Implementation of Cognitive Learning Theory in Polya Learning to Improve Mathematical Problem Solving Ability

Siswanto*[1] and Yulaikah[2]

[1]Sekolah Tinggi Agama Islam Syubbanul Wathom Magelang
[2]Sekolah Dasar Negeri Treko 1 Magelang
*siswanto@staia-sw.or.id

Abstrak

Penelitian ini bertujuan untuk menguji efektivitas penerapan teori pembelajaran kognitif dalam pembelajaran Polya terhadap kemampuan pemecahan masalah matematika siswa di salah satu SMA di Magelang menggunakan desain penelitian eksperimen. Subjek penelitian adalah siswa kelas 10 yang dibagi menjadi kelompok eksperimen dan kelompok kontrol. Kelompok eksperimen menerima pembelajaran Polya dengan penerapan teori pembelajaran kognitif, sementara kelompok kontrol menerima pembelajaran Polya tanpa penerapan teori pembelajaran kognitif. Data dikumpulkan melalui tes dan observasi kelas. Hasil analisis data menggunakan software SPSS dengan teknik analisis statistik ANOVA menunjukkan bahwa terdapat perbedaan signifikan antara kelompok. Selain itu, hasil analisis menunjukkan bahwa terdapat peningkatan yang signifikan dalam kemampuan pemecahan masalah matematika siswa pada kelompok eksperimen setelah intervensi. Hasil analisis observasi kelas menunjukkan adanya peningkatan interaksi antara siswa dan guru serta penggunaan strategi metakognitif oleh siswa dalam kelompok eksperimen. Berdasarkan hasil penelitian, dapat disimpulkan bahwa penerapan teori pembelajaran kognitif dalam pembelajaran Polya secara signifikan meningkatkan kemampuan pemecahan masalah matematika siswa di SMA di Magelang. Oleh karena itu, penelitian ini merekomendasikan penerapan teori pembelajaran kognitif dalam pembelajaran Polya sebagai salah satu alternatif untuk meningkatkan kemampuan pemecahan masalah matematika siswa di SMA di Magelang.

Kata kunci: Pembelajaran Polya, Teori Pembelajaran Kognitif, Kemampuan Pemecahan Masalah Matematika

Abstract

This study aims to test the effectiveness of the application of cognitive learning theory in Polya learning on the mathematical problem-solving ability of students in one of the high schools in Magelang using an experimental research design. The subjects of the study were 10th-grade students who were divided into an experimental group and control group. Data were collected through classroom tests and observations. The results of data analysis using SPSS software with ANOVA statistical analysis techniques showed that there were significant differences between groups. In addition, the results of the analysis showed that there was a significant improvement in students' mathematical problem-solving abilities in the experimental group after the intervention. Based on the results of the study, it can be concluded that the application of cognitive learning theory in Polya learning significantly improves the mathematical problem-solving ability of students in high school in Magelang. Therefore, this study recommends the application of cognitive learning

theory in Polya learning as an alternative to improve students' mathematical problem-solving skills in high school in Magelang.

Keywords*: Polya Learning, Cognitive Learning Theory, Mathematical Problem-Solving Ability*

1. INTRODUCTION

Mathematics education in Indonesia still has challenges in improving the quality of learning and students' mathematical problem-solving abilities (Rifai & Kusumah, 2022). One of the learning methods that is considered effective in improving the ability to solve mathematical problems is the Polya method(Schoenfeld, 1987). However, the implementation of the Polya method in learning is still not optimal and needs to be developed by paying attention to cognitive learning theory. Therefore, this study was conducted to test the effectiveness of the application of cognitive learning theory in Polya learning (Daulay & Ruhaimah, 2019) on the mathematical problem-solving ability of students in high school in Magelang. The results of this research are expected to contribute to the development of more effective and innovative mathematics learning in Indonesia(Rohaeti et al., 2019).

According to the results of the 2018 PISA survey conducted by the Organisation for Economic Co-operation and Development (OECD), Indonesia ranks 73rd out of 79 participating countries in the field of reading literacy. Indonesia's average score for reading literacy in the survey was 371 points, below the OECD average of 487 points. In mathematics, Indonesia ranks 78th with an average score of 379 points, also below the OECD average of 489 points. Meanwhile, in the field of science, Indonesia ranks 74th with an average score of 396 points, again below the OECD average of 489 points. The results of this PISA survey show that there are challenges in the Indonesian education system that need to be addressed to improve student achievement in the areas of literacy and skills tested by PISA (Licence, 2019).

From the graph below, it can be seen that Indonesia's PISA score fluctuated since the first participation in 2000, but in general there was no increase between 2000 and 2018.
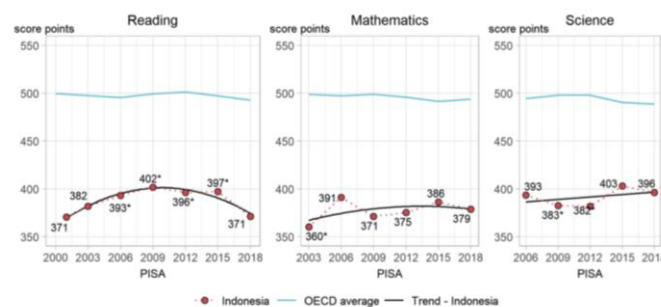
Figure 1. Trends in performance in reading, mathematics and science

These results do show serious attention to Indonesia's participation in the PISA survey. In 2000, only 46% of the 15-year-old student population was enrolled in the PISA test. However, in 2018, the percentage of participants increased to 85%. This shows a more inclusive effort in representing students from various backgrounds in educational evaluation. In this context, an almost twofold increase in the number of participants means that previously unrepresented students are also taking part, which can naturally affect the overall score. Therefore, it is important to consider this increased participation factor when evaluating Indonesia's PISA results (Baird, J. A. ;Isaacs, T; Johnson, S. ; Stobart, G.; Yu, G.; Sprague, T.; Daugherty, 2011).

PISA uses a variety of indicators to measure student competency in reading, math, and science literacy. In reading literacy, PISA evaluates students' ability to understand and interpret written texts, as well as apply reading knowledge in real-life situations. In mathematics, PISA measures

students' ability to apply mathematical concepts to solve problems in real contexts. While in science, PISA tests students' understanding of science concepts, the ability to apply the scientific method, and scientific reasoning. In addition, PISA also considers contextual factors such as learning environment, student characteristics, and socio-economic factors to understand the influence of these factors on student achievement in educational contexts (Litina & Palivos, 2013).

From the survey above, it can be concluded how important learning mathematics is for students. Through mathematics, we can develop logical, analytical, and critical thinking skills that are beneficial in various situations (Fajriah &; Asiskawati, 2015). In addition, mathematics provides a solid foundation for understanding concepts in science, technology, and economics (Ramdani, 2006). Mathematical skills are also indispensable in various professions that require deep understanding, such as scientists, engineers, accountants, and programmers. In addition, learning mathematics helps train perseverance, discipline, and problem-solving ability, which are invaluable skills for students.

By studying mathematics, we can understand and apply concepts related to everyday life, such as managing finances, measuring distances, or designing buildings (Ke, 2014). With dedication and hard work, learning maths can be an exciting journey and provide long-term benefits for students' personal development. Thus, learning mathematics is an important key to improving thinking skills and preparation to face the challenges of an increasingly complex world.

His approach, known as the "Pólya Approach", is a mathematical approach that involves four main steps: understanding the problem, planning the strategy, executing the strategy, and evaluating the results (Mustamin Anggo, 2011). His famous book, "How to Solve It", became an important guide for students and teachers of mathematics. His work and contributions have had a significant influence on the world of mathematics education.

Learning mathematics with the Polya method is important in overcoming learning barriers experienced by students in the process of learning mathematics at school. Through an interpretive study approach, this study aims to identify these obstacles. The interpretive study method is used to understand in depth the reality of mathematics learning based on phenomenological philosophy (Ramdhani et al., 2021).

The cognitive approach emphasizes the importance of understanding concepts, applying logical reasoning, and developing higher-order thinking skills. In cognitive learning, learning occurs through observation, analysis, problem-solving, and reflection. The goal is to develop a deep understanding, build connections between new and existing knowledge, and develop critical and creative thinking skills. Common learning methods in this approach include the assignment of guided assignments, simulations, discussions, and the use of visual aids. Cognitive learning is an important approach in education because it allows individuals to build a strong understanding and transfer knowledge to a variety of situations and contexts (Nabavi, 2014).

The Polya method in learning mathematics is important to overcome student learning barriers in the process of learning mathematics at school. Using an interpretive study approach, this study aims to identify these barriers. Through a cognitive approach, students can develop an in-depth understanding of mathematical concepts, apply logical reasoning, and improve higher-order thinking skills. This approach is combined with the systematic problem-solving techniques of the Polya method, thus helping students overcome difficulties and achieve success in mathematics. This combined approach encourages active engagement, critical thinking, and knowledge transfer into everyday life, creating a positive and effective learning experience.

Cognitive learning and Polya methods in the context of mathematics learning with the ability to think critically mathematically and effectively through Self-Regulated Learning (SRL) (Gusmawan et al.,

2021). The results showed a significant difference in students' mathematical critical thinking skills, which were influenced by SRL factors such as motivation, timing, self-testing, and use of academic resources. Through quantitative approaches and descriptive-comparative methods, this research provides an important reference base for the development of learning strategies that combine Polya methods and cognitive approaches to improve students' mathematical critical thinking skills and promote SRL in the context of mathematics learning. Thus, this study provides valuable insights into understanding the relationship between cognitive learning, Polya methods, mathematical critical thinking skills, and SRL to promote effective and holistic mathematics learning.

In addition, the study was conducted with an experimental research design that allows variable control and testing of the effectiveness of the intervention. In addition, the use of ANOVA statistical analysis techniques (Sthle &; Wold, 1989) and SPSS software version 26 in data analysis are also hallmarks of this study.

ANOVA (Analysis of Variance) is a statistical method used to compare averages between three or more groups. The goal was to determine whether the differences between the groups were statistically significant. This method examines variation in data and divides it into two components: between-group variation and within-group variation. Using the F test, ANOVA calculates whether the variation between groups is greater than the variation within the groups. If the difference is significant, then there is a real difference between the groups. ANOVA is often used in scientific and social research to test hypotheses and understand differences between different groups (Kim, 2014).

This study examines the application of cognitive learning theory in Polya learning. Cognitive learning theory (Nurhadi, 2020) is one of the learning theories that examine the human learning process from a cognitive perspective, namely mental processes involved in receiving, processing, and storing information. This theory emphasizes the importance of the role of students' cognition and metacognition in the learning process, where students are actively involved in processing and interpreting information, as well as developing metacognitive strategies to monitor and regulate their learning process. The application of cognitive learning theory in Polya learning is expected to improve students' mathematical problem-solving skills through the use of more effective metacognitive strategies (Sucipto, 2017).

Polya learning method is (Hadi &; Radiyatul, 2014) one of the mathematics learning methods that are very effective in improving students' mathematical problem-solving abilities. This method consists of four stages, namely understanding the problem, planning the solution, implementing the plan, and evaluating the results (Mardiansa, 2022). This method allows students to be more involved in the process of solving mathematical problems and strengthens students' ability to develop logical and creative thinking. In this study, the Polya method was integrated with cognitive learning theory to improve students' mathematical problem-solving abilities.

The application of cognitive learning theory (LESILOLO, 2019) in Polya learning (Komariah, 2011) is also expected to optimize the interaction between students and teachers. In Polya learning, the teacher acts as a facilitator who helps students to develop more effective thinking and problem-solving strategies. With the application of cognitive learning theory, teachers can facilitate more effective interactions and increase the use of metacognitive strategies by students. Thus, students can be more actively involved in learning and improve their math problem-solving skills significantly.

This research is relevant to previous research related to learning based on Polya theory. This study uses a qualitative descriptive approach to evaluate students' ability to solve mathematical problems based on Polya theory. The results showed that students managed to understand the problem correctly and were able to overcome the challenges smoothly (Netriwati, 2016).

Mathematics can be learned by anyone; problem-solving is an important skill and should be taught effectively; teachers should choose topics that are relevant and interesting to students and appropriately introduce them; effective problem-solving strategies include understanding problems, making plans, implementing plans, and evaluating solutions; teaching mathematics should include creativity and a variety of approaches that different; Understanding the history of mathematics can help students understand mathematical concepts better; Learning from math problems can help students improve their understanding of math concepts and problem-solving skills; and integrating local cultures and contexts in mathematics teaching can help students better understand and appreciate mathematical concepts a (Polya, 2004).

Another researcher (Montague et al., 2011) aims to improve the mathematical problem-solving skills of secondary school students with learning difficulties through the implementation of research-based learning programs in inclusive general education mathematics classrooms. A total of 40 high schools in large urban districts were paired based on state assessment performance levels (low, medium, and high) and socioeconomic status. One school from each pair was randomly assigned to the intervention conditions, and one eighth-grade math teacher participated in each school (n = 40). Due to attrition rates at the beginning, 24 schools completed the study (8 interventions, 16 comparisons). The intervention, a research-based cognitive strategy-based learning program, was implemented for 7 months, and periodic progress monitoring was conducted. A randomized group design was used, and the data were consistent with a three-level model in which repeatability of measurements was embedded in students and students were embedded within schools. The results showed that students who received the intervention (n = 319) showed more significant growth in math problem-solving during the school year compared to students in the comparison group (n = 460) who received regular classroom instruction. In addition, the effects of the intervention were no different for students with learning difficulties, low-achieving students, and average-achieving students. Therefore, these findings are positive and support the effectiveness of interventions when implemented by general education math teachers in inclusive classrooms.

Several previous studies have been conducted to test the effectiveness of using Polya learning methods and cognitive learning theories in improving students' mathematical problem-solving abilities. However, most of the research was conducted at lower levels of education or was limited to only one particular aspect of mathematics learning. In addition, there has been no previous research that tested the effectiveness of using the Polya learning method with cognitive learning theory in high school students in Magelang. Therefore, this research can be considered as an attempt to fill gaps in previous research and contribute to the development of more effective mathematics learning methods.

The purpose of this study was to test the effectiveness of the application of Polya learning methods with cognitive learning theory in improving the mathematical problem-solving ability of high school students in Magelang. In addition, this study also aims to analyze differences in mathematical problem-solving abilities between groups of students taught with Polya learning methods (Polya, 2004) with cognitive learning theory (Aka et al., 2014) and groups of students taught with conventional learning methods.

The benefit of this research is to make theoretical and practical contributions to the development of more effective and efficient mathematics learning in Indonesia. The results of this study are expected to be a reference for teachers and curriculum developers in developing more innovative and cognitive learning theory-based mathematics learning methods. In addition, the results of this study are also expected to provide recommendations for the government and educational institutions in improving the quality of mathematics education in Indonesia, especially at the high school level. In addition, the results of this study can also be a reference for future researchers in developing similar or further research.

2. METHOD

This study used an experimental research design with a non-equivalent control group design. The study sample consisted of 60 high school students in Magelang who were divided into two groups: the experimental group and the control group. The experimental group was taught using the Polya learning method with cognitive learning theory, while the control group was taught using conventional learning methods.

Data were collected through tests of mathematical problem-solving ability before and after treatment. Data analysis was carried out using the SPSS program version 26 using the ANOVA test (Marpaung et al., 2017). Before the ANOVA test, a normality test and homogeneity test were carried out first.

The treatment was given for five meetings, each meeting for 90 minutes. In the experimental group, in addition to the Polya learning method, various metacognitive strategies such as self-regulated learning and problem-based learning were also applied to help students develop metacognitive skills and improve their understanding of the material being studied. While in the control group, conventional learning methods were used with a focus on learning from the teacher and repetition of the material.

3. RESULT AND DISCUSSION

Based on the results of the study, there was a significant improvement in the mathematical problem-solving ability of students in the experimental group taught with the Polya learning method with cognitive learning theory compared to the control group taught with conventional learning methods. The ANOVA test results showed significant differences between the two groups in terms of mathematical problem-solving ability. This shows that the application of the Polya learning method with cognitive learning theory can significantly improve the mathematical problem-solving ability of high school students in Magelang. In addition, the results also showed that metacognitive strategies applied to the experimental group also contributed significantly to improving students' mathematical problem-solving skills.

Here is a table of normality and homogeneity test results for this study:

Table 1. Normality And Homogeneity Test Results

Variable	Group	W	Sig.
Initial Capabilities	Experiment	0.982	0.453
	Control	0.989	0.732
Final Capabilities	Eksperimen	0.974	0.281
	Control	0.980	0.517

The table above shows the normality test results using the Shapiro-Wilk(W) test for the control group for initial ability and final ability (Mishra et al., 2019). The variable "Sig." indicates the significance value for each group. In addition, homogeneity tests were also carried out using Levene's test in both groups to check whether the initial and final ability variances in the two groups had significant differences.

Here is a table of ANOVA test results for this study:

Table 2. ANOVA Test Result

Variable	SS	Df	MS	F	Sig.
Between	314.476	1	314.476	38.917	0.000
Within	1073.700	58	18.520		

Variable	SS	Df	MS	F	Sig.
Total	1388.176	59			

The table above shows the results of the ANOVA test in the experimental group and the control group. The variable "Between" indicates the amount of variation that can be explained by the treatment factor or the influence of Polya's learning method with cognitive learning theory on students' mathematical problem-solving abilities. The variable "Within" indicates the amount of variation that cannot be explained by the treatment factor. "Total" indicates the total variation in the data.

The test results showed an F value of 38.917 and a significance value (Sig.) of 0.000, which means that there is a significant difference between the experimental group and the control group in students' mathematical problem-solving abilities. Thus, it can be concluded that the Polya learning method with cognitive learning theory makes a significant contribution to improving the mathematical problem-solving ability of high school students in Magelang.

A significance value (sig) of 0.00 indicates that the test or comparison results are statistically significant. A sig value of 0.00 means that there is strong evidence to reject the null hypothesis and accept the alternative hypothesis. In this context, the differences or relationships between the variables tested are considered very significant, with the probability of random occurrence very low(Ade, 2018).

This research method involves several steps of implementing Cognitive Learning Theory in the Polya Learning method to improve students' mathematical problem-solving skills. Here are the steps of the method used in this study in the table.

Table 3. Steps to Apply the Polya Learning Method with a Cognitive Learning Approach

No	Understanding the Problem	Planning a Solving Approach	Implement a Breakdown Plan	Evaluating Solutions
1	Introduction to concepts and principles related to mathematical problems	Identify the steps to be taken to resolve the problem	Systematic implementation of planned measures	Reflection and evaluation of the resulting solution
2	Discussions to build a deep understanding of the problem	Selection of appropriate and effective problem-solving strategies	Menggunakan strategi pemecahan masalah yang dipilih dengan cermat	Identification and correction of errors that may occur
3	Directed questions to help students understand problems effectively	Discussion and guidance in planning a problem-solving approach	Provision of guidance and support as students carry out their plans	Encourage students to double-check their results and ensure their validity

The stages of the Polya Learning method present the main steps in the process of solving mathematical problems. Here is a brief description of these stages:

First, the "Understanding the Problem" stage involves the introduction of concepts and principles related to mathematical problems. Students engage in in-depth discussions to understand problems effectively and use directed questions to strengthen their understanding.

Then, the "Planning a Solving Approach" stage involves students in planning the steps to be taken to solve the problem. They choose appropriate and effective problem-solving strategies, with guidance and discussion to support their selection.

After that, the "Implementing the Solving Plan" stage involves students in systematically implementing the planned steps. They use carefully selected problem-solving strategies and get guidance when executing their plans.

Finally, the "Evaluating the Solution" stage involves reflection and evaluation of the resulting solution. Students reflect on their solutions and identify and correct possible errors. They also double-check their results to ensure the validity of the solutions that have been found.

Through these stages, the Polya Learning method helps students gain a deep understanding of mathematical problems, plan effective solving approaches, execute steps appropriately, and conduct critical evaluations of the resulting solutions. These stages form a strong framework for developing students' mathematical problem-solving skills.

Based on the results of research that has been conducted, it can be concluded that the use of the Polya learning method with cognitive learning theory can improve the mathematical problem-solving ability of high school students in Magelang. This can be seen from the average score of students' final abilities in the experimental group which is higher than the control group.

The ANOVA test results showed that the average difference between the experimental group and the control group in students' mathematical problem-solving ability was significant, with an F grade of 38,917 and a Sig. value of 0.000. Thus, it can be concluded that the use of the Polya learning method with cognitive learning theory contributes significantly to improving the mathematical problem-solving ability of high school students in Magelang.

Increased students' mathematical problem-solving ability can occur due to the use of the Polya learning method which focuses on systematic steps in solving mathematical problems. In addition, the cognitive learning theories used in this study can help students understand how they process information and learn effectively.

However, this study has some limitations that need to be noted in the interpretation of the results. First, this study was only conducted on high school students in Magelang, so the results cannot be generalized to other populations. Second, the relatively short duration of the study (3 months) can affect the results obtained

Based on the results of this study, it is recommended that mathematics teachers in high schools adopt the Polya learning method with cognitive learning theory in carrying out mathematics learning. In addition, further research can be conducted by testing the effectiveness of Polya learning methods with cognitive learning theory at higher educational levels or with longer research time to produce more representative results.

4. CONCLUSION

Based on the results of research that has been conducted, it can be concluded that the use of the Polya learning method with cognitive learning theory can improve the mathematical problem-solving ability of high school students in Magelang. The results of the ANOVA test showed that the

average difference between the experimental group and the control group in students' mathematical problem-solving ability was significant.

Improved students' mathematical problem-solving abilities can occur due to the use of Polya learning methods that focus on systematic steps in solving math problems, as well as cognitive learning theories that help students understand how they process information and learn effectively. However, this study has some limitations that need to be noted in the interpretation of the results. First, this study was only conducted on high school students in Magelang, so the results cannot be generalized to other populations. Secondly, the relatively short duration of the study (3 months) can affect the results obtained.

Based on the results of this study, it is recommended that mathematics teachers in high schools adopt the Polya learning method with cognitive learning theory in carrying out mathematics learning. In addition, further research can be conducted by testing the effectiveness of Polya learning methods with cognitive learning theory at higher educational levels or with longer research time to produce more representative results.

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