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The Effect of Geogebra-Assisted Problem Solving on Mathematical Thinking Ability Reviewed from Self Efficacy

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Abstract

Mathematical thinking is the ability to identify real-world phenomena in order to provide practical solutions to the problems under study. Previous research has aimed to analyze students' mathematical thinking abilities in relation to their levels of self-efficacy. This study aims to investigate the impact of the Geogebra-assisted Problem Solving (PS) Learning Model on the mathematical thinking skills of elementary school students. An experimental method with a posttest-only control group design was used, employing Cluster Random Sampling to select a sample of 100 students. The research instrument consisted of a mathematical thinking ability test, which was analyzed using a two-way ANOVA with Jamovi software. The ANOVA results showed a significant difference in mathematical thinking ability between the experimental group and the control group. The findings indicate that the Geogebra-assisted Problem Solving model significantly improves the mathematical thinking ability of elementary school students, proving to be more effective than the expository model.

Keywords: ***Problem Solving; mathematical thinking, self efficacy***

INTRODUCTION

The role of mathematics is increasingly important in the modern era along with the rapid development of technology. Mathematics is not merely a collection of formulas and calculations, but also involves understanding concepts, logical thinking, and problem-solving skills which are

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important for students' intellectual development (Wiryana & Alim, 2023). In line with Isoda and Katagiri (2012) that mathematics is also an important subject for innovation, as it develops creative and critical thinking in general, as well as mathematical and statistical thinking in specific situations. Mathematics is not merely calculation, but also a science that studies structure, relationships, patterns, and abstractions. This idea is also in line with the principles of The National Council of Teachers of Mathematics (NCTM, 2000) which underlines the goal for students learning mathematics, namely to develop and improve understanding of mathematical concepts and connections when constructing, comparing, and applying various representations.

This is also affirmed in one of the goals of the Learning Outcomes at the Basic Education Level (2025) of the Ministry of Education and Culture, namely solving problems which includes the ability to understand problems, design mathematical models, solve models or interpret the solutions obtained (mathematical problem solving) which links learning materials in the form of facts with life. Based on the goals to be achieved, there are five abilities that students must have in mathematics learning, namely mathematical problem solving, mathematical reasoning, mathematical communication, mathematical connections, and mathematical representation (NCTM, 2000). Uyangör (2019) also states that the combination of estimation, induction, deduction, generalization, analogy, reasoning, confirmation, and complex processes are included in mathematical thinking ability. This mathematical thinking ability has an important role for students in their lives, both in the classroom and in daily life (Saefuloh et al., 2023).

Several experts argue that mathematical thinking is implicitly very important for understanding, problem solving, and their daily lives. In line with Schoenfeld who states that thinking about mathematics is a pervasive ability, not only limited to mathematical skills, but also includes how a person views their work and the world as a whole (Saefuloh et al., 2023). When viewed from another side, Stacey (2006) states that mathematical thinking as an ability needed by a teacher in managing their class will also affect the students' mathematical thinking ability. Mason et al., (2010) identified four abilities in mathematical thinking, namely identifying problems (specialization), predicting (generalization), reflecting on ideas (conjecture), and convincing. This mathematical thinking ability becomes the foundation for students in acquiring mathematical knowledge through the implementation of learning models applied by teachers in the classroom.

However, many students still find it difficult to develop their mathematical thinking abilities. Like the research conducted by Triyono and Murdiasih (2023) their research findings show that students' initial competence is still low so it requires intervention, this indicates the learning method has not been optimal in developing students' mathematical thinking. Besides

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that, students also experience difficulties linking mathematical concepts with real situations Tang et al. (2020). This indicates the need for learning that emphasizes reasoning, exploration, and systematic problem solving to develop mathematical thinking abilities.

There are several studies that have examined efforts to improve students' mathematical thinking abilities through various learning models and learning media. Kamarulzaman et al., (2022) have researched the improvement of mathematical thinking ability with differentiated instruction (DI). The findings are that DI is effective in improving the mathematical thinking of gifted students. Different from the research to be conducted, namely the learning model carried out, the use of GeoGebra media as a facility that can help in improving mathematical thinking ability. Furthermore, these findings were obtained using surveys and regression analysis, different from what will be done with experiments.

In addition, several other studies also examine the effect of learning models and media on the mathematical thinking abilities of elementary school students. This study aims to fill that gap through the application of the Geogebra-assisted Problem Solving model to measure computational thinking ability by paying attention to the affective aspect, namely self-efficacy. Different from previous research which tends to use problem based learning, this study collaborates the systematic and creative Problem Solving model to help students formulate problems mathematically and produce effective solutions through algorithm design.

The Problem Solving (PS) learning model is basically a process or system used to approach problems both imaginatively and realistically to produce effective solutions. The main goal of Problem Solving is to help students develop systematic thinking skills, reasoning, and train students in the analytical and reflective thinking process (Krulik & Rudnick, 1987; Polya, 1957). In its application, the use of Geogebra facilitates students in understanding concepts, solving mathematical problems, and clarifying the meaning of a concept through visual display Handayani et al. (2022).

This study not only measures mathematical thinking ability, but also by looking at its affective side. One of the affective domains needed by students is self-efficacy. Bandura (1997) defines self-efficacy as a multidimensional construct related to individuals' beliefs that they can complete tasks or challenges in the future. Self-efficacy in mathematics is the belief in the ability to present and solve mathematical problems, the way of learning or working in understanding concepts and completing tasks (Mahmudah & Hermanto, 2024). Research by Abidin et al., (2024) shows that differences in self-efficacy levels also determine variations in students' mathematical thinking abilities, because self-efficacy affects learning success and therefore it is very important

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for learning (Roick & Ringeisen, 2018). Mathematics self-efficacy is closely related to students' mathematics achievement, this is influential in daily life because mathematics is very beneficial in life.

Referring to the description above, this research will focus on a study regarding how to support mathematical thinking abilities in elementary school students using the Geogebra-assisted Problem Solving model reviewed from students' self-efficacy. The results of this study are expected to be a reference for educators to determine the effectiveness of this Geogebra-assisted Problem Solving model on students' mathematical thinking abilities and looking from the aspect of students' self-efficacy. Therefore, this study was conducted with the title "How to Support the Mathematical Thinking Ability of Elementary School Students Using the Geogebra-Assisted Problem Solving Learning Model Reviewed from Self-Efficacy?".

RESEARCH METHODOLOGY

This study uses an experimental method. Experimental research identifies independent, dependent, and confounding variables and demonstrates how randomization and statistical aspects of the experiment should be conducted. The main goal of an experimental design is to establish a cause-and-effect relationship between independent and dependent variables (Miller et al., 2020; Roger et al., 2009). Based on the view of Creswell (2023) emphasizing the importance of controlled treatments to test effects quantitatively, and in line with Campbell and Stanley (1963) who assert that experiments involve administering treatment to an experimental group and comparing it with a control group. The experimental design used is a posttest-only control group design, the research sample is selected randomly after which testing following pretreatment is likely unnecessary when randomization is used and a large number of students and/or teachers are involved (Gribbons & Herman, 1997; Shadish & Cook, 2002). This study is arranged in a 2x2 factorial structure to test the effect of learning models, self-efficacy, and the interaction of both on mathematical thinking ability. This design structure can be explained through the following table:

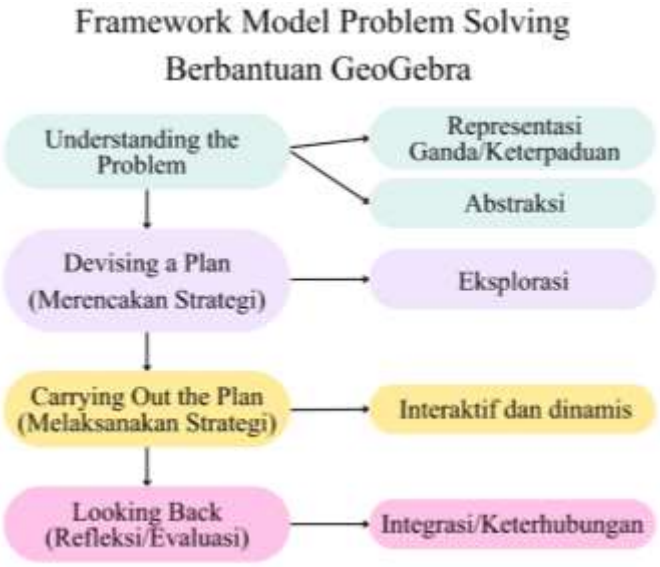
Table 1. 2x2 Factorial Research Design

Self Efficacy (B)	Geogebra-Assisted Problem Solving Model (A1)	Expository Model (A2)
Low (B1)	A1B1	A2B1
High (B2)	A1B2	A2B2

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The sample was selected using the purposive sampling method from elementary schools, East Jakarta. The population consisted of fifth-grade students at SDN Jatinegara 03 and SDN Jatinegara 05. The purposive sampling method was used to select specific classes (A, B, and C) that are representative of the student population in terms of academic achievement and demographics. This method ensures that the sample accurately reflects the population's characteristics and allows for targeted assessment of the intervention's effectiveness. The implementation of the Geogebra-assisted Problem Solving Learning Model in this study uses four learning stages described in the Figure below:

Figure 1. Framework of Geogebra-assisted Problem Solving Model



The following is the framework for Geogebra-assisted problem solving learning; Figure 1 Framework of Geogebra-assisted Problem Solving Model

Based on the figure, this learning framework applying the Geogebra-assisted problem solving model is built by linking the problem solving syntax with the characteristics of GeoGebra with an explanation of each point as follows, namely: In the initial stage, students are directed to identify, read, and understand the problem context thoroughly. GeoGebra integration helps students visualize mathematical objects or situations that are difficult to understand solely through text. GeoGebra provides strong support through multiple representations/integration, namely the ability to display information in graphical, geometrical, tabular, and algebraic forms

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simultaneously. This multiple representation makes the initial stage of problem understanding more accurate, especially for problems involving shapes, patterns, positions, or functions. Besides representation, the problem understanding stage also emphasizes the characteristic of GeoGebra namely abstraction, which is the process of filtering important information and eliminating irrelevant parts. Abstraction helps students realize the mathematical essence of the problem before determining a resolution plan.

At the plan devising stage, the exploration feature in GeoGebra becomes the most dominant element. Exploration allows students to try various possibilities quickly, such as shifting points, changing parameters, or displaying alternative equations. Furthermore observing the patterns that emerge when objects are moved dynamically. Developing several strategy options, such as whether it is more effective to use graphical, geometrical, or algebraic approaches. Developing conjectures (initial guesses) before confirming a strategy. Thus the GeoGebra exploration characteristic makes the strategy planning stage more creative, flexible, and investigative.

Next, when a strategy has been selected, students carry it out with the help of GeoGebra's interactive and dynamic features. At this stage, GeoGebra helps students, following strategy steps with direct object operation (drag, slider, input, construction), seeing instant reactions from every change, so errors are found quickly, observing visual feedback on the solution being executed, increasing accuracy because GeoGebra automatically calculates, constructs lines, determines intersection points, and executes other computations. The interactivity and dynamics of this tool make the resolution process more directed and efficient.

At the final stage in Polya's model is looking back at the solution. GeoGebra strengthens this stage through integration/connection, namely the ability to understand how various concepts are connected to each other. With GeoGebra, students can; re-examine the solution by shifting parameters or changing conditions, assess whether the relationship between mathematical elements is consistent, look back at the connection between images, formulas, and numerical values to ensure a logical solution. Integration/connection helps students not only check the correctness of the answer, but also understand the mathematical reasons behind the solution.

Data and Data Sources

The research instrument used is a mathematical thinking ability test in the form of essay questions. There are eight essay questions covering the concepts of area and perimeter of two-dimensional figures. This test is designed to evaluate mathematical thinking skills. This test is given

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after treatment to both groups, both the experimental group and the control group, without differences, and the test construction is based on mathematical thinking ability indicators which include; 1) identifying problems (specialization), 2) predicting (generalization), 3) reflecting on ideas/notions (conjecture), 4) convincing, and 5) justifying. Before the test questions are given, validity and reliability were tested by experts in the field of mathematics.

Data Collection Techniques

The validity test results showed that the mathematical thinking problems were declared feasible and could be used in research, then a trial was conducted on grade V students who had studied the area of two-dimensional figures material to determine the difficulty index. After the question trial, eight questions were declared valid with a "medium" question difficulty category and a "sufficient" question discriminating power so that those eight questions were used because they had met the important requirements in experimental research. The quality of experimental research is considered in terms of its reliability and validity. Reliability refers to the extent to which measurements or experimental procedures lead to consistent interpretations of the constructs intended to be measured (Miller et al., 2020).

Data Analysis

Data analysis was obtained from the posttest results of students' mathematical connection ability after being given treatment. The posttest result data was then analyzed with Two-Way Analysis of Variance or abbreviated (ANOVA). ANOVA is used to test hypotheses stating differences in averages between sample groups both those using Two Factorial Design and Treatment by Level (Kadir, 2015).

RESEARCH RESULTS

The results in this study were obtained from the computational thinking ability test conducted on two groups: the experimental group (using the Geogebra-Assisted Problem Solving Learning Model) and the control group (using the expository model). The following is a description of the analysis of the test results:

Table 2 Descriptive Statistics Data

Learning Method	Self Efficacy	Mean	Std. Deviation
Geogebra-assisted Problem Solving	High	87.6	6.45

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	Low	68.2	9.01
Expository	High	68.2	10.8
	Low	77.1	5.95
Total	High	77.89	13.16
	Low	72.65	8.77

Table 2 above, it can be seen the average score of mathematical thinking ability of students who have high self-efficacy in the experimental class which is 87.6 is better than students in the control class which is equal to 68.2. Before conducting hypothesis testing, data normality testing and homogeneity testing were performed. If the data is normally distributed, parametric statistical techniques can be used; Conversely, if the data is not normally distributed, nonparametric statistical techniques can be used. The initial step is to analyze data normality using the Kolmogorov-Smirnov test, the results of which are listed in Table 1.4 below.

Table 3 Normality Test Results

Data Type	**Learning Model**	**Self Efficacy**	**Statistic**	**Df**	**Sig.**	**H0**
Group	Geogebra-assisted Problem Solving	High	0.888	16	0.051	Accepted
		Low	0.948	16	0.464	Accepted
	Expository	High	0.899	16	0.077	Accepted
		Low	0.926	16	0.212	Accepted
Combined	Learning Model	Self Efficacy	0.110	64	0.426	Accepted

From Table 3, it was found that the normality test produced a significance value. This indicates that the data from both groups comes from a normally distributed population. The next step is to check whether both groups have homogeneous variances. The homogeneity test was performed using the Levene test. The homogeneity test results are in Table 1.5 below:

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Table 4 Homogeneity Test Results

Levene Statistic	df1	df2	Sig. Score	H0
2.62	3	60	0.059	Accepted

After the data was declared to fulfill the prerequisites, then a two-way Anova test was performed to determine the effect of the learning model, self-confidence, and the interaction between both on students' computational thinking ability. The following are the results of the two-way Anova test using Jamovi:

Table 5 Two-Way Anova Results

Source	Sum of Square	df	Mean Square	F	p
Overall Model	4080	3	1360.0	19.79	< 0.001
Model	436	1	435.9	6.35	0.014
Self Efficacy	438	1	438.2	6.38	0.014
Model*Self Efficacy	3206	1	3205.9	46.66	< 0.001
Residual	4122	60	68.7		

After obtaining the two-way Anova test results showing a significant difference, the analysis was continued with a post hoc test using the Tukey test. The Tukey test was conducted to determine which groups had a significant difference in average mathematical thinking ability. The following are the results of the Tukey test using Jamovi:

Table 6 Tukey Test Calculation Results

(I) POSHOC	(J) POSHOC	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1B1	A2B1	19.3750	2.93	< 0.001	1.511	3.163
A1B2	A2B2	-8.9354	2.93	0.017	-1.812	-0.344

The Tukey test results indicate that there is a significant difference between the A1B1 and A2B1 groups as well as between the A1B2 and A2B2 groups with significance values of <0.001 and 0.017. This indicates that the learning model and self-efficacy exert an influence on students'

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mathematical thinking ability.

The Effect of Geogebra-Assisted Problem Solving Learning Model on Mathematical Thinking Ability

The two-way ANOVA calculation results indicate an interaction between the learning model and self-efficacy on students' mathematical thinking ability. This means that the effect of the learning model on mathematical thinking ability does not apply equally to all students, but depends on the level of self-efficacy possessed. In other words, the effectiveness of the GeoGebra-assisted Problem Solving model as well as the Expository model is influenced by students' beliefs in their abilities in solving mathematical problems. This finding is in line with the Aptitude–Treatment Interaction (ATI) theory put forward by Snow (1991), which explains that the success of a learning model will be optimal if the learner's characteristics (aptitude) match the demands of the learning (treatment) provided. In this study, self-efficacy acts as an individual characteristic that determines how students respond to the GeoGebra-assisted Problem Solving model or the Expository model.

Students who have high self-efficacy acquire higher mathematical thinking abilities when learning using the GeoGebra-assisted Problem Solving model compared to the Expository model. This condition indicates that students with high self-belief are more prepared to follow learning that demands independent thinking activities, exploration, and reflection.

The success of students with high self-efficacy in the GeoGebra-assisted Problem Solving model is also influenced by the psychological characteristics they possess. According to Bandura (1997), individuals with high self-efficacy have the belief that they are able to complete challenging tasks so they are more persistent in facing difficulties, brave in trying various strategies, and do not easily give up when experiencing failure. These characteristics make students able to follow every stage of Problem Solving optimally without feeling burdened by the complexity of the problem given. This finding is in line with research by Mukhtar et al., (2021) stating that the use of GeoGebra in problem-solving-based learning can improve mathematical thinking ability and self-efficacy because students get the opportunity to independently explore concepts, test hypotheses, and verify settlement results.

Different from that condition, students who have low self-efficacy actually show relatively higher mathematical thinking abilities when learning using the Expository model compared to the GeoGebra-assisted Problem Solving model. These results indicate that students in that group are not entirely ready to follow learning that demands high independence in solving problems. In the

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GeoGebra-assisted Problem Solving model, students must understand problems, determine settlement strategies, operate GeoGebra, evaluate results, and draw conclusions independently. These demands require high self-belief so that students remain persevering when facing difficulties. However, students who have low self-efficacy tend to doubt their own abilities so they are more prone to experience confusion in determining settlement strategies, lack confidence in expressing mathematical reasons, and are reluctant to compare various alternative settlements. Consequently, mathematical thinking ability indicators have not optimally developed.

This finding is in line with the Cognitive Load Theory put forward by Sweller et al., (2007). This theory explains that learning which demands independent exploration, problem solving, and decision making can increase extraneous cognitive load if the students' learning readiness is inadequate. Under such conditions, students' working memory capacity is used more to understand learning procedures rather than building conceptual understanding. Consequently, students experience difficulties in developing mathematical thinking abilities, such as finding patterns, selecting the right strategy, or providing justification for the settlement performed. This explanation also states that learning with minimal guidance is less effective for students who do not yet have learning readiness or the ability to independently regulate their learning process. Therefore, problem-solving-based learning requires students' internal readiness so that its benefits can be optimally acquired.

Conversely, the Expository model provides relatively better results for students who have low self-efficacy because the teacher provides concept explanations gradually, presents clear settlement examples, and guides students through structured exercises. This condition helps students understand basic concepts before being faced with more complex problems. This is in accordance with Vygotsky's theory (Noviyanti & Purwandari, 2025) which emphasizes the importance of scaffolding, namely the assistance provided by the teacher to students until they are able to complete tasks independently. Such systematic guidance reduces students' doubts regarding their abilities, so they can focus more on understanding concepts rather than thinking about various alternative settlement strategies. Thus, Expository learning provides support that conforms to the needs of students who still have low self-efficacy.

Based on these results it can be concluded that the effectiveness of learning models is influenced by students' self-efficacy levels. The GeoGebra-assisted Problem Solving model is more effectively applied to students who have high self-efficacy because it is able to facilitate the development of mathematical thinking ability indicators through exploration, reasoning, reflection, and solution verification activities. Conversely, the Expository model is more

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appropriately applied to students who have low self-efficacy because it provides a clearer learning structure, reduces cognitive load, and provides the scaffolding needed by students. Therefore, teachers should consider students' self-efficacy levels in determining the learning model so that the development of mathematical thinking ability can take place more optimally.

CONCLUSION

Based on the analysis and discussion, it can be concluded that the mathematical thinking ability of students who learn through the GeoGebra-assisted Problem Solving model is higher compared to students who learn through the Expository model. The GeoGebra-assisted Problem Solving model provides an opportunity for students to understand problems, explore various settlement strategies, visualize mathematical concepts dynamically, and evaluate the solutions obtained so that each mathematical thinking ability indicator develops more optimally. Conversely, Expository learning is more teacher-centered so that students' opportunities to independently develop mathematical thinking abilities become more limited.

Research findings also show an interaction between the learning model and self-efficacy on students' mathematical thinking ability. The GeoGebra-assisted Problem Solving model is proven more effectively applied to students who have high self-efficacy because it is able to facilitate exploration, reasoning, and reflection activities optimally. Conversely, students with low self-efficacy show better mathematical thinking ability development when learning using the Expository model which provides guidance and a clearer learning structure.

The application of the GeoGebra-assisted Problem Solving model also provides opportunities for students to develop various mathematical thinking ability indicators, such as making conjectures, finding patterns, selecting the right settlement strategy, providing mathematical reasons, and comparing various alternative settlements. The interactive visualization provided by GeoGebra helps students understand abstract mathematical concepts to become more concrete so that the process of exploration, proving, and reflection can take place more effectively. Thus, students not only master settlement procedures, but also understand the concepts and reasons underlying each problem-solving step.

This study has limitations in terms of generalization because it was conducted in a limited context and sample. Therefore, future research is advised to involve a broader and more diverse sample and examine the long-term effect of applying the Geogebra-assisted Problem Solving model on mathematical thinking abilities as well as other abilities. In addition, subsequent

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research can explore specific strategies to increase students' self-efficacy so that the effectiveness of the learning model can be felt evenly.

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