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SYSTEMATIC LITERATURE REVIEW: APPLICATION OF DYNAMIC GEOMETRY SOFTWARE TO IMPROVE MATHEMATICAL PROBLEM-SOLVING SKILLS

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ABSTRACT

This study aims to review the literature on applying dynamic geometry software to improve mathematical problem-solving skills. The research method used is Systematic Literature Review (SLR), which includes planning, implementation, and reporting. Searching for articles using the Publish or Perish tool in the Google Scholar database. There were 100 articles found at the initial stage, with 15 that met the inclusion and exclusion benchmarks. The results of this study show that: 1). The Asian continent is the most widely used location in the application of dynamic geometry software, 2) Secondary school education level dominates research exposure, 3) Geogebra is the most widely used software in the application of dynamic geometry software to improve mathematical problem-solving, 4) The application of dynamic geometry software is dominated by Schoenfield's problem-solving theory where the use of software can meet five stages of problem-solving Schoenfield, i.e., reading, analysis, exploration, planning, implementation, and verification.

Keywords: Systematic Literature Review, Dynamic Geometry Software, Mathematical Problem Solving Skills

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PRELIMINARY

In the last decade, many schools from several developed and developing countries have used information technology to improve and support learning and teaching systems. Indeed, learning objectives can be achieved with the support of technology in it (Koyuncu et al., 2015; Mthethwa et al., 2020). Technology plays a role in the teaching and learning of mathematics where its presence in various variants, one of which is in the form of software for different graphic data, computer algebra systems, programming languages, and dynamic geometry software (DGS) (Koyuncu et al., 2015; Segal et al., 2016). The use of technology in learning provides many benefits, including teachers getting the opportunity to improve the quality of the learning process (Haron et al., 2021); teachers can also increase their creativity in teaching and learning activities (Marsigit et al., 2020).

The importance of using technology in learning is motivated by the many students who perceive learning mathematics as complicated and tedious (Maharjan et al., 2022). Therefore, the involvement of technology in a learning process is needed to increase the output of an educational process. Technological intervention is essential in solving problems, especially in mathematics. One of the various software that facilitates student learning in mathematical problem-solving activities is dynamic geometry software (Fung & Poon, 2021).

It can be known, currently, problem-solving is still a crucial issue in the world of education. Various international surveys show that students' mathematical problem-solving ability is still low, one of which is in Indonesia (OECD, 2019). Indonesia is ranked 46 out of 51 countries in TIMSS and 74th out of 79th in PISA (Fenanlampir et al., 2019; Mullis et al., 2016; OECD, 2019). The exposure is also supported by the fact that the results of the mathematical problem-solving competency test of students are still low in one of the private schools in Surabaya at the elementary, junior high, and high school levels, where the data exposure is stated in Figure 1:

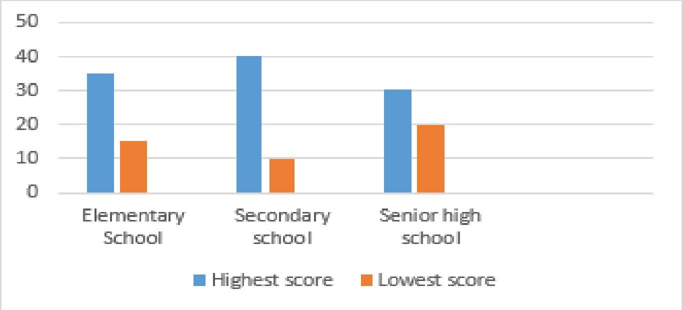

Figure 1. Results of Students' Mathematical Problem-Solving Competency Test

Based on the results of the student's mathematical problem-solving competency test, it was found that the highest scores of students at the elementary, junior high, and high school levels were still in the low category, which was ideally based on the completion target of Indonesian students (Hidayati, 2020), The minimum completeness criteria for mathematics subjects at the elementary, junior high and high school levels is 75 out of a maximum of 100 which is the ideal completeness criterion. In addition, many studies state that students' mathematical problem-solving skills are still low (Zulkarnain, Hutkemri Zulnaidi, Susda Heleni, 2021; Ratnaningsih & Firmansyah, 2018, Hidayat et al., 2018). Soft student skills in solving mathematical problems cause students to be unable to solve various problems (Karimah et al., 2018; Ratna et al., 2020). As for these difficulties, according to exposure (Supandi et al., 2021) is that students are less able to use strategies correctly and are not creative in solving problems. This happens because students are not used to solving problems through actual stages.

In global studies, problem-solving is a mathematical standard focusing on conceptual understanding (Drijvers et al., 2010; Lindquist & Gates, 2020). The use of problem-solving context is more widely used in solving non-routine problems (Temur, 2012) and complex issues (Grei & Fischer, 2013), and the troubleshooter doesn't know how the previous schema was (A. H. Schoenfeld, 2016). Problem-solving is an activity that associates various kinds of efforts or actions with the mind, including accessing and utilizing experience and knowledge (Lerman, 2020). Problem-solving involves learners thinking systematically (Pier et al., 2019) and thinking mathematically (Rott et al., 2021; Susanto et al., 2022). Problem-solving is an essential skill students possess in life (Hidayat et al., 2018). It has also become the most crucial part and focus of the curriculum in various countries such as Indonesia (Sari et al., 2019), French (Houdement & Artigue, 2007), Australia (Clarke et al., 2007), Netherlands (Doorman et al., 2007), China (Cai & Nie, 2007), Hungaria (Szendrei, 2007), England (Burkhardt & Bell, 2007), dan United States (A. Schoenfeld, 2007).

For the explanation above, teachers need to be aware of the mistakes and difficulties that students have to foster a solution in improving problem-solving skills, especially in mathematics learning. Kokol-Voljc 2007 (Koyuncu et al., 2015) states that Dynamic Geometry Software is the right tool for solving problems, especially in geometry studies. The dynamic geometry software application uses four software including Geogebra, Cabri, SketchUp, and SketchPad, which focus on visualizing mathematical concepts in learning (Dahal & Pant, 2019). Currently, there have been many studies that explain the use of dynamic geometry software and its relationship to students' mathematical problem-solving abilities, which are contained in various studies such as research (Fung & Poon, 2020; Gabr, 2015; Hayati, 2013; Koyuncu et al., 2015; Oner, 2013; Rico et al., 2023; Yao, 2020), etc. but no one has yet conducted a comprehensive review of the study. Therefore, it can be stated that the purpose of this study is to describe the results of previous research related to the application of dynamic geometry software in improving mathematical problem-solving. Based on the findings on this background, it can be stated that the urgency in this study benefits further researchers and educators in improving mathematical problem-solving through dynamic geometry software in the form of a systematic literature review.

METHODS

The research method used in this study is a systematic literature review (SLR) which focuses on the stages of planning, implementing, and reporting research results in previous research to answer predetermined research questions (Kitchenham & Charters, 2007). This study used a qualitative descriptive analysis approach to systematically review the application of dynamic geometry software and mathematical problem-solving. The data collection tool in this study used Publish or Perish. In line with the research objectives, publish or perish helps researchers answer research questions determined and stated in Table 1. Furthermore, this study's systematic literature review elaborates comprehensively on applying dynamic geometry software and mathematical problem-solving. Based on the research question, the application dynamic geometry software in question is a type of software in research on the application of dynamic geometry software. While the mathematical problem-solving in question is, the theoretical framework dominates the research. The study review also examines most locations in research on applying dynamic geometry software to improve mathematical problem-solving skills and education level in research on using dynamic geometry software to improve mathematical problem-solving skills. Thus, it can be stated that the components described in this study include the location of the study, the level of education, the type of software, and what kind of theoretical framework for problem-solving is used. Furthermore, the study used SLR guidelines presented by Kitchenham and Charters (Kitchenham & Charters, 2007). Based on these guidelines, SLR is divided into three stages: planning, implementation, and reporting. The SLR systemization in this study follows the SLR systemization proposed by (Schön et al., 2017).

1. Planning Stage

Publish or Perish assists the process of searching the literature. This software can analyze and take academic citations from various sources to obtain raw data that can be interpreted into useful information (Lee, 2012). As for the research questions, they are made in line with the needs of the research topic that has been chosen. The research question can be known in Table 1 below.

Table 1. Research Questions

No	Questions
1	What is the most research location in applying dynamic geometry software to improve mathematical problem-solving skills?

No	Questions
2	What are the dominating levels of education in research on applying dynamic geometry software to improve mathematical problem-solving skills?
3	What are the most widely used types of software in research on applying dynamic geometry software to improve mathematical problem-solving skills?
4	How does the theoretical framework dominate the research on applying dynamic geometry software to improve mathematical problem-solving skills?

2. Implementation Stage

To answer the research questions that have been set, researchers use the keywords "Dynamic Geometry Software, Mathematics Problem Solving" in the Google Scholar database. Researchers apply several benchma

rks for inclusion and exclusion in selecting articles described in Table 2.

Table 2. Inclusion and Exclusion Benchmarks

Benchmarks	Description
Inclusion	The articles used are related to dynamic geometry software and mathematical problem-solving capabilities. Articles published in the period 2013-2023 Articles in the English Language Articles indexed by Google Scholar
Exclusion	Related or unrelated articles about dynamic geometry software to improve mathematical problem-solving skills

The first step is to select articles according to titles related to the research topic, where each title should not be duplicated. Second, continue to conduct abstract analysis on each paper chosen to determine whether the article is relevant or less relevant. Meanwhile, relevant and less suitable articles will be continued at the analysis stage, while those irrelevant will fall or not continue at the extraction stage. After conducting the extraction stage to get relevant articles and according to the selected criteria, researchers obtained 15 reports from 100 articles published in international journals Google Scholar database on publish or perish. Data analysis is done descriptively. Exposure to the results of article extraction can be seen in Table 3, which states the location of research, level of education, type of software, and theoretical framework used. In this study, SLR was carried out on several articles in the publication period between 2013-2023.

3. Reporting stage

The reporting process consists of data extraction and discussion activities, report presentation, and report evaluation. For discussion and presentation of the report will be discussed in the results and discussion section, and the assessment of the information will be addressed in the conclusion section.

RESULT AND DISCUSSION

1. Planning Stage

Searching for articles based on keywords in the Google Scholar database assisted by Publish or Perish obtained 100 articles. Based on this number, several articles are not relevant to the purpose of the research. For this reason, a data screening process is carried out according to the research objectives. The stages of data screening results can be seen in Figure 2.

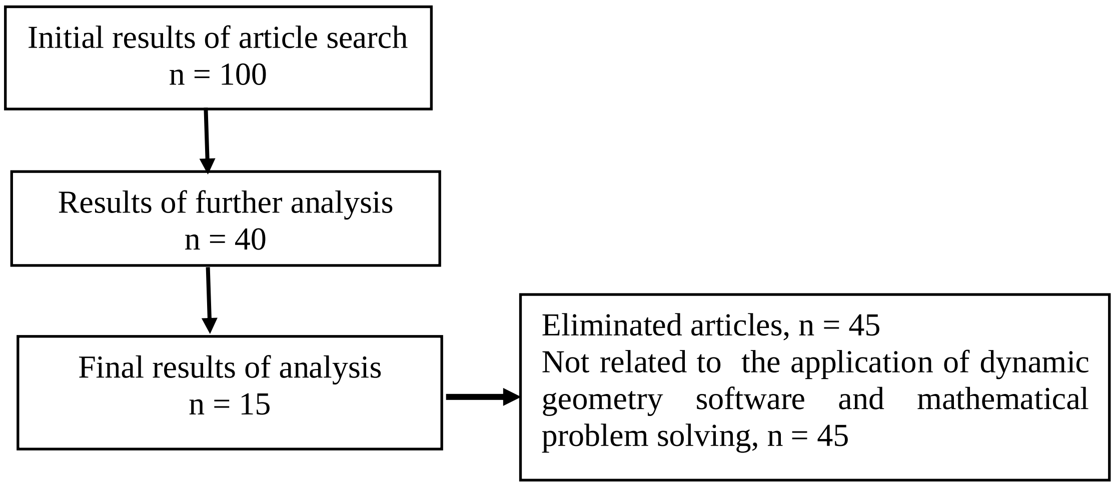

Figure 2. Stages of Data Screening Results

Based on Figure 2, it can be seen that the initial results of the article search were obtained with a total of 100 articles; then, in the final results of the analysis obtained, selected relevant articles of 15 articles. The article's exposure is tabulated systematically and according to the established method. The exposure to the following screening results is based on a review of research questions that have been determined, including: (1) What is the most location in research on applying dynamic geometry software to improve mathematical problem-solving skills?; (2) What are the dominating levels of education in research on applying dynamic geometry software to improve mathematical problem-solving skills?; (3) What are the most widely used types of software in research on applying dynamic geometry software to improve mathematical problem-solving skills?; and (4) How does the theoretical framework dominate the research on using dynamic geometry software to improve mathematical problem-solving skills?

2. Implementation stage

As for this stage, the results of extracting selected relevant articles are presented based on the data screening carried out at the planning stage. The presentation of extracted results is presented in Table 3 as follows:

Table 3. Extraction results of selected relevant articles

Country & Continents	Education Level	Software	Theoretical Framework (Name of expert theory and steps)	Code Data
Portugal & Europe	Secondary school	GeoGebra	Schoenfield (1. Reading, 2. Analysis, 3. Exploration, 4. Planning, and Implementation, 5. Verification)	R01 (Jacinto & Carreira, 2017)
Spain & Europe	College	GeoGebra	Schoenfield (1. Reading, 2. Analysis, 3. Exploration, 4. Planning, and Implementation, 5. Verification)	R02 & (Hernández et al., 2020)
Sweden & Europe	Secondary school	GeoGebra	Schoenfield (1. Reading, 2. Analysis, 3. Eksploration, 4. Implementation, 5. Verification)	R03 & (Granberg, 2016)
Turkey & Asia	College	GeoGebra	Blum (1. Understanding the problem, 2. Looking for math, 3. Using math, 4. Explain the result)	R04 & (Koyuncu et al., 2015)
India & Asia	Secondary school	GeoGebra	Polya (1. Understanding, 2. Planning, 3. Implementing, 4. Looking back)	R05 & (Bhagat & Chang, 2015)
Malaysia & Asia	Secondary school	GeoGebra	Vygotsky (1. Self-exploration, 2. Social Interaction, 3. Visualization, 4. Understanding)	R06 & (Praveen & Leong, 2013)
Vietnam & Asia	Secondary school	GeoGebra	Polya (1. Understanding, 2. Planning, 3. Implementing, 4. Looking back)	R07 & (Tran et al., 2014)
Sweden & Europe	Secondary school	GeoGebra	Schoenfield (1. Reading, 2. Analysis, 3. Eksploration, 4. Implementation, 5. Verification)	R08 & (Olsson, 2017)
Nepal & Asia	Secondary school	GeoGebra	Vygotsky (1. Self-exploration, 2. Social Interaction, 3. Visualization, 4. Understanding)	R09 & (Dahal & Pant, 2019)
Not mentioned	College	GeoGebra	Polya (1. Understanding, 2. Planning, 3. Implementing, 4. Looking back)	R10 & (Daher & Anabousy, 2020)
Indonesia & Asia	College	GeoGebra	Ekstig (Computer Based Problem Solving: 1. Construct, 2. Investigate, 3. Represent, 4. Implementation)	R11 & (Yurniwati & Soleh, 2020)
Indonesia & Asia	Secondary School	GeoGebra	Polya (1. Understanding, 2. Planning, 3. Implementing, 4. Looking back)	R12 & (Nursasongko et al., 2020)

Country & Continents	Education Level	Software	Theoretical Framework (Name of expert theory and steps)	Code Data
America & America	College	Geometer's Sketchpad (GSP)	Schoenfield (1. Reading, 2. Analysis, 3. Eksploration, 4. Implementation, 5. Verification)	R13 & (Kuzle, 2013)
Indonesia & Asia	Secondary School	GeoGebra	Crawford (1. Relating, 2. Experiencing, 3. Applying, 4. Cooperating, 5. Transferring)	R14 & (Jelatu, 2018)
Vietnam & Asia	Secondary School	GeoGebra	Bruner (1. Evaluate, 2. Consider, 3. Analyze, 4. Synthesize)	R15 & (Tran et al., 2014)

3. Reporting stage

1) The Most Locations in Research on The Application of Dynamic Geometry Software

Dynamic geometry software has been widely used in various countries in the world. However, some countries are not as fast as others in implementing it. In this case, researchers need to know the origin of the continent; that is the object of research. The exposure of the object of research is located in Table 3, where it can be known there is one article, namely R10, which does not state the continent where the study is. While the European continent has four articles (R01, R02, R03, R08), the Asian continent has nine articles (R04, R05, R06, R07, R09, R11, R12, R14, R15), and the American continent has one article (R13). Following the research (Fenanlampir et al., 2019) stated that developing countries, especially those in the Asian region, still have a low ability to solve problems, so many researchers are trying to overcome these problems with the application of technology to overcome them and in this case is the application of dynamic geometry software. Therefore, this study recommends other researchers apply dynamic geometry software to improve mathematical problem-solving. Figure 3 shows the percentage of locations where the most dynamic geometry software applications are applied. The Asian continent obtained the highest percentage, reaching 60%.

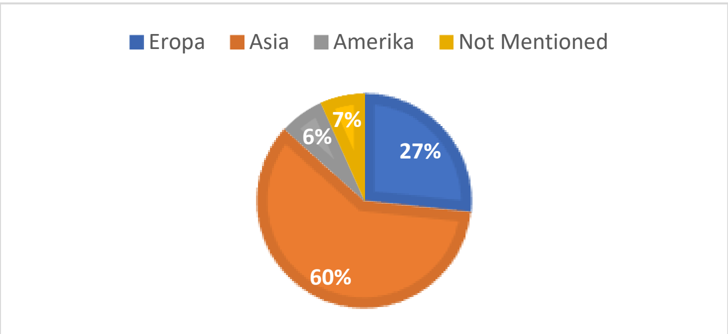

Figure 3. Percentage of Locations with The Most Applications Of Dynamic Geometry Software

2) Education Level in Research on The Application of Dynamic Geometry Software

In this study, it appears that the application of dynamic geometry software is spread at various levels of education, two of which are high school and college. Based on fifteen articles extracted, as many as ten articles (R01, R03, R05, R06, R07, R08, R09, R12, R14, R15) conducted research at the secondary school level and continued as many as five articles (R02, R04, R10, R11, R13) conducted research at the university level. In this study, the secondary school education level dominated the exposure to the study. It can be stated that there are still many mathematical problem-solving problems for students at the high school level. Therefore, this study recommends that other researchers review problem-solving skills at the primary level, the first stage in the education cycle. Meanwhile, figure 4 states the percentage of the level of education of the article in research on the application of dynamic geometry software. It can be seen that the secondary school education level obtained the highest percentage, reaching 67%.

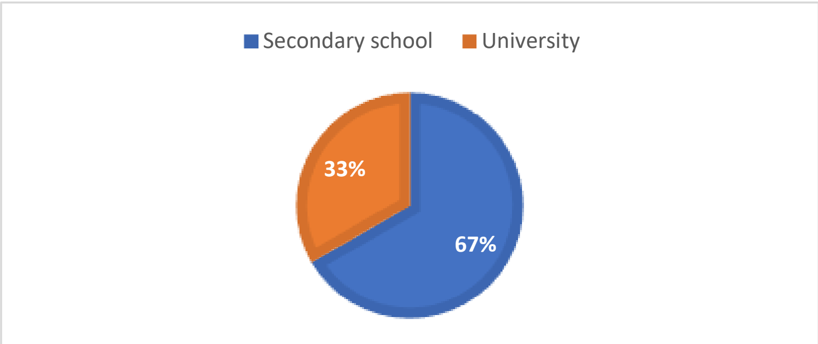

Figure 4. Percentage of the Education Level of Application of Dynamic Geometry Software

3) Types of Software in Research on The Application of Dynamic Geometry Software

Various studies have widely described the application of dynamic geometry software to learning. It can be known the application of dynamic geometry software consists of the use of geometry software such as Geogebra, Cabri, SketchUp, SketchPad, etc., which focuses on visualizing mathematical concepts in learning (Dahal & Pant, 2019). The results of the study were obtained: a) 14 articles (R01, R02, R03, R04, R05, R06, R07, R08, R09, R10, R11, R12, R14, R15) which used the application of dynamic geometry software in the form of geogebra and b) 1 article (R13) which used the application of dynamic geometry software in the form of geometer's sketchpad. In this study, the geogebra software type dominated the research exposure. Therefore, this exposure provides recommendations for other researchers in various regions to choose geogebra as software for improving mathematical problem-solving. Meanwhile, figure 5 states the percentage of use of multiple types of software based on articles obtained in research on the application of dynamic geometry software. It can be seen that Geogebra software received the highest percentage of applications, reaching 93%.

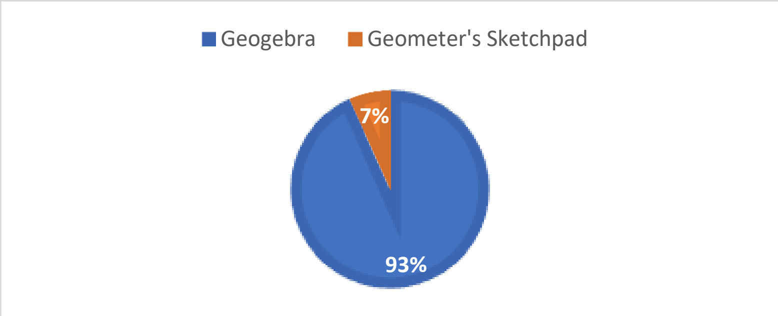

Figure 5. Percentage of Software Types in The Application of Dynamic Geometry Software

4) Theoretical Framework in Research on The Application Of Dynamic Geometry Software

Based on the extraction results, it was found that the application of dynamic geometry software includes many kinds of problem-solving theories that are used to improve students' mathematical problem-solving. As for this study, it can be found that the application of dynamic geometry software can enhance mathematical problem solving based on theory and several stages of expert exposure, including a) Schoenfield (1. Reading, 2. Analysis, 3. Exploration, 4. Planning and Implementation, 5. Verification) with exposure to five articles (R01, R02, R03, R08, R13), b) Polya (1. Understanding, 2. Planning, 3. Implementing, 4. Looking back) with exposure to four articles (R05, R07, R10, R12), c) Vygotsky (1. Self-exploration, 2. Social Interaction, 3. Visualization, 4. Understanding) with exposure as many as two articles (R06, R09), d) Ekstig (Computer Based Problem Solving: 1. Construct, 2. Investigate, 3. Represent, 4. Implementation) with exposure as much as one article (R11), e) Crawford (1. Relating, 2. Experiencing, 3. Applying, 4. Cooperating, 5. Transferring) with exposure to one article (R14), and f) Bruner (1. Evaluate, 2. Consider, 3. Analyze, 4. Synthesize) with exposure of one article (R15). It can be stated that the theoretical framework based on Schoenfield dominates in research, so this presentation provides recommendations so that other researchers can make Schoenfield's problem-solving theory the primary theoretical basis for improving students' subsequent mathematical problem-solving. In this study, applying dynamic geometry software to Schoenfield's theory fulfilled the five stages of Schoenfield's problem-solving approach: reading, analysis, exploration, planning, implementation, and verification. Meanwhile, figure 6 states the percentage of theoretical frameworks based on experts on problem-solving theory in research on the application of dynamic geometry software. It can be seen that Schoenfield's theoretical framework obtained the highest percentage reaching 33%.

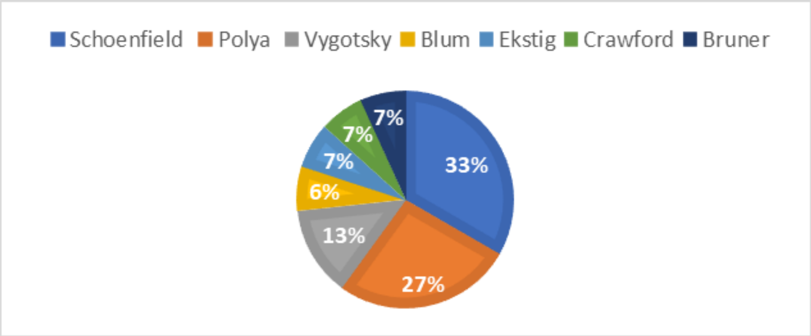

Figure 6. Percentage of a Theoretical Framework Based on Experts

CONCLUSION

Based on the presentation of the results and discussion, the results of this study show that: 1. The Asian continent dominates the location of the most applications of dynamic geometry software; 2. High school education dominates research exposure; 3. Geogebra is the most widely used software in applying dynamic geometry software as a tool that can improve students' mathematical problem-solving, 4. The application of dynamic geometry software is dominated by Schoenfield's problem-solving theory, where the software can fulfill Schoenfield's five stages of problem-solving: reading, analysis, exploration, planning, implementation, and verification.

Based on the results of this analysis, it can be stated that applying dynamic geometry software in education has an important relationship with students' problem-solving abilities. In this study, the urgency of using dynamic geometry software to improve mathematical problem-solving skills is recommended to be further expanded to regions or continents that have not become dominant and have not applied dynamic geometry software to improve mathematical problem-solving skills, including the European continent, the American continent, the African continent, the Australian continent, and the Antarctic continent. In addition, it can be stated that the level of secondary school education is the level that is the most objective in the presentation of this study. This means many mathematical problem-solving problems are still at the high school level.

Therefore, this study recommends other researchers apply dynamic geometry software at the secondary school level to improve students' mathematical problem-solving. Furthermore, applying dynamic geometry software as a geogebra application is recommended as software that can be chosen to assist educators in improving students' mathematical problem-solving skills. As for this study, it can be seen that Schoenfield's theory became the most dominant theory used in previous studies. Therefore, in the results of this research extraction, it is also explained that the use of geogebra software as a tool in improving the ability to solve dominant mathematical problems using Schoenfield's theory and being able to pass five stages of problem-solving in view so, for further research, it is recommended to combine the use of geogebra software with Schoenfield's problem-solving theory for a deeper review of students' mathematical problem-solving.

The implication that can be stated in this finding is that dynamic geometry software can be combined in tandem with problem-solving theory to improve students' mathematical problem-solving abilities. This research can also provide input to educators to use geogebra software to enhance students' mathematical problem-solving in learning. The limitation of this study is that it only discusses the literature review of the application of the dominant dynamic geometry software without a specific assessment of the application of the software found. It is expected that for further research, there will be a deeper study of the findings in this study, especially the application of geogebra to improve mathematical problem-solving in meta-analysis research studies.

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