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Problem-based learning in mathematics learning to improve reflective thinking skills and self-regulated learning

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Abstract

This research was aimed to determine the effectiveness of the Problem-Based Learning (PBL) model in mathematics learning on students' reflective thinking skills and self-regulated learning. The researchers employed the quantitative-qualitative method. The quantitative data was obtained through pretest and posttest, and qualitative data were obtained through interviews with three students selected using a purposive random sampling technique. The research subjects were selected using the accidental sampling technique because it was still in the new normal era of the COVID-19 pandemic. The subjects consisted of 33 eighth-grade students. The data was collected using test instruments and questionnaires. Furthermore, the data was tested using the independent sample t-test. This research found three results. First, there was a significant increase in reflective and self-regulated thinking skills through the application of the PBL model. Second, based on the t-test, there was a reflective thinking skills difference between pretest and posttest, with a higher score was found in the posttest. Third, there was no self-regulated learning difference between the pretest and posttest.

INTRODUCTION

Thinking is an activity to develop (Haryati et al., 2017). Etymologically, reflective comes from the Latin word "*reflectere,*" which means looking or bending backward (Nuriadin et al., 2015). It is an activity of remembering what has been done to state what has been done. Reflective thinking, according to Dewey, is the active, persistent, and careful consideration of any belief or conjecture of knowledge in light of the reasons that support it and the possible conclusions. According to (Lipman, 2003), reflective thinking skills are the ability to generate assumptions (hypotheses/known elements) and implications based on reasons or evidence to support a conclusion.

According to the view of pragmatism (Masamah, 2017), reflective thinking skills require teachers to create situations that make students feel a problem and foster a desire to solve it without depending on others, especially the teacher. Learning situations that have problems will develop students' reflective thinking skills (Nuriadin et al., 2015; Rohana, 2015). Therefore, mathematical models of a problematic situation should go through a certain transition level and be taken into account. So, teachers need appropriate actions to make the process of learning mathematics or the process of solving a mathematical problem in the classroom easier. The reflective thinking process is not just a sequence of ideas but a sequential process so that each idea refers to the previous idea to determine the next step. All

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successive steps are connected, support each other, and contribute to a common conclusion. In line with Dewey's exploration (Nuriadin et al., 2015), reflective thinking is self-regulation to generate interpretation Up to the conclusion. The resulting interpretation is the ability to identify a problem, change one idea to another that refers to the concept, and ask and answer questions to clarify the solution process.

Mathematics learning in most levels of education in Indonesia is conventional, which generally focuses on drilling or algorithmic questions that are procedural and mechanistic rather than understanding (Alghadari, 2020). Teachers usually explain concepts informatively and do not contribute much to developing higher-order thinking skills (Masamah, 2017). As a result, students' high-level cognitive abilities are weak because the usual learning activities only encourage them to memorize or imitate (Yuni et al., 2018). Therefore, mathematical models and problem situations used by teachers in teaching must go through a certain transition level model and must be taken into account (Rakhmawati, 2020).

This problem was experienced by students of SMPN 4 South Cikarang, Bekasi. Based on the preliminary research results by giving a pretest, the students' mathematical reflective thinking ability only reached an average value of 14.7 (the maximum score is 23) or 63,4%. The impact of student self-regulated learning only reached 67% of all students surveyed, while the target from school administrators was 80%. Innovations are needed to develop reflective thinking skills in learning mathematics based on the existing problems. One alternative is problem-based learning.

Mathematical reflective thinking skills can be trained and accustomed through the learning process. The learning process that refers to improving critical, logical, creative thinking skills and socio-emotional intelligence needs to be carried out and improved through the habit of solving contextual problems. (Mulyana & Sumarmo, 2015) state that mathematics learning is directed at developing (1) mathematical thinking skills, which include understanding, problem-solving, reasoning, communication, and mathematical connections; (2) critical thinking skills and open and objective attitudes; and (3) a mathematical disposition, habit, and a high-quality learning attitude.

The problem-based learning model (PBL) is the most significant innovation in education because it includes the pattern of competencies needed in the 21st-century (Megahati et al., 2018). Education is preparing for the future and how to create a good future. One of the learning models used is PBL to develop a learning process that can improve competence. PBL is a learning model that challenges students to find solutions to real-world problems (Yudhanegara et al., 2014). It is student-centered learning and centered on solving a problem (Francis, 2005). In PBL, teachers help students reflect or evaluate their investigations and the processes they use. This is one of the activities needed to train and develop reflective thinking skills. Besides, learning activities through problems may support reflective thinking skills (Nismawati et al., 2019). Reflective thinking skills can be increased in a class discussion situation that discusses certain concepts (Cahyo, 2016). PBL is oriented towards solving problems where students collaborate and communicate.

The PBL steps (Nismawati et al., 2019) consist of (1) orienting students to the problem; (2) organizing students for research; (3) assisting independent and group investigations; (4) developing and presenting the work; and (5) analyzing and evaluating the problem-solving process. PBL implementation must begin with understanding the problem by identifying the problem first. What is known, what is asked, or the solution will be found. The teacher acts as a guide who directs students to identify problems. Students in solving mathematical problems need mathematical reflective thinking skills and self-regulated learning. Besides, reflective thinking skills are also needed to equip students to solve problems in their lives (Nuriadin et al., 2015; Saputra, 2017; Widiyawati et al., 2018). The knowledge obtained must continue to be used so that students do not easily forget. The PBL steps, in general, begin with formulating the problem, digging up information related to the problem, making a strategy to solve the problem, and applying the strategy. Learning activities with PBL can develop students' mathematical reflective thinking skills and self-regulated learning (Masamah, 2017; Rozana et al., 2020; Yuliati et al., 2018).

Self-regulated learning is a process of careful self-design and monitoring cognitive and affective processes in completing academic tasks (Hendriana, 2012). Another opinion states that self-regulated learning is the ability to monitor one's behavior (Marcos et al., 2009). Zimmerman (Hendriana, 2012) classifies three phases of self-regulated learning activities: designing learning, monitoring learning activities, and evaluating and reflecting. The phases coincide with the stage of reflective thinking skills. Based on the opinion of Bandura and Zimmerman, the indicators of self-regulated learning are compiled into: (1) initiative and intrinsic learning motivation, (2) the habit of diagnosing learning needs, (3) setting learning targets, (4) choosing and implementing learning strategies, and (5) self-confidence (Mulyana & Sumarmo, 2015). These five indicators were used in this research. One of the efforts made to grow and develop students' reflective thinking skills is applying learning models following the characteristics of reflective thinking abilities. Therefore, problem-based learning is an environment that supports the creation of students' reflective thinking skills (Cahyo, 2016).

Several studies related to the application of the PBL model have been carried out (Alfianiawati et al., 2019; Hursen, 2021; Putra & Bektiarso, 2017). Some of them have shown that the PBL model has positive impacts on learning outcomes (Sudiatmika et al., 2016; Wulandari & Surjono, 2013), problem-solving abilities (Argaw et al., 2016; Chiang & Lee, 2016; Gallagher et al., 1992; Supiandi & Julung, 2016), student perceptions (Lancaster et al., 1997) and critical thinking (Masek & Yamin, 2011). However, research that looks at the effect of the PBL model on students' mathematical reflective thinking skills and self-regulated learning has not been found. Departing from this background and problems, this research was related to applying the PBL model in learning mathematics. Through the PBL learning model, the teacher understands how to teach with various concepts. Thus, this research was intended to see the implementation of the PBL model in mathematics learning to improve reflective thinking skills and self-regulated learning.

METHODS

The research data were collected using a test instrument measuring reflective thinking skills and questionnaires about self-regulated learning. The researchers employed the quantitative-qualitative method (Arikunto, 2011; Creswell, 2009; Sugiyono, 2010). The quantitative data were obtained by pretest and posttest techniques. The qualitative data was obtained through interviews with three students selected using a purposive random sampling technique (Sugiyono, 2010). The normalized gain formula (Meltzer, 2002) was performed to determine improved reflective thinking skills and self-regulated learning. The classification is presented in Table 1.

Table 1. The Classification of the Normalized Gain (N-Gain)

N_Gain Value Range	Classification (Ability)
N_Gain > 0,7	High
0,3 < N_Gain < 0,7	moderate
N_Gain ≤ 0,3	low

The research subjects were 33 eighth-grade SMP Negeri 4 Cikarang, South Bekasi students. The research subjects were selected using accidental sampling because they were available to participate. The sampling technique was chosen because it was still in the new normal era of the COVID-19 pandemic (Edmonds & Kennedy, 2017).

The reflective thinking skills ability (RTS) indicators (Angkotasan, 2013; Nindiasari et al., 2014) are contained in Table 2.

Table 2. The Indicator of Reflective Thinking Skills

Indicators	Classification
1. Defining the problem	Understand the problem by mentioning what is known and what is being asked.
2. Diagnosing the problem	Analyze the problem by identifying the relationship between statements or questions and the concepts given by the questions.
3. Formulating alternative strategies	Develop the right strategy to solve the problem.
4. Determining and implementing preferred strategies	Implement the chosen and mastered problem-solving strategy.
5. Conducting evaluations	Evaluate the problem-solving process.

The RTS ability classification adopts the criteria for higher-order thinking skills (Badjeber & Purwaningrum, 2018), as displayed in Table 3.

Table 3. The RTS Ability Classification

Low ability	moderate ability	High ability
Test score < 50	50 ≤ test score ≤ 70	Test score > 70

The SRL indicators (Hendriana, 2018) can be seen in Table 4.

Table 4. The Indicator of Self-Regulated Learning (SRL)

Indicators	Classification
1. Initiative to learning	Trying to find help when experiencing difficulties.
2. Diagnose learning needs	Trying to find out weaknesses when learning mathematics.
3. Set learning targets	Determining the goals/targets to be achieved after learning mathematics.
4. See adversity as a challenge	Feeling pleased when solving problems.
5. Utilize and search for relevant learning resources	Using the internet to learn mathematics.
6. Strong self-confidence	Feeling confident in solving problems.
7. Evaluate learning processes and outcomes	Re-checking the answers.

SRL questionnaire score ranges can be seen in Table 5 (Hendriana, 2018).

Table 5. The Self-Regulation Learning (SRL) Criteria

Low	moderate	High
questionnaire score < 50	50 ≤ questionnaire score ≤ 70	questionnaire score > 70

Based on Table 5, if students get a score of less than 50, their learning independence is low. The students in the low category always want to learn mathematics. If they get a score between 50 to 70, then their learning independence is in the moderate category. The students in the moderate category sometimes need guidance. At other times, they can be independent in learning mathematics. Meanwhile, those who score more than 70 mean high learning independence and rarely ask to be guided in learning mathematics.

RESULTS AND DISCUSSION

The researchers employed five mathematics questions measuring reflective thinking ability and 23 questionnaire items measuring learning independence in this research. The instruments had been tested for validity and reliability.

The reflective thinking skills (RTS) data were collected using tests, and self-regulated learning (SRL) was collected using questionnaires. Data was obtained after giving treatment to the sample. The pretest and posttest data are presented in Table 6.

Table 6. The Descriptive Data of RTS and SRL

Data	Variable	N	Mean	Min Score	Max Score	SD	Std. Error
Pretest	RTS	33	14,70	7	23	3,836	0,668
	SRL	33	70,88	43	90	12,839	2,235
Posttest	RTS	33	18,91	11	23	3,476	0,605
	SRL	33	79,58	53	92	11,869	2,066

Table 6 shows that the average posttest data of RTS was greater than the pretest. Furthermore, the average posttest data of SRL was greater than the pretest. Therefore, there was an improvement in each indicator after implementing the PBL model.

Figure 1 shows the students' RTS achievements, namely the scores on the pretest based on each indicator.

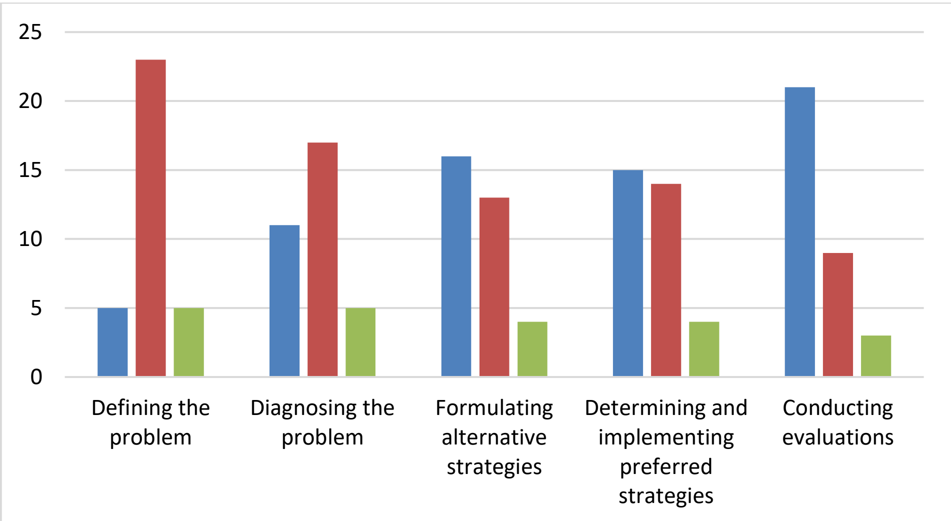

Figure 1. The Pretest Data of Students' RTS

Based on Figure 1, the student's scores on each indicator were between 50 and 70. The posttest score is presented in Figure 2.

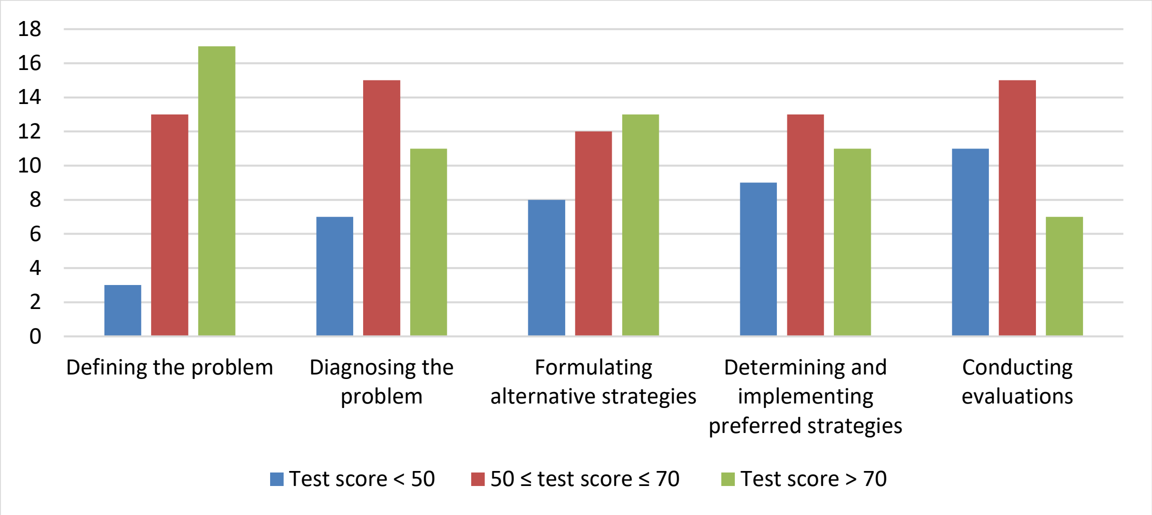

Figure 2. The Posttest Data of Students' RTS

Figure 1 and Figure 2 show an increase in the number of students who scored more than 70. An analysis was carried out through pretest and posttest scores to determine the increase in students' RTS on each indicator. The RTS improvement data is shown in Table 7 below:

Table 7. The RTS Improvement

RTS Indicators		Pretest	Posttest	N_Gain	Criteria
1.	Defining the problem	10,34	15,90	0,783	High
2.	Diagnosing the problem	11,56	16,03	0,641	moderate
3.	Formulating alternative strategies	12,67	15,98	0,472	moderate
4.	Determining and implementing preferred strategies	12,03	15,61	0,484	moderate
5.	Conducting evaluations	13,14	15,33	0,286	Low
Average		11,95	15,77	0,533	moderate

Table 7 shows that the average final score of students' RTS has increased. The category of RTS improvement was known by calculating the N-Gain. Based on Table 7, the first indicator experienced the highest increase, as indicated by the N-Gain value of 0.783 (high category). The second indicator increased into the moderate category. This increase was due to students receiving guidance from the teacher to identify the concepts in the problem and organize learning tasks related to problem-solving. At the PBL model learning steps, the students are trained continuously to understand the problem by reading the questions repeatedly and writing down what is known and what is asked. At this stage, students must connect previous knowledge.

However, 33% of students forgot the previous lesson associated with the problem to be solved. The third and fourth indicators were not much different since their N-Gain scores were 0.472 and 0.484 on the moderate criteria. The indicators improved because the teacher trained students to determine their steps in solving mathematics problems. This step is part of the PBL model, namely organizing student learning and encouraging students to seek information and conduct experiments to solve problems. At first, the teacher guided and directed the students. After being guided and directed twice, the students were required to determine the problems' steps. The teacher provided motivation and reinforcement by saying: "never be afraid of being wrong in answering mathematics questions. After experiencing a mistake, you will correct the error." The students were motivated to determine the solution strategy, even if they were wrong. They did it repeatedly without despair and managed to present correct answers. This experience made students want to do it again independently. They stated that finding their answers presented a sense of satisfaction and pride.

The improvement in indicators 3 and 4 was only in the moderate category. However, the fifth indicator (conducting evaluations) increase was in a low category. The evaluation stage was difficult for students because they were not checking their work. So far, the students have relied on the teachers in evaluation. Teachers experienced problems in training students to evaluate the results of their work, especially students with less than 70 RTS scores. The sample problems can b found in proving the area of a triangle with the area of a trapezoid. Geometrically, students could prove by constructing the grids of a circle into a trapezoidal shape (in Figure 3). However, they forgot the formula for the area of a trapezoid. After writing the formula for the area of a triangle, students did not know what to do next until it was proven that the triangle area was equal to the area of a trapezoid (in Figure 4).

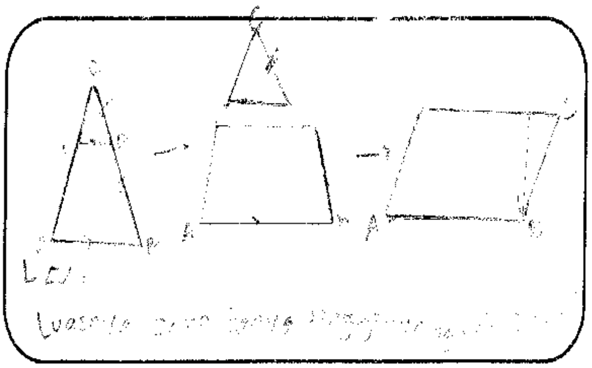

Figure 3. Geometric proof

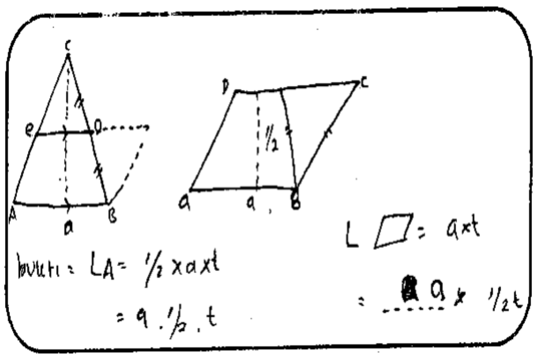

Figure 4. Algebraic proof

In contrast to students who scored more than 70, when they experimented to find answers, they indirectly learned to analyze the solution step by step. If there was an incorrect step, it was hard for them to continue solving the problem in the next stage. Then, they consulted with the teacher to get the directions to rearrange the strategy from the wrong move. Overall, the increase in students' RTS was in the moderate category, indicated by an average N-Gain score of 0.533.

Improving reflective thinking skills and independent learning was not easy since they must be done continuously (Yuni & Fisa, 2020). The results of this research about RTS are supported by previous research (Masamah, 2017). The research results concluded that the improvement of students' mathematical reflective thinking skills who received problem-based learning was significantly better than students who received conventional learning in terms of students' initial mathematical abilities. Also, referring to the N-Gain test of mathematical reflective thinking skills, it was found that there was an interaction indicating that the learning affects the improvement of mathematical reflective thinking skills based on students' initial mathematical abilities (Masamah, 2017).

Figure 5 is the result of the pretest of students' SRL before receiving the PBL model. The blue bars are more dominant than other colors. They indicate that students with low SRL scores were more than students with moderate and high scores.

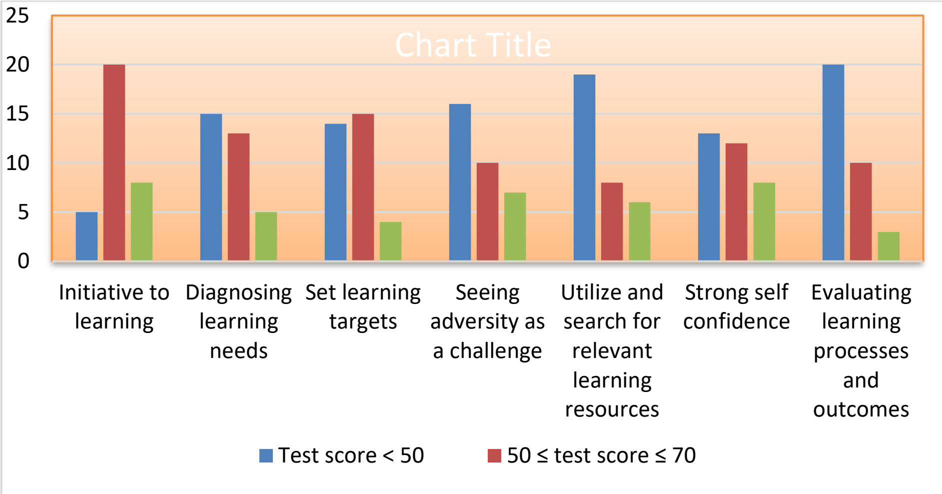

Figure 5. The Pretest Data of Students' SRL

Figure 6 is students' SRL posttest data. The blue bars are less than the other two colors. They indicated that students who got scores of more than 50 and 70 were increasing.

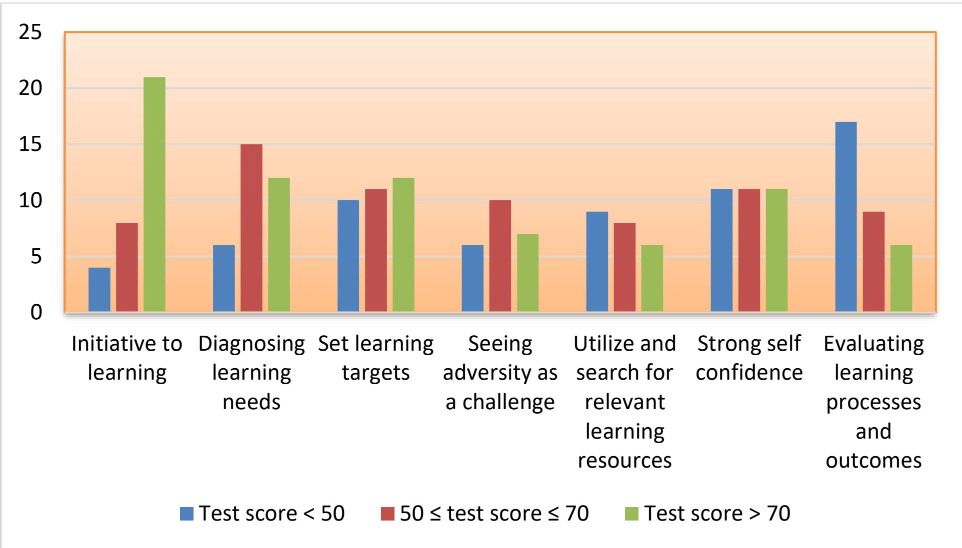

Figure 6. The Posttest Data of Students' SRL

An analysis was carried out on the pretest and posttest scores to determine the increase in students' SRL on each indicator. The SRL improvement data is shown in Table 8 below:

Table 8. The SRL Improvement

	RTS Indicators	**Pretest**	**Posttest**	**N_Gain**	**Criteria**
1.	Initiative to learning	11,21	15,29	0,529	Moderate
2.	Diagnose learning needs	12,37	15,22	0,366	Moderate
3.	Set learning targets	12,67	15,89	0,453	Moderate
4.	See adversity as a challenge	12,53	14,81	0,278	Low
5.	Utilize and search for relevant learning resources	13,24	15,93	0,380	Moderate
6.	Strong self-confidence	12,66	16,91	0,698	Moderate

RTS Indicators	Pretest	Posttest	N_Gain	Criteria
7. Evaluate learning processes and outcomes	13,14	15,18	0,261	Low
Average	12,55	15,60	0,424	Moderate

The N-Gain value between pretest and posttest on SRL is shown in Table 8. On average, students' SRL N-Gain value was 0,424 within the moderate category (Meltzer, 2002). In terms of indicators, the average increase was in the moderate category. Based on the questionnaire results, the fourth indicator was in a low category since 63% of students did not consider the difficulty in solving mathematics problems as challenges. They thought the questions were difficult, so the teacher must guide them. Therefore, it was difficult to increase students' learning independence. The low average of the fourth indicator affected the seventh indicator. Those who did not yet have a high SRL found it difficult to evaluate their work. Thus, it was difficult to increase students' learning independence. The findings can be seen in Figure 7. The students who were not challenged with difficult problems expected help from the teacher. On the other hand, students who considered difficult questions challenging had high learning independence and self-confidence.

(a) **(b)**

Figure 5. Students' Independent and Dependent Learning Atmosphere

In practice, the teacher acted as a facilitator and guided students individually and in groups. Figure 5 depicts students who were independent (Figure 5. a). They were not confident to solve the problem. Hence, the teacher was asked to guide them. Contrary to Figure 5(b), the students looked confident in completing answers since the teacher only observed and evaluated the results of their work.

The RTS and SRL improvement through the PBL model was described and proven by the N-Gain calculation. These findings were strengthened by calculating the t-test. Based on the statistical tests, the t-count value was 7.849, and the t-table was 1.68 (significance level of 0.05). Therefore, it was concluded that there was a significant RTS difference before and after the PBL model was applied. The average increase of each indicator was in the moderate category. The SRL data was obtained by distributing a questionnaire, where the t-count value was 0.028, and the t-table was 1.68 (significance level of 0.05). Therefore, there was no significant difference in the students' SRL before and after the PBL model was applied in mathematics learning.

Based on interviews with three students, each represents the SRL criteria (Table 5). The three students stated that they liked and could follow the PBL learning steps. The teacher was very clear in guiding students to solve problems. Moreover, the teacher's explanation was assisted by concrete media so that the teacher's explanation could be understood quickly. Students can use the media used by the teacher to conduct experiments. With the learning media, the students developed strategies to prove the area of a two-dimensional shape.

Figure 6. Learning Media Used by Teachers and Students

When the teacher asked why students' learning independence was not optimal and still expected help from the teacher, the students with SRL scores of less than 70 answered that they were not sure their answers were correct without the teacher's guidance. In contrast, students with SRL scores of more than 70 stated that they always wanted to find solutions to any difficult problems on their own because they considered the problems as challenging and interesting. There was a certain satisfaction in finding answers without the help of a teacher. When you tried it for the first time, it felt difficult. However, there is a certain satisfaction when you succeed, and you want to do it again. Very strong self-motivation drove them to succeed independently in solving problems.

Based on the N-Gain value, there was an increase in the average of each indicator. However, there was no difference in students' SRL before and after applying the PBL model. It happened because SRL is intrinsic, appears or awakens from within the students, and will be stronger if they have high confidence in their abilities. Building a person's independence relying on the environment will certainly not work optimally if one does not have SRL (Sundayana, 2018). The results of this research are in line with Sundayana's research (Sundayana, 2018). Sundayana found no difference in the level of self-regulated (student learning independence) in learning mathematics in terms of students' learning style. In contrast, Melissa found through classroom action research that the PBL Model can increase students' learning independence or SRL (Melissa, 2016).

CONCLUSIONS

Based on the research, there were differences in the use of the PBL model on students' mathematical reflective thinking skills. The PBL model prioritizes giving problems to students and training them to solve problems based on the knowledge they already have. However, it did not show a difference in students' SRL abilities, although there was an increase based on the value of N-Gain. Therefore, it can be concluded that the PBL model had a positive effect on students' RTS but had no effect on students' SRL abilities. There was a limitation when selecting the subjects since the research was conducted when social distancing level 3 was in effect. Although the school did not apply face-to-face learning, the students were so enthusiastic about applying the PBL model when learning mathematics. Another limitation was that the research time was not full like before the Covid-19 pandemic. Face-to-face meetings only lasted 50% of normal conditions before the pandemic. Therefore, it is necessary to do further research to improve the weaknesses of this research.

AUTHOR CONTRIBUTIONS STATEMENT

YY contributed to ideas in research and research design. APK tasked with collecting data, and analyzing data. NH is responsible for composes conclusions.

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