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The Enhancement of Mathematical Problem-Solving Skills among Junior High School Students Using Problem-based Learning

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Abstract: Improving problem-solving in mathematics education can be achieved by applying a Problem-Based Learning (PBL) approach that prioritizes active student involvement. This research offers a PBL model that is integrated with digital technology to improve students' problem-solving skills more effectively and efficiently. This study aims to analyze the effectiveness of the implementation of the problem-based learning model in improving the problem-solving ability of junior high school seventh-grade students. The research method used was quasi-experimental with a pretest-posttest design of the control group. The research sample consisted of 66 randomly selected seventh-grade students. The selection of 66 students as a research sample was carried out to ensure adequate representativeness, taking into account the diversity of academic backgrounds and problem-solving skills, so that the results of the study can accurately describe the impact of the implementation of Problem-Based Learning (PBL) on various levels of student ability. The instruments used include problem-solving ability tests berjumlah 5 soal and observation sheets for learning activities. The data analysis technique used was the Mann Whitney to see the difference in improvement from the two groups of research samples. The results showed that students' mathematical problem-solving skills experienced a high improvement (Ngain = 0.813) after learning mathematics using problem-based learning. Furthermore, the implementation of the problem-based learning model significantly improves students' mathematical problem-solving skills. These findings indicate that open-ended problem-based learning is one of the effective alternative interventions in improving students' mathematical problem-solving skills. Therefore, educators in the field of mathematics, such as teachers and lecturers, can use open-ended problem-based learning to improve students' mathematical problem-solving skills.

Keywords: problem-based learning, problem-solving skills.

▪ INTRODUCTION

Problem-solving skills are very important for students to have, because they are the foundation for various other mathematical skills (Effendi, 2019). According to (Branca, 1980), This ability is one of the main goals of mathematics teaching, where problem-solving that includes methods, procedures, and strategies is a core element of the mathematics curriculum and becomes a fundamental ability in the mathematics learning process. In addition, by mastering problem-solving skills, students can evaluate the adequacy of data, build a mathematical model of a problem, select and apply a solution strategy, explain the results obtained, and apply mathematics meaningfully (Huda et al., 2020). In problem solving, reasoning skills have an important role. Through good reasoning skills, students are able to solve the problems they face effectively (Elmiwati et al., 2020). Reasoning skills are an important aspect in mathematics that involves logical, analytical, and critical thinking patterns (Herawati & Amelia, 2021). The curriculum also states that reasoning is the main component of high-level mathematical thinking skills and is considered a basic competency that students must master (Diputra et al., 2019). Mathematical reasoning skills are important for students because they help

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students understand the usefulness of mathematics, making it easier for students to understand and solve mathematical problems (Handayani et al., 2024). Thus, mathematical reasoning skills are part of the importance of problem-solving skills. Low mathematical problem-solving skills in students can negatively impact their ability to understand more complex mathematical concepts, hinder the development of critical and analytical thinking skills, and reduce confidence in facing tasks related to mathematics. It can also affect overall academic achievement, as many mathematical concepts are interrelated and require good problem-solving skills to understand and apply. Additionally, students with low problem-solving skills tend to have a harder time adapting to new challenges in learning, which can ultimately affect their motivation to learn and reduce interest in math subjects. The long-term impact is a decrease in students' readiness to face career challenges that require good analytical and problem-solving skills.

Although problem-solving skills are very important, the number of students with these good abilities is still relatively small. Research by Hidayati and Wagiran (2020) shows that students make mistakes in three of the four indicators of problem-solving ability. In line with that, several studies reveal students' low problem-solving skills, which are influenced by various factors such as early ability (Widodo and Darmawan, 2019; Rahmatullah et al., 2022), learning styles (Hidayat and Irawan, 2017; Ekasari et al., 2023), and fighting power (Widodo & Darmawan, 2019; Rahmatullah et al., 2022; Nadila, 2023; Islami., et al (2022). One of the main causes of this low ability is the lack of student habits in solving problems in the form of problems. This shows that students are not used to using context in understanding a given problem. In the learning process, the use of contextual problems is very important as a bridge to relate the material to real life. Contextual problems are problems that are relevant to the situation students face, reflect their daily lives, and are close to their experiences Hidayati and Wagiran (2020). Some empirical studies show that students' mathematical problem-solving skills still tend to be low, as found in research by (Klegeris & Hurren, 2011; Indrawsari & Rahmat, 2022) which noted the low ability of students to apply mathematical concepts in real situations. These studies reveal that although students can memorize mathematical formulas and procedures, they often have difficulty in solving problems that require a deep understanding and application of concepts. This shows that there is a gap between the theoretical knowledge that students have and their ability to apply it in more complex situations. This problem is caused by several main factors, such as students' varied initial abilities, learning styles that are not in accordance with conventional teaching methods, and low student resilience in facing mathematical challenges (Widodo & Darmawan, 2019; Rahmatullah et al., 2022). In addition, mathematics learning which tends to be boring and less relevant to daily life also exacerbates this condition (Hidayat & Irawan, 2017). As a solution, research shows that engaging learning that can encourage collaboration between students, such as Problem-Based Learning can improve students' problem-solving skills. Learning that involves students in discussions, exploration, and the application of concepts directly can motivate them to be more active and critical in solving mathematical problems.

Problem-Based Learning is an educational approach that focuses on learning through problem-solving that is authentic and relevant to real life. In PBL, students are faced with problems that require collaborative investigation and solving, where they develop critical, analytical, and creative thinking skills. According to Julfianto et al (2022), PBL provides opportunities for students to play an active role in the learning process, not only as recipients of information, but also as investigators who seek solutions to the problems they face. This approach allows students to integrate theoretical knowledge with practical skills in real-world contexts. PBL's main advantage is its ability to increase student engagement, encourage them to take more responsibility for their learning, and strengthen cooperation, communication, and problem-solving skills (Hidayati & Wagiran, 2020). The application of PBL in the context of mathematics, especially in improving problem-solving skills, shows a positive impact on the development of students' mathematical skills. Problem-solving skills in mathematics taught through PBL focus on applying mathematical concepts in unstructured situations, which requires students to identify and formulate problems, as well as find and evaluate appropriate solutions. According to (Julfianto et al., 2022), in PBL, students not only memorize formulas or procedures, but they are trained to understand concepts in depth and relate them to real-world problems. PBL's success in improving mathematical problem-solving skills lies in an approach that allows students to develop a strong conceptual understanding as well as skills in solving problems independently and creatively. The advantage of PBL in improving mathematical problem-solving skills lies in learning based on real experience and collaboration. As explained by Ulandari et al. (2019), PBL motivates students to work together in groups, share ideas, and discuss to solve complex problems. This collaborative learning provides students with the opportunity to learn from others, broaden their horizons, and develop social skills that are essential in everyday life. Additionally, by integrating technology in PBL, students can access a variety of information sources that enrich their knowledge and aid in the problem-solving process. PBL also provides space for students to face challenges head-on, which can increase their resilience and fighting power in facing difficulties in learning mathematics (Umar & Zakaria, 2022). Overall, the implementation of PBL not only improves students' technical ability in solving mathematical problems, but also forms a positive attitude towards mathematics. With a focus on developing more structured, critical, and creative problem-solving skills, PBL is a very effective approach to overcome the difficulties that students often face in learning abstract mathematical concepts (Munzar et al., 2021; Hurst & Linsell, 2020).

Several studies have shown that Problem-Based Learning can significantly improve students' problem-solving abilities, especially in the field of mathematics. For example, research conducted by Qadri (2023) shows that students who are applied with PBL have better problem-solving skills compared to students who are taught with traditional methods. In his research, Firdaus found that students involved in PBL were more active in finding solutions, more confident in applying mathematical concepts, and more skilled in working in groups to solve complex problems. This research is in line with the findings by Wang et al (2023) which show that PBL provides space for students to develop their cognitive and metacognitive skills, which are essential in solving math problems effectively. Another relevant study was conducted by Fang (2023), which examined the effect of PBL on improving problem-solving skills at the junior high school level. The results of this study show that students who are taught using PBL have a significant improvement in their problem-solving skills, especially in solving mathematical problems that require a high level of reasoning. PBL, which emphasizes contextual learning and social interaction, helps students to better understand difficult mathematical concepts in a more applicable and practical way. Students' involvement in group discussions and the use of technology in PBL also improves their understanding of mathematics material and improves their collaboration skills in solving problems. Research conducted by Napitupulu et al. (2019) further strengthens these findings by showing that PBL not only improves mathematical problem-solving skills, but also affects students' attitudes towards mathematics learning. In their research, Napitupulu et al. (2019) noted that students taught with the PBL method showed increased interest and higher motivation to learn, which had a positive impact on their ability to solve mathematical problems. PBL motivates students to find out more deeply about the material being taught, as well as providing opportunities for critical and creative thinking in dealing with various problem situations. The novelty of the application of PBL in this context is an approach that integrates technology and collaborative learning, which not only improves mathematical problem-solving but also prepares students to face real-life challenges. This approach encourages students to think more independently, while also strengthening their social and communication skills. With the increase in interaction between students, as well as the application of technology in the learning process, PBL provides a more immersive and relevant learning experience for students, which contributes to significantly improving problem-solving skills.

The purpose of this study is to explore the effect of the application of Problem-Based Learning (PBL) on improving students' mathematical problem-solving skills. This study also aims to identify factors that affect the effectiveness of PBL in improving students' problem-solving skills, such as student engagement levels, learning styles, and motivation. The significance of this research contribution is to provide empirical evidence regarding the effectiveness of PBL in improving mathematical problem-solving skills, which can be used as a basis for designing more innovative and relevant learning methods in the classroom. The research questions (RQ) asked were: "How does the application of PBL affect the improvement of students' mathematical problem-solving ability?"

▪ METHOD

Participants

This study involved 66 grade seventh-grade students one of the junior high schools located in the city of Bandung as the research population. The research sample consisted of two groups, namely 32 students distributed in an experimental class that applied Problem-Based Learning and another 34 students distributed in a control class that used the direct learning method. The sampling technique used in this study is purposive sampling, in which the students are selected based on certain criteria, such as their readiness to participate in both different types of learning and their willingness to participate in the research. The selection of experimental and control classes was carried out randomly from several classes in the school, with the aim of obtaining representative and valid data regarding the comparison of the effectiveness of the two learning methods in improving students' mathematical problem-solving skills.

Research Design and Procedures

This research is a quasi-experimental research using a non-equivalent control group design, which is a research design that does not randomly group subjects because the group used has been determined by the school. In this study, two different classes, namely the experimental class and the control class, were used as research samples. The experimental class will get a Problem-Based Learning learning model with a scientific approach, while the control class will get conventional learning that is generally applied in schools. The selection of the non-equivalent control group design was carried out due to limitations in random grouping and because the classroom used already existed as part of the existing education system in the school, thus allowing the research to be carried out in a more natural and realistic environment. This design still makes it possible to compare the results between the two groups even though random grouping is not carried out. The research steps applied include the preparation stage, pre-test, learning intervention, post-test, data analysis and conclusions. The duration of this study is 3 months. The first month is used for the preparation and collection of preliminary data (pre-test), the second month for the implementation of learning interventions in both classes, and the third month for the collection of final data (post-test) and analysis of research results. With this timeframe, the research is expected to provide representative results and contribute to the development of effective learning methods.

Instruments

The instrument used in this study is a mathematical problem-solving skills test consisting of 5 essay questions on the topic of Pythagorean Theorem. The five questions are designed to measure four main indicators in mathematical problem solving, which include: (1) the ability to understand and identify mathematical problems, (2) the ability to formulate problem-solving strategies, (3) the ability to apply appropriate procedures in solving problems, and (4) the ability to critically examine and interpret the results of the solution. The test has gone through a validation process to ensure that the questions given can measure the indicators in question accurately. The validity of the instrument is tested using a content validity technique that involves assessment by material experts and mathematics education experts to ensure the suitability of the questions with the purpose of measurement. Based on the validity test, the r-value of each question showed a significant number, with an r value > 0.625, which indicates that the questions have good validity in measuring students' mathematical problem-solving skills. In addition, the test has also been tested for reliability using the Cronbach Alpha coefficient, which shows a value of $\alpha = 0.892$, which indicates an excellent level of reliability. This Cronbach Alpha value indicates that the test instrument has a high internal consistency, meaning that the test can provide stable and reliable results if used in similar measurements in the future. Thus, the instruments used in this study can be considered valid and reliable, and qualified to be used in measuring the improvement of students' mathematical problem-solving abilities accurately and consistently.

Data Analysis

To describe the improvement of students' mathematical problem-solving skills, the N-gain value is used which is a measure to assess changes in students' abilities between pre-test and post-test. The N-gain value is calculated by the formula:

$$NGain = \frac{Posttest\ score - Pretest\ score}{Maximum\ score - Pretest\ score}$$

The results of this N-gain calculation are then grouped into three categories based on the general interpretation used in educational research. To test the improvement of students' mathematical problem-solving skills, a mann whitneyy was used to compare the difference in pre-test and post-test scores in each group. This test is used because the data obtained is paired data, where the scores before and after the treatment are taken from the same subject, making it possible to measure changes in problem-solving skills in the same individual. To test the difference in improving mathematical problem-solving skills between the experimental class and the control class, an independent t-test was used. This test was used to compare the average difference in N-gain between two independent groups, namely the group taught with the PBL learning model and the group taught with direct learning. Using an independent t-test, the researchers were able to test whether there was a significant difference in the improvement of mathematical problem-solving skills between the two groups after treatment. The statistical techniques used are appropriate to analyze the data obtained and ensure the validity and reliability of the research results.

▪ RESULT AND DISSCUSSION

The results of this study are a quasi-experimental research conducted in a junior high school in the city of Bandung, West Java. This research was carried out in seventh-grade students by taking the main material of the Pythagorean Theorem. The researcher uses the purposive sampling technique in determining the two classes used as research objects, namely the experimental class that applies the problem-based learning model and the control class that applies the direct learning model. The problem-based learning class consists of 32 students and the direct learning class consists of 34 students. The following are the results of the data analysis obtained by the researcher.

Descriptive Analysis

Student problem-solving data in this study was obtained through pretest and posttest. The pretest was given to determine the initial problem-solving ability of students, this test was given before students received treatment in the form of the application of problem-based learning. Meanwhile, the posttest is given after the student receives the treatment to measure how much effect the treatment has on the student's problem-solving ability. The results of the troubleshooting test are briefly described in Table 1. Next

Table 1. Problem-Solving Ability Test Results

Data		**Class**	
N		**Problem-Based Learning**	**Direct Learning**
Pretest	Min.	15	20
	Max.	85	100
	$\bar{x}$	38.43	44
	s	20.17	21.45
Posttest	Min.	40	15
	Max.	100	100
	$\bar{x}$	72.4	61.85
	s	24.04	21.37
Ideal Maximum Score			100

Based on Table 1, it can be seen that in the pretest, the maximum score that students can achieve is 100, with 1 student in the control class achieving it, while in the experimental class, no student achieved a perfect score. However, after the treatment, seventh-grade students in the experimental class managed to achieve the maximum score on the post-test. For pretest scores, students who took part in problem-based learning had an average score of 38.43, lower than the direct learning class which had an average pretest score of 44. However, the standard deviation value of the class that used problem-based learning (20.17) was smaller than that of the direct learning class (21.45), which showed that the distribution of students' problem-solving skills in the experimental class was more concentrated than that of the control class. After the treatment, there was a significant increase in the average problem-solving ability score in the experimental class, which was 72.4, which was higher than the control class, which obtained an average of 61.85. Although the maximum score in both classes remained 100, a significant difference occurred in the minimum score, where the experimental class had a minimum score of 40, while the control class only had 15. The distribution of students' problem-solving skills in the experimental class was also wider compared to the control class, indicating that the application of problem-based learning had a greater impact on improving students' problem-solving skills.

To provide a deeper understanding of improving problem-solving skills, an analysis was carried out on each indicator of mathematical problem-solving ability measured through the tests that had been given. Each indicator, ranging from the ability to understand problems, formulate strategies, apply procedures, to check and interpret the results, will be analyzed separately to see the extent of the difference in the development of skills between learning groups. In this way, we can more clearly illustrate how each indicator contributes to the overall improvement of students' problem-solving abilities in both classes, whether using problem-based learning (PBL) or hands-on learning. The data on mathematical problem-solving ability per indicator can be seen in the following Figure 1:

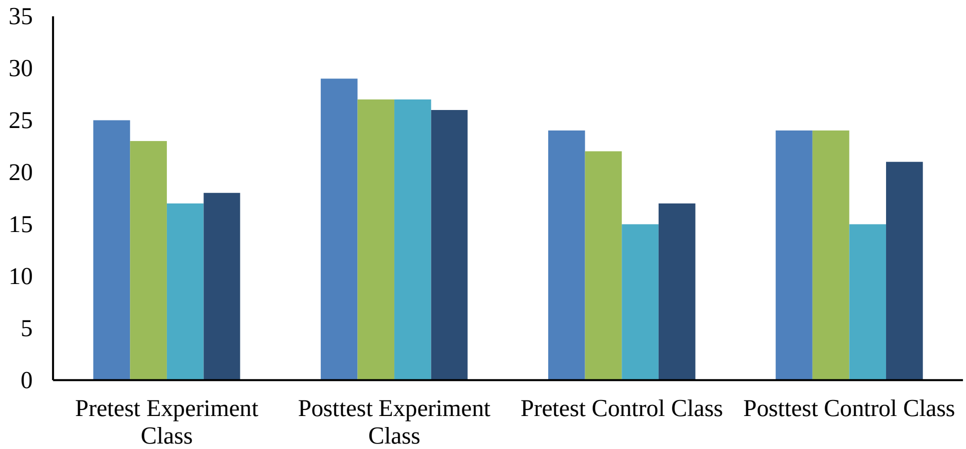

Figure 1. Mathematical problem-solving ability data per indicator

The mathematical problem-solving ability data per indicator can be seen in Figure 1 below, which shows the average score for each indicator measured in the problem-solving ability test. The first indicator, the ability to understand and identify problems, showed results that varied considerably between the two groups. Students in problem-based learning (PBL) classes showed little improvement in these abilities after treatment, although initially they had lower average scores compared to students in hands-on learning classes. This shows that although PBL classes provide more space for students to analyze problems in more depth, some students still face difficulties in identifying the components of the problem precisely. In the second indicator, namely the ability to formulate problem-solving strategies, the PBL class showed a more significant improvement compared to the control class. Students in PBL classes are better able to develop structured solving steps after following a problem-based learning approach. The third and fourth indicators, namely the implementation of procedures and the examination of solution results, also showed a higher upward trend in the PBL class. Students in this class are more confident in implementing the right procedures and more thorough in checking their final results. Figure 1 clearly illustrates how the two groups experienced differences in each indicator of problem-solving skills, with PBL classes showing better results on almost all indicators after the learning treatment.

Inferential Analysis

Inferential analysis at this stage is used to answer the formulation of the problem " How does the application of PBL affect the improvement of students' mathematical problem-solving ability?". Assuming that the data is normally distributed and homogeneous, the next analysis can be carried out to calculate the N-gain value as an indicator of improving students' mathematical problem-solving ability. These increases will then be grouped into high, medium, or low categories according to the N-gain value obtained. The results of the N-Gain Test of Mathematical Problem Solving Ability problem-solving ability are summarized in Figure 2 below:

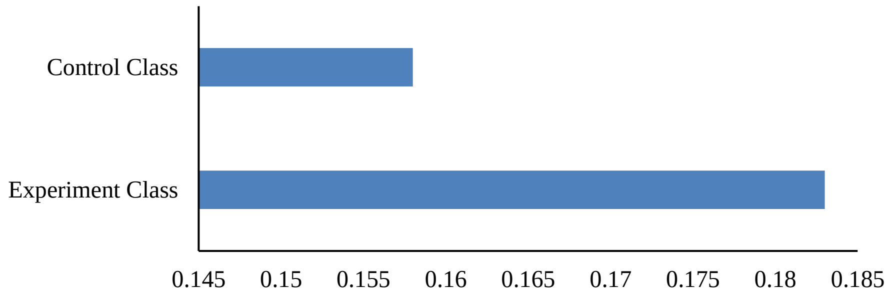

Figure 2. N-Gain test of mathematical problem-solving ability

This N-gain value showed an improvement in mathematical problem-solving ability in both groups, although the increase was relatively greater in the experimental class. The higher N-gain value of the experimental class illustrates that the application of problem-based learning has a more significant impact on the improvement of students' problem-solving skills, although this difference is not always noticeable in each indicator. To test whether the difference in N-gain between the two groups is significant, the Mann-Whitney test is then carried out. This test was chosen because the data obtained were not normally distributed, so this non-parametric test was more appropriately used to test the difference between two independent groups. After the Man Whitney test, Asymp results were obtained. Sig. (2-tailed) is 0.013, where 0.013 was 0.05 so it was accepted. This indicates that there is a significant difference between the improvement of students' problem-solving ability in the experimental group and the control group. $\leq H_0$

The Problem-Based Learning approach can improve students' problem-solving steps by providing them with the opportunity to actively engage in a process that requires them to think critically and systematically. Based on the problem-solving stages theory from Schoenfeld (1985), PBL supports students in every stage of problem-solving, from understanding the problem to examining the results and improving the solution. In the first stage, students in PBL are faced with real-world problems that motivate them to identify important information and formulate problems better, as well as plan appropriate solution strategies (Septiana & Ibrahim, 2020). Collaboration in groups allows students to share ideas and formulate more effective approaches to solving problems (As-Sa'Idah, 2022).

In addition, PBL reinforces the stage of executing and examining results, where students apply mathematical procedures or strategies they have developed, and then reflect on the results. In PBL, the teacher acts as a facilitator who helps students analyze the results and adjust solutions if needed, according to the final stage in Schoenfeld's theory. By providing space for students to continuously develop and adapt their approaches, PBL improves students' ability to solve problems holistically (Schoenfeld, 1985). This approach not only strengthens technical skills but also critical and collaborative skills that are important in the mathematical problem-solving process.

The application of Problem-Based Learning to the Pythagorean Theorem material allows students to understand abstract mathematical concepts in a more concrete and relevant way through real-world problems. For example, students may be given situations such as calculating the diagonal length of a rectangular piece of land or determining the shortest distance between two points on a map. This activity encourages students to explore the relationship between the lengths of the sides of a right triangle in a meaningful context, so that they can more easily understand the square relationship that underlies the theorem (Kadir et al., 2016). PBL also allows students to work in groups to discuss solving steps, such as drawing, measuring, and counting, which helps overcome students' difficulties in visualizing abstract concepts. This approach not only strengthens conceptual understanding but also improves students' critical thinking skills through reflection and collaboration (Farida et al., 2020).

The success of the implementation of Problem-Based Learning in the Pythagorean Theorem material is greatly influenced by students' learning styles, such as visual, kinesthetic, and auditory. Students with a visual learning style, for example, will find it easier to understand the relationships between the sides of a right triangle through visual representations such as triangular images, diagrams, or interactive simulations used in PBL. On the other hand, students with a kinesthetic learning style will better understand concepts through hands-on activities, such as creating a model of a triangle using a rope or wood to physically measure and verify the length of the sides. Meanwhile, auditory students tend to be more effective in learning when concepts are explained verbally through group discussions or presentations. In PBL, students have the opportunity to work with a variety of media and methods that suit their respective learning styles, thus maximizing their understanding of abstract concepts such as the Pythagorean Theorem.

This approach encourages a diversity of learning strategies, which ultimately increases learning engagement and effectiveness (Cahya, 2023).

In the context of student learning styles, observations during learning sessions using Problem-Based Learning material from the Pythagorean Theorem show how each student interacts according to their learning preferences. Students with visual learning styles seem enthusiastic when working with triangle diagrams or graphic-based applications to visualize quadratic relationships between sides. Students with a kinesthetic learning style are more involved in physical activities such as building a model of a triangle using simple tools, while students with an active auditory style contribute to group discussions by conveying ideas or listening to classmates' explanations. The observed interactions also showed cross-learning collaboration, where students with different styles complemented each other, such as visual students who helped create diagrams for kinesthetic students, or auditory students who conveyed solution steps based on the results of the group's visual observations. These findings reflect how PBL creates an inclusive learning environment, which not only strengthens conceptual understanding but also improves students' social and communication skills (Hendarwati et al., 2021).

Observations in the classroom during the implementation of Problem-Based Learning on the Pythagorean Theorem material show that PBL not only improves students' problem-solving skills but also encourages collaborative interaction across learning styles. These findings are in line with studies (Win et al., 2015) that show that PBL is effective in improving students' mathematical disposition, including confidence, perseverance, and ability to work together. In the context of these observations, students with different learning styles appeared to be more confident in solving complex problems through directed group discussions. Students also show perseverance in understanding abstract concepts such as square relations on the right triangle side, which is one of the indications of a better mathematical disposition. This study provides novelty through a holistic approach to the assessment of mathematical problem-solving ability, different from previous studies that tend to use a more segmented evaluation method. The assessment in this study not only focuses on the final result, but also on the process of students in understanding the problem, planning solutions, and reflecting on the results. This approach provides a more thorough picture of how students solve mathematical problems, as well as how PBL affects their critical and collaborative skills. Thus, this study expands on existing literature, such as studies (Win et al., 2015) by showing that the effectiveness of PBL is not only limited to mathematical dispositions but also includes comprehensive problem-solving abilities.

To integrate Problem-Based Learning into everyday learning, teachers can use learning modules specifically designed for Pythagorean Theorem material. This module can cover a variety of contextual problems that challenge students to apply theorem concepts creatively, such as calculating the diagonal distance of a field or determining the shortest route in a map. Modules can also be complemented by a guide to problem-solving steps, collaborative worksheets, as well as space for individual and group reflection. With this module, teachers can easily facilitate PBL sessions in a limited time, ensuring that curriculum goals remain achieved while providing a more meaningful learning experience for students. In addition, the use of technology such as mathematical simulation software, such as GeoGebra or AR (Augmented Reality)-based applications, can enrich the PBL experience. This technology allows students to visualize the relationships between the sides of a triangle in various situations, manipulate variables, and explore solutions dynamically. This kind of simulation not only helps students with visual learning styles, but also increases kinesthetic and auditory student engagement through hands-on interaction and data-driven discussions. By integrating technology into PBL, teachers can create a learning environment that is more interesting, adaptive, and relevant to the needs of students in the digital era (Winoto et al., 2019).

▪ CONCLUSION

Overall, the results showed that there was a significant difference in the improvement of problem-solving skills between students in the experimental group and the control group. This indicates that the intervention or method used in the experimental group is effective in improving these abilities. These findings reinforce the importance of applying appropriate learning methods to support the development of students' problem-solving skills. Therefore, the approach used in the experimental group can be considered as an effective alternative in the learning process. The limitations of this study, such as the use of samples that only come from one school, can affect the internal and external validity of the results. Internally, these limitations may limit the research's ability to fully control external variables that may affect outcomes, such as differences in students' motivation levels or unmeasurable initial abilities. Externally, the generalization of research results to a wider population becomes less robust, as the characteristics of students and the learning environment in other schools may differ. To address these limitations, further research is suggested involving a larger and more diverse sample of different schools, including variations in educational contexts, such as geographic location or students' socio-economic backgrounds. In addition, the research can expand the focus to other learning materials to test the consistency of PBL's findings in improving mathematical problem-solving skills. With this reflection, it is hoped that future research can provide more comprehensive and generalist insights into the effectiveness of PBL in mathematics learning.

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