM disciplines alongside other fields [29]. CT-STEM research is also quantitative, in addition to correlational studies. Interestingly, the technology element is the subject of quantitative development in CT and STEM research; according to [30], there have been many innovations in the use of technology in education, especially in the teaching and learning process, over the last decade.

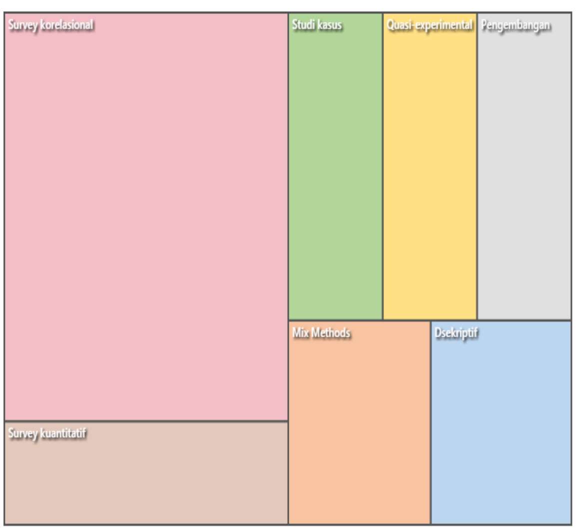

Figure 5. Tree Map Hierarchical Diagram of Trends in Types of CT-STEM Research

Incorporating components of the CT approach into STEM courses is one of the keys to promoting STEM [31]. CT abilities and essential reading, writing, and math skills are required for everyone by the middle of the twenty-first century. As a result, CT thinking has become a popular research topic in recent years [32].

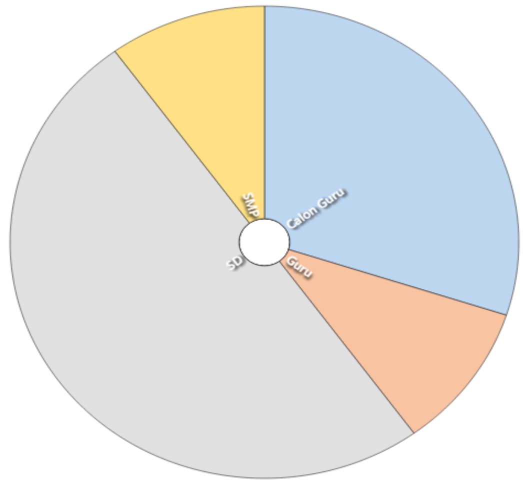

Figure 6. Trends in CT-STEM in terms of research subjects

In the 21st century, CT can help people in every professional field, so [33] emphasize that CT should be taught to elementary, junior high, and high school students. Figure 3 shows that CT-STEM integration is more widely applied to elementary school science groups, while CT-STEM interventions in grades 5–9 positively impact students and they become more active [34].

According to [35], CT can change the understanding of teachers in the future and how it can be integrated into the classroom. We need to develop teachers' understanding of computational thinking in the material they teach. Integrating mathematical thinking (STEM components) and quality computational thinking can improve science teaching, which can assist in simulating phenomena, analyzing data sets, and studying many quantitative relationships according to disciplines [36]. Computational thinking is important for students not only for those who want to pursue careers in mathematics and science, but also for developing science and mathematics literate citizens in society [11].

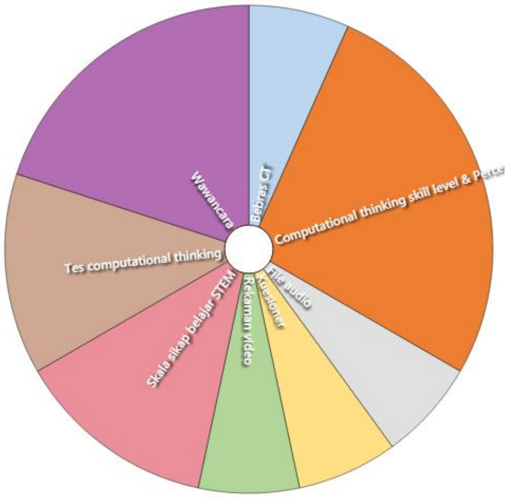

Figure 7. Trends by Data Collection Tool

The most widely used research instrument in CT-STEM research is computational thinking skills, adapted from [37]; there are four factors: creativity, algorithmic thinking, collaboration, critical thinking, and problem-solving. Then the instrument for the perception of STEM skills was adopted from [37], interviews, and STEM learning attitudes. In addition, several articles have been analyzed using the free test as a CT measuring tool, and the freebras community around the world has developed this test. Bebras is an international competition that aims to promote computer science and CT among students of all ages. All problems in bebras are related to computing topics, such as cryptography, trees, etc.

The Bebras test is designed to test students' CT skills before and after the study [38]. In Indonesia itself, there is the Bebras Indonesia Challenge 2020 competition, which is participated in by students from various levels, namely: the little one category (grades 1-3 SD and MI) followed by 2543 students, the standby category (grades 4-6 SD and MI) followed by 3297 students, the raising category (SMP and MTS) was attended by 5870 students, and the driving category (SMA, MA, and SMK) was attended by 4476 students (https://bebras.or.id/v3/). In addition to free tests, the researcher also used the "Level of computational thinking skills" and the "Perception of STEM skill level." As for the qualitative research instrument, the researcher used the CT assessment rubric, the attitude assessment rubric, interviews, and observations, as well as audio and video files.

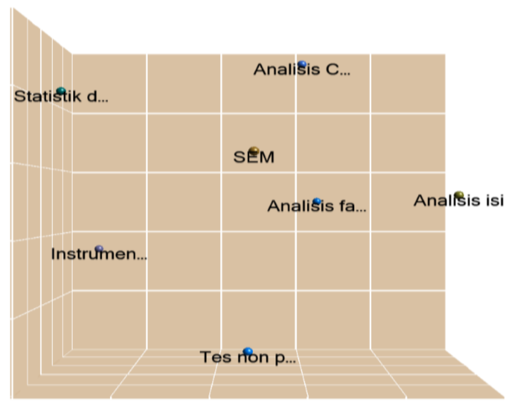

Figure 8. Trends based on data analysis Techniques

Content analysis and descriptive statistics are the most extensively used data analysis approaches, as seen in Figure 8. Content analysis is a type of research that entails a detailed examination of written or printed content in the media. Content analysis can provide information, fresh insights, fact representations, and actionable instructions by drawing replicable and valid inferences from data in context Krippendorff, 1980 [39].

Harold D. Lasswell, the father of content analysis, invented the symbol coding approach, which allows you to systematically capture symbols or messages and subsequently understand them. Content analysis can be used for more than just visualizing a message. A message's causes can also be deduced through content analysis. Furthermore, descriptive statistics are utilized to examine the data, which can help to improve the educational process when dealing with both quantitative and qualitative data [40].

IV. CONCLUSION

Computational thinking (CT) and STEM have urgency in improving students' skills in the future. This study focuses on how CT-STEM research in science learning has been published in various international journals. A total of 106 articles have been published, and we found ten articles that focus on the integration of CT and STEM in science learning. In addition, correlational survey research dominates the methods used by researchers, and the most commonly used instruments are CT skills and STEM skills. Meanwhile, elementary school students are the most popular research subjects, and the dominant data processing techniques used are content analysis and descriptive statistics.

Some recommendations for following up on further research are: 1) there is a need for development research related to the integration of CT-STEM in science learning, in the form of learning devices, media, etc., because its application in Indonesia will adjust the characteristics of science students in Indonesia. 2) Researchers need to explain what instruments will be used to measure student skills in the 21st century. From these conclusions, it can be suggested that researchers can choose research methods according to research objectives and suitable instruments to measure what they want to measure in research.

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