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Systematic Literature Review: GeoGebra as a Mathematics Learning Media to Improve 4C Skills

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Abstract

Mathematics curricula provide learners with methodologies for cognitive processes, analytical reasoning, and logical deduction through specific mental exercises that facilitate an uninterrupted stream of thought. Learners exhibiting proficient cognitive abilities, analytical reasoning, and logical deduction are likely to influence the competencies requisite for the 21st century, specifically the 4C skills (critical thinking, communication, collaborative, creativity). Using GeoGebra in mathematics learning will be very interesting, interactive and easy for students to understand. This research aims to study the effects of using GeoGebra to improve students' 4C skills in mathematics learning. The method for writing this article is Systematic Literature Review (SLR). In order to conduct this investigation, the researchers systematically gathered journal articles from the Google Scholar database utilizing the Publish or Perish application. The articles that were compiled consisted solely of those published within the timeframe of 2016 to 2022. From a diverse array of articles, the researchers meticulously selected 30 articles that were closely aligned with the specified keywords. The findings from the analysis of these 30 articles indicate that the application of GeoGebra in the context of mathematics education can significantly enhance 4C competencies. However, there are few articles discussing GeoGebra's role in improving collaboration skills, presenting a challenge for teachers and researchers to further explore its potential as a medium for enhancing students' collaboration. GeoGebra is flexible so it gives teachers the opportunity to create varied mathematics learning.

Keywords: *GeoGebra; 4c Skills; Mathematics Learning Media*

Introduction

Mathematics constitutes a mandatory discipline imparted to students from elementary through middle school levels. The study of mathematics equips learners with the ability to engage in critical thinking, reasoning, and cognitive activities that foster a coherent progression of thought, ultimately resulting in a comprehensive understanding of mathematical content encompassing facts, concepts, principles, operations, relationships, problems, and specific mathematical solutions of a formal and universal nature (Kemendikbudristek, 2022). Students who exhibit proficiency in logical reasoning and critical thinking are likely to enhance their competencies in the context of 21st-century skills.

21st century skills are very necessary to compete in the world of work. Currently, many jobs can be replaced by robots. The level competition within the professional realm is concurrently escalating as a result of the growing educational attainment among individuals. Many people understand the importance of education which does not result in low unemployment rates. According to statistics provided by the Central Statistics Agency (BPS), it is projected that the number of individuals classified as unemployed in Indonesia will attain 8.4 million by August 2022, constituting 5.86% of the overall national labor force (BPS, 2022). This cohort of 8.4 million individuals is actively engaged in efforts to secure employment or to innovate job opportunities. Therefore, students must be equipped with additional skills, not just knowledge, to be able to compete with the 8.4 million people. The skills that workers must have in the 21st century include the 4Cs (Critical Thinking, Communication, Collaborative, Creativity) (Redhana, 2019). Graduates who have these four skills will be more resilient in the competitive world of work and be able to create new, innovative jobs.

Learning activities in schools must refer to the 4 characteristics of 21st century learning which are usually formulated in the 4Cs, namely critical thinking skills, communication skills, collaboration skills, and creative and innovative thinking skills (As'ari, 2016). This learning activity will facilitate students in developing their 4C skills. Teachers have a big role in creating this learning. Planning, selecting a model or strategy and selecting learning media are very important before learning is carried out. This is accomplished through a meticulous consideration of the circumstances and requirements of learners.

Effective educational media significantly enhances students' comprehension of the concepts under examination, particularly within the domain of mathematics. Mathematics is a lesson with abstract concepts, therefore learning media is really needed. As science develops in the 21st century, technology has become a learning medium for transferring knowledge. Technology, especially computers, is a medium for connecting abstract mathematical ideas with concrete mathematical ideas. Study time will be much more effective if the learning strategy uses a computer. Computers possess a multitude of software applications that can assist in the educational process, particularly in the domain of mathematics. A notable software application that facilitates the acquisition of mathematical knowledge is GeoGebra.

One thing that can improve 4C skills is by using interactive software that can be used in the learning process, namely GeoGebra. The program features dynamic geometry software, a computer algebra system and also a spreadsheet and is all integrated in one GeoGebra package (Belgheis & Kamalludeen, 2018). GeoGebra is a computational software innovated by Markus Hohenwarter in the year 2001, and it is available for complimentary download at www.GeoGebra.org. The fundamental principles of GeoGebra are rooted in algebra and geometry (Bhagat et al., 2017).

GeoGebra serves as an instrument for illustrating or visualizing mathematical principles, functioning as a means to construct mathematical concepts (Purnomo, 2021). Furthermore, Purnomo (2021) elucidated that the application of GeoGebra within the realm of mathematics education can foster innovative mathematical reasoning, facilitate collaborative efforts, enhance student engagement in the learning process, and activate multiple sensory modalities in educational experiences, thereby rendering learning more efficacious. Using GeoGebra can support thinking and reasoning training; develop creativity; develop problem solving. GeoGebra offers teachers and students the opportunity to use it freely both in the classroom and at home. GeoGebra provides learning resources that can be accessed at any time and makes mathematics learning easier for teachers and students. GeoGebra also offers classrooms, which give students the freedom to study material and meet with teachers during and outside of learning, where teachers can review their students' activities in the classroom.

Based on the aforementioned description, the objective of this investigation is to ascertain the impact of employing GeoGebra on the development of 4C skills (Critical Thinking, Communication,

Collaborative, Crea-tivity) students in mathematics learning.Please note that the first paragraph of a section or subsection is not indented.

Methods

The methodology employed in this study is referred to as a Systematic Literature Review (SLR). The SLR constitutes an appraisal of extant research through the application of explicit and accountable research methodologies (Gough, et al in Newman & Gough, 2020), which involves the identification, examination, evaluation, and interpretation of all pertinent research. Utilizing this methodology, scholars conduct reviews and systematically identify relevant articles, adhering to predefined procedural steps throughout each phase.

In order to execute this research, researchers amassed articles from the Google Scholar database, employing the Publish or Perish application as an auxiliary tool. The key terms utilized in this study were GeoGebra and 4C skills. The assembled articles were exclusively those published within the timeframe of 2016 to 2022. From the diverse array of articles, researchers meticulously selected 30 articles that exhibited a close correlation to the specified keywords. The methodology for article selection is delineated in Figure 1.

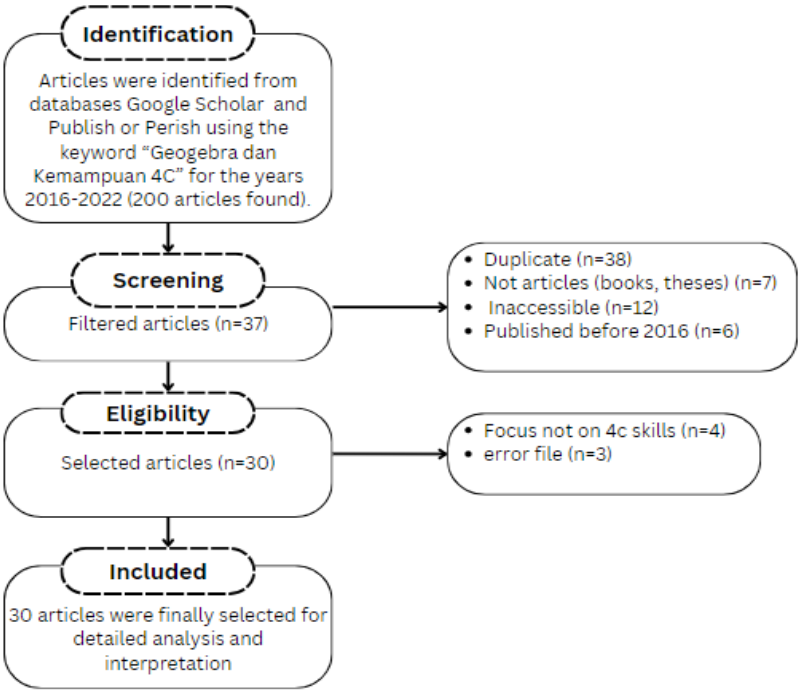

Figure 1. Article Selection Flowchart

The subsequent phase involved the categorization of scholarly articles that utilized GeoGebra as an educational tool aimed at advancing 4C competencies, both in aggregate and in relation to individual components of 4C skills. The information derived from these articles has been systematically organized into a table, which encompasses the author's name, publication year, and the outcomes of the research. Subsequently, the investigator conducted a thorough review and analysis of the articles, with particular emphasis on the research findings articulated in the discussion and conclusion segments. Ultimately, the researcher juxtaposes the results delineated in the article and articulates conclusions (Newman & Gough, 2020).

Results and Discussion

The 30 articles on the use of GeoGebra to improve 4c skills are categorized into four main sections. Content: The articles focus primarily on algebra (11 articles) and geometry (9 articles), with fewer studies on numbers (1 article), and some not mentioning content (4 articles). Grade: GeoGebra is used across various education levels, with 12 articles focusing on junior level, 12 on secondary, 5 on higher education, and 1 article not specifying the grade. Competence: The majority of articles address critical thinking (9), creative thinking (9), and communication (11), but only 1 article discuss-es collaboration. Method: The dominant research method is experimentation (21 articles), followed by RnD (4), action research (3), and mixed methods (2). The re-search predominantly focuses on using GeoGebra to enhance algebraic and geometric learning at junior and secondary levels, with emphasis on critical thinking, communication, and creativity. Collaboration is less explored, and experimental studies dominate the research methodologies.

In mathematics learning, the process of using learning media with the help of GeoGe-bra becomes more effective and efficient in the learning process and can improve 4C skills (Critical Thinking, Communication, Collaborative, Creativity) to students.

The findings derived from the research data encapsulated in this literature review constitute a comprehensive analysis and synthesis of scholarly articles pertinent to GeoGebra as an educational tool for mathematics, aimed at enhancing the four critical competencies, specifically critical thinking, communication, collaboration, and creative thinking, which are delineated in the succeeding table.

Table 1. GeoGebra implementation of critical thinking skills (Critical Thinking)

Researcher	Research result
Setiawi et al.	The pedagogical approach of Problem-Based Learning, augmented by GeoGebra, significantly enhances students' abilities in critical thinking and problem-solving.
Andriani et al.	The pedagogical approach of Flipped Learning, particularly when integrated with GeoGebra, has demonstrated efficacy in enhancing the critical thinking capabilities of students in studying mathematics online compared to models *Flipped Learning* and direct learning models.
Sari et al.	Model learning *Problem Based Learning* with Komika Pro media assisted by GeoGebra, this PTK, critical thinking skills increased even up to cycle 2. For cycle 3 it decreased due to character factors, student and teacher attitudes which could also be one of the obstacles.
Rahman et al.	The instructional methodology of Flipped Learning, especially when synergistically combined with GeoGebra, has evidenced significant effectiveness in augmenting the critical thinking skills of learners
Batubara	The enhancement of critical thinking abilities via the guided discovery learning approach facilitated by GeoGebra surpasses that observed in students who engaged in the guided discovery method devoid of GeoGebra..
Ardiyanto et al.	The utilization of the GeoGebra Applet-based CORE learning model has been shown to be more effective in enhancing students' critical thinking abilities in comparison to traditional direct learning models.
Hikmah R., et al.	The enhancement in critical mathematical reasoning abilities among students utilizing GeoGebra media surpasses that of their counterparts engaged in conventional educational methodologies.

Hidayati and Kurniati	Teachers or lecturers are required to possess the capability to devise innovative pedagogical strategies and necessitate an active engagement in the educational process, particularly through the utilization of GeoGebra, which has been empirically demonstrated to facilitate the development of self-regulated learning, thereby fostering the cultivation of critical mathematical thinking abilities.
Munandar et al.	The utilization of GeoGebra software in the context of mathematics education significantly influences the enhancement of students' critical thinking skills.

Critical thinking represents a fundamental competency among the essential skills requisite for students in the 21st century, facilitating their preparedness for navigating the complexities of globalization. This cognitive process serves as a foundational mechanism through which students can navigate and mitigate future uncertainties. The possession of critical thinking skills significantly aids learners in the discernment of vital information, as well as in the transformation and preservation of such data (Setiawi et al., 2021).

Based on Table 1, it is evident that educational interventions facilitated by GeoGebra exert a favorable influence on the enhancement of students' critical thinking abilities. The findings derived from experimental research suggest that instructional methodologies incorporating GeoGebra yield superior outcomes in the development of critical thinking skills when compared to traditional instructional approaches devoid of GeoGebra (Andriani et al., 2022; Ardiyanto et al., 2022; Coal, 2019; Wisdom, 2020). Nevertheless, the application of GeoGebra does not uniformly lead to the augmentation of critical thinking skills, as evidenced by the research conducted by Sari et al. (2022). The second cycle of the investigation revealed an upward trajectory in critical thinking skills; however, an observed decline in these skills occurred during the third cycle. Sari et al. (2022) postulates that this regression is attributable to an elevated level of difficulty, which, coupled with students' unfamiliarity with critical thinking tasks, results in overwhelming challenges in their attempts to respond. Additional contributing factors may include fatigue and a lack of preparedness for the assessment.

Therefore, teachers do not only focus on the learning process but also on the assessment process by paying attention to several factors that allow students to fail in taking exams. This notion was similarly articulated by Batubara (2019), who posited that within each instructional session, educators are compelled to cultivate an educational environment that facilitates students' opportunities to articulate mathematical concepts in their own vernacular and through their unique methodologies. This approach ultimately fosters greater assertiveness in students' viewpoints, enhances their self-efficacy, and stimulates their creativity.. Furthermore, Setiawi et al., (2021) also provides suggestions that teachers are expected to be able to prepare relevant tools, concepts and problems in full, so that misconceptions do not occur and it takes time.

In this way, students' understanding will increase and time efficiency can be maximized to improve students' learning achievements. The engagement of students in mathematical education through the utilization of GeoGebra has the potential to enhance their cognitive abilities, provided that educators engage in meticulous preparation for both the instructional process and evaluative measures, while also considering the contextual factors affecting students and their respective learning environments.

Table 2. GeoGebra Implementation of Communication Skills

Researcher	Research result
Dwijayani, N	There exist distinctions in the impact on the mathematical communication competencies of students utilizing GeoGebra-assisted worksheets compared to those engaging in traditional pedagogical approaches. The mean mathematical communication proficiency of students in the experimental group surpasses that of students in the control group..
Istikomah et al.	Enhancing the mathematical communication competencies of students in the experimental group (utilizing GeoGebra) is more effective than the enhancement of mathematical communication competencies in the control group (which does not utilize GeoGebra).
Mujiasih et al.	The utilization of the EPIC-R model, augmented by GeoGebra, among students enrolled in the Mathematics Education Program demonstrates a significant correlation with the enhancement of communicative competencies.
Muqtada et al.	The reciprocal learning framework facilitated by GeoGebra has the potential to enhance the mathematical communication competencies of students in the eleventh grade.
Lestari et al.	The implementation of the reciprocal peer tutoring technique, facilitated by GeoGebra, exerts a considerable influence on the mathematical communication competencies of students..
Perawansa et al.	The educational instruments formulated through pedagogical insights utilizing the SAVI methodology, in conjunction with GeoGebra, fulfill the criteria of validity, practicality, and efficacy in enhancing mathematical discourse and fostering student motivation in the learning process..
Yuliardi & Casnan	A significant positive correlation exists between spatial reasoning capabilities and mathematical communication skills. The utilization of Computer Assisted Instruction (CAI), particularly facilitated by GeoGebra Software, is strongly advocated for implementation within the mathematics educational framework at vocational high schools (SMK/SMA) and their equivalent institutions..
Kustiawati	The mean mathematical communication competence of students instructed through the utilization of GeoGebra software in the context of geometry education surpasses the mean mathematical communication competence of students educated through traditional instructional media..
Rusmini et al.	The evaluation of students' mathematical communication competencies (TKKM), which can be assessed through the efficacy of problem-solving instructional strategies facilitated by GeoGebra, fulfills the criteria for effectiveness as evidenced by the attainment of completeness, the active engagement thresholds of students, their responses to worksheets, and the positive development of their mathematical communication abilities.
Fitra Awaludin	The implementation of the GeoGebra-assisted pedagogy has the potential to enhance the mathematical communication competencies of ninth-grade students in junior secondary education in relation to the topics of Exponents and Radicals.
Maryono et al.	The advancement and enhancement of students' mathematical communication competencies through the GeoGebra-assisted ELPSA methodology surpasses the advancement and enhancement of students' mathematical communication competencies achieved through traditional instructional techniques (direct instruction).

Communication (communication) is an important part of social life. Good commu-nication will produce good social relations as well. Therefore, communication skills need to be developed in students from the start. One form of communication that must be developed is mathematical communication. Mathematical communication is a way to share mathematical ideas and clarify understanding of those ideas (NCTM, 2000).

Based on Table 2 can be concluded that using GeoGebra in mathematics learning can improve students' mathematical communication skills. Kustiawati (2017), Dwijayani (2019), Maryono et al., (2021) and Istikomah et al., (2021) states that learning mathematics using GeoGebra can improve mathematical communication skills better than conventional learning (without GeoGebra). This is supported by the findings of Mujiasih et al., (2021), Muqtada etc., (2018), Lestari et al., (2019), and Fitra (2018) that learning mathematics using GeoGebra has a positive correlation with improving students' mathematical communication skills.

GeoGebra as a medium to assist learning will certainly produce maximum results if supported by thorough conceptual preparation from the teacher. A valid learning design that suits students' needs certainly makes mathematics learning more mean-ingful. Mathematics learning using GeoGebra is recommended to improve communication skills (Indah Perawansa et al., 2019; Rusmini et al., 2019; Yuliardi & Casnan, 2017).

Table 3. GeoGebra implementation of creative thinking skills

Researcher	Research result
Septian et al.	Improving students' creative mathematical thinking skills through Android-based GeoGebra is better than ordinary learning.
Selvy et al.	The enhancement of creative mathematical thinking skills and the motivation levels of students who received instruction through the Problem-Based Learning (PBL) model facilitated by GeoGebra exhibited a greater degree of improvement in comparison to those students who were instructed using the PBL model devoid of software assistance.
Setiawan et al.	The instructional resources that have been formulated with the assistance of GeoGebra yield both valid and pragmatic educational materials conducive to the learning process aimed at enhancing creative thinking competencies..
Romaito et.al.	Students participating in mathematics instruction facilitated through the GeoGebra platform exhibit superior creative thinking abilities compared to their counterparts who undergo conventional mathematics instruction devoid of GeoGebra.
Yildiz etc.	The use of GeoGebra software had a positive impact on the probationary teachers, and thus, significant differences were noted in the post-test in all dimensions of creativity, except one.
Bachore	Students subjected to a mathematics learning intervention utilizing GeoGebra software exhibit superior creative thinking capabilities in comparison to students receiving instruction through traditional pedagogical models.
Wibowo et al.	(1) The Discovery Learning Model, supported by the GeoGebra Applet, is classified as valid, practical, and effective; (2) An enhancement in the creative thinking capabilities of students is observed subsequent to the implementation of the Discovery Learning Model, utilizing the GeoGebra Applet in the context of rectangular plane material.

Aminy et al.	Increasing students' mathematical creative thinking abilities through learning models *Problem Based Learning* GeoGebra's assistance is better than students' mathematical creative thinking abilities through a scientific approach in high school
Samura et al.	The implementation of the GeoGebra-facilitated community learning framework has the potential to enhance the creative thinking skills of junior high school students.

Apart from being able to improve critical thinking and communication skills, GeoGe-bra can also help improve students' creative thinking skills. Based on Table 3 Several studies have concluded that using GeoGebra in mathematics learning can improve students' creative thinking skills. Class action research conducted by Romaito et al., (2021) and Samura et al., (2021) shows the same results, namely that the use of Ge-oGebra in mathematics learning can improve creative thinking skills.

Experimental research conducted by several researchers shows that improving stu-dents' creative skills in mathematics learning using GeoGebra is better than without using GeoGebra (Aminy et al., 2021; Bachore, 2021; Romaito dkk., 2021; Selvy et al., 2020; Septian et al., 2020). One indicator of creative students is being able to show several ideas in solving a problem. By using GeoGrbra, students have the opportunity to show their various ideas more easily. This is in line with Purnomo's statement (2021) that the use of GeoGebra in mathematics learning can foster creative thinking skills and make learning more effective. One of the learning designs developed is a learning-based model discovery learning assisted by the GeoGebra application com-piled by Wibowo et al., (2022) is declared valid and can be used to improve students' creative thinking skills. This strengthens GeoGebra as a good learning media to be applied to mathematics learning.

Table 4. GeoGebra implementation of collaborative skills

Researcher	Research result
Susanti et al.	The utilization of GeoGebra in conjunction with a cooperative model of group investigation in mathematics education can significantly enhance students' competencies in communication, collaboration, and problem-solving. Furthermore, the cooperative model augmented by GeoGebra serves as a valuable pedagogical tool for educators seeking to foster the capabilities and skills essential for 21st-century learners. It is imperative that mathematics instruction is systematically structured to cultivate students' collaborative, problem-solving, and communication proficiencies. Such competencies play a crucial role in equipping students to tackle increasingly intricate challenges.

The last 21st century skill is collaboration or cooperation (collaboration). Researchers have difficulty finding articles regarding GeoGebra's implementation of collaboration. Researchers only found one relevant article, namely on Table 4.

This does not mean that GeoGebra cannot be used to help improve students' collabo-ration skills. Collaboration is closely related to the learning model used. Cooperative learning is the most suitable learning model to improve collaboration skills. Cooperative learning requires students to have discussions both with other students and with the teacher. Using the GeoGebra application in cooperative learning will be more effective in improving collaboration skills (Susanti et al., 2022).

Based on the description in table 1, table 2, table 3, and table 4 shows that the use of GeoGebra in improving 4C skills in students. However, in the literature results from several studies, not many researchers have discussed the 4C skills at once, so each 4C skill is explained. This can be a recommendation for future researchers regarding how GeoGebra accommodates students in developing collaboration skills. Teachers also face new challenges to create mathematics learning using GeoGebra so that they are able to develop 4C skills as a whole through selecting learning models, planning learning activities, creating GeoGebra applets, and project ideas for students using the GeoGebra application.

Another finding from the 30 articles is about the advantages and disadvantages of using GeoGebra. There are 5 advantages of using GeoGebra in math learning. (1) GeoGebra enhances critical thinking, communication, collaboration, and creativity (4C skills) in mathematics learning, making it a valuable educational tool. (2) The software makes learning mathematics interesting and interactive, which helps students understand concepts better. (3) Teachers can design varied learning experiences across different mathematical subjects, such as geometry, algebra, and calculus, using GeoGebra . (4) GeoGebra encourages students to explore multiple solutions to problems, fostering creativity in their mathematical thinking. (5) GeoGebra provides learning resources that can be accessed anytime, facilitating both classroom and home learning.

We find 2 disdvantages of using GeoGebra in math learning. First, when we use GeoGebra learning can run smoothly depending on the technology used. Effective use of GeoGebra requires access to technology (need electricity, cell phone or computer, signal, ect) which may not be available to all students or educational institutions. Second, GeoGebra maybe is a new thing to student or teacher. Some users may find it challenging to learn how to effectively use the software, which could hinder its potential benefits. It is also need more time consume to learn GeoGebra works and mathematics concept itself.

The result can be a reference for other researchers in obtaining new research ideas, especially for researchers who will research GeoGebra in mathematics learning. GeoGebra is a flexible application so researchers can apply this application to various learning models or methods. The use of GeoGebra to develop collaboration skills is still very lacking, so this is an opportunity for other researchers to develop it.

Conclusion

Based on the results and previous discussion, it can be concluded that by using GeoGebra as a mathematics learning medium you can improve 4C skills (Critical Thinking, Communication, Collaborative, Creativity) learners. GeoGebra is a learning media that is suitable for several mathematics subjects, for example geometry, algebra, statistics and calculus so that it can support learning objectives on these mathematics topics. Teachers can take advantage of the features available in GeoGebra by de-signing materials, examples, practice questions or assignments according to the indicators of each 4C skill they want to achieve. Learning using digital technology also makes learning interactive between students and teachers and students, learning be-comes more interesting, easy to understand and meaningful for students. So that the application of GeoGebra in mathematics learning is effective in improving 4C skills. This research has limitations, namely the selection of articles that are less varied and more than 50% of the articles are articles from Indonesia research, so it is recommended for other researchers who will research similar things to find other articles that are more varied and come from researchers outside Indonesia.

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