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The Influence of Problem Based Learning Models and Metacognition Knowledge on Students Mathematics Learning Outcomes

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Abstract
The aim of this research is to explore and identify the influence of using the Problem Based Learning (PBL) model on the mathematics learning outcomes of class VII students at Public Middle School 1 Tanjung Jabung Timur, as well as to understand the relationship between students' metacognitive knowledge and their learning outcomes in the context of using the PBL model. In this study, the research design followed a 2x2 factorial design with a pretest and posttest. The sampling technique in this research used simple random sampling. The experiment consisted of 4 meetings in a series of activities, namely the first was pre-learning preparation and group division and determining group leaders. The instruments in this research used a metacognitive knowledge questionnaire and learning outcomes tests. Analysis of this research data uses a pretest average similarity test (one way ANOVA). Based on research on the use of the PBL model in class VII students at Public Middle School 1 Tanjung Jabung Timur, it can be concluded that the PBL model has a positive effect on students' mathematics learning outcomes, with a higher level of achievement compared to the conventional approach. In addition, metacognitive knowledge also influences mathematics learning outcomes, where students with high metacognitive knowledge show statistically significant differences compared to students who have low metacognitive knowledge.

Keywords: Learning Outcomes; Mathematics; Metacognitive; Problem Based Learning

INTRODUCTION

Problem-based learning (PBL) in the field of educational technology is included in the assessment/research area, namely problem analysis. Problem-based learning is learning that requires students' mental activity to understand a learning concept through situations and problems presented at the beginning of learning (Fadila, 2021; Sakir & Kim, 2020). The problems presented to students are problems of everyday life (contextual). This problem-based learning is designed with the aim of helping students develop thinking skills and develop problem-solving abilities, learning various adult roles through their involvement in experiences (Hoyi & Liza, 2021; Kolar & Hodnik, 2021). In problem-based learning, students are required to solve the problems presented by digging up as much information as possible, then analyzing and finding solutions to existing problems (Shantha Nair et al., 2020). The solution to this problem does not absolutely have one correct answer, meaning that students are also required to learn creatively (Sandari, 2020; Sumarni & Kadarwati, 2020). Students are expected to become individuals who have broad insight and are able to see the relationship between learning and aspects of the environment.

Problem-based learning makes changes in the learning process, especially in terms of the teacher's role. The teacher does not just stand in front of the class and act as a guide for students in solving problems by providing ready-made solution steps, but the teacher goes around the class facilitating discussions, asking questions, and helping students to become more aware of the learning process (Isa, 2020; Suhendri & Kurniawan, 2022; Wicaksono et al., 2021). In the world of education, metacognition does not exist as much as in the world of psychology. Sometimes after hearing mathematics, people feel that there is something so dangerous that it seems scary. In fact, mathematics is something that is very enjoyable to dive deeper into (Ho & Devi, 2020; Setiana et al., 2021). For this reason, the teacher's role is very important in providing a cheerful, cheerful and encouraging atmosphere when mathematics learning takes place. This is closely related to efforts to foster students' metacognition in the mathematics learning process. The manifestation of mathematics subjects in primary and secondary education is school mathematics. School mathematics are elements or parts of mathematics that are chosen based on or oriented towards educational interests and the interest in mastering and utilizing technology in the future (Ngkoti, 2021; Soboleva et al., 2020). Therefore, mathematics subjects given in primary and secondary education are also intended to equip students with logical, analytical, systematic, critical and creative thinking skills, as well as the ability to work together.

The problem-based learning model is a learning model with a student learning approach to authentic and meaningful problems for students which functions as a basis for student investment and inquiry, so that students can construct their own knowledge, develop higher skills and inquiry, make students independent, and increase confidence self. This model is characterized by using real life problems as something and improving critical thinking and problem solving skills, as well as gaining knowledge of important concepts (Maknun, 2020; Wulan, 2020). This learning model prioritizes the learning process where the teacher's task must focus on helping students achieve self-direction skills. Problem-based learning is used at a higher level of thinking, in problem-oriented situations, including how to learn (Hajarina, 2021; Servant-Miklos, 2020).

PBL is a learning model based on the principle that problems can be used as a starting point for gaining or integrating new knowledge. It seems that presenting problems at the beginning of learning is not difficult, because this opportunity invites students' curiosity, inquiry, involvement in learning and motivation to learn (Cabello et al., 2021; Ningsih, 2020). Existing problems are used as a means so that students can learn something that can support their knowledge. PBL is a learning process whose starting point is learning based on problems in real life, then from these problems students are stimulated to study problems based on the knowledge and experience they have previously so that from this new knowledge and experience will be formed (Servant-Miklos, 2020). Discussion using small groups is the main point in implementing PBL (Ngadiso et al., 2021). The PBL model tested in this research follows five phases, namely: 1) Orienting students to the problem; 2) Organizing students to study; 3) Assisting independent and group investigations; 4) Develop and present artifacts (work results) and exhibit them; 5) Analysis and evaluation of the problem solving process.

However, the definition of metacognition is a person's awareness of their own thinking process. Meanwhile, thinking awareness is a person's awareness of what is known and what will be done. The most common understanding of metacognition is thinking about how to think. Metacognition is a theory of cognition (Kuhn, 2022). Metacognition also means knowledge about the cognitive abilities possessed and how those abilities can be applied to cognitive processes (Salam et al., 2020). Furthermore, metacognition is often related to personal, task and strategy. Metacognitive abilities are believed to be high-level cognitive abilities necessary for knowledge management. Students are required to set their own learning goals and determine appropriate learning strategies to achieve these goals. Learner responsibilities also include monitoring the learning process and changing learning strategies when necessary.

Metacognition as knowledge and awareness about cognitive processes. Metacognition is a process of generating interest because someone uses cognitive processes to reflect on their own cognitive processes. Metacognition is very important because knowledge about cognitive processes can guide students in developing and choosing strategies to improve positive performance (Stephanou et al., 2020). Thus metacognition relates to a person's knowledge about their own cognitive processes and the ability to use these processes. Students need to be aware of the strengths and weaknesses of their cognitive abilities and try to organize them to be applied appropriately in solving tasks or problems.

Metacognition refers to higher-level thinking that involves active control in the cognitive learning process. Activities such as planning how to approach a given learning task, monitoring understanding, and evaluating progress in completing tasks are metacognitive in nature (Stanton et al., 2021). Metacognition is the ability to think where the object of thinking is the thought process that occurs within oneself. In the learning context, students know how to learn, know their abilities and learning modalities, and know the best learning strategies for effective learning. Metacognition is a form of ability to look at oneself so that what one does can be controlled optimally. Students with metacognitive knowledge are aware of their strengths and limitations in learning (Ramadhanti & Yanda, 2021). This means that when students know their mistakes, they are aware of admitting that they were wrong, and trying to correct them.

Previous research found that the Problem Based Learning (PBL) model was effective on students' metacognitive skills in class X Science (Sari et al., 2022). This can be seen in, the characteristics of learning using the PBL model for students' metacognitive skills to support each other. Thus, learning stages that are easy to understand are very necessary in implementing learning so that students are not burdened with complicated steps, but can focus on the learning process so as to improve students' metacognitive skills. So as a form of novelty and generalization of previous research, this research was carried out, the difference is that this research was carried out at junior high school level in mathematics subjects.

Metacognition is a person's ability to regulate and control their thinking processes, which include problem solving, decision making, critical thinking, and creative thinking. It consists of two main components: metacognitive knowledge, which includes awareness of thinking and strategy selection, and metacognitive experience/metaregulation, which includes planning, evaluation, and monitoring. The components of metacognition include knowledge about cognition (declarative, procedural, conditional) and regulation of cognition (planning, information management strategies, monitoring understanding, debugging, evaluation). Learning outcomes are a process that involves behavior, talent, training, and experience, not just final achievement (Asim et al., 2021). In learning, it is important to understand what material will be taught and how to teach it to achieve learning objectives.

Learning needs to be adapted to environmental conditions and the existence of learning facilities available at the school or those that can be created by the teacher himself. The meaning of learning outcomes cannot be separated from what happens in teaching and learning activities, learning outcomes both in the classroom, at school and outside school. In the teaching and learning process, student learning outcomes are the grades obtained after completing the learning process and are carried out through tests at the end of each lesson. It is important for teachers to know student learning outcomes as a basis for creating more appropriate learning objectives. After the learning process is complete, student success is measured through the implementation of teaching objectives (instructional objectives). The aim of this research is to explore and identify the influence of using the Problem Based Learning (PBL) model on the mathematics learning outcomes of class VII students at Public Middle School 1 Tanjung Jabung Timur, as well as to understand the relationship between students' metacognitive knowledge and their learning outcomes in the context of using the PBL model.

RESEARCH METHODS

Research Design

In this study, the research design followed a 2x2 factorial design with a pretest and posttest. Both groups of students; treatment and control, following learning with the same materials, objectives, learning resources and teachers. The implementation of learning differs in terms of the methods used. The first group as the treatment group carried out learning using the PBL method, while the second group or control group carried out conventional learning. Each group conducts learning in the same room and environmental conditions at Public Middle School 1 Tanjung Jabung Timur.

In line with the hypothesis to be tested, namely the effect of using the PBL model with the influence of high and low student metacognitive knowledge variables, as well as the influence of the interaction between these two variables on the dependent variable, namely mathematics learning outcomes, a 2x2 type factorial experimental design was used in this research. Table 1 below shows the factorial design (2x2) used in this research.

Table 1. Factorial Design (2x2)

Metacognitive Knowledge	A_1 PBL model	A_2 Conventional Learning
B_1 (low)	A_1B_1	A_1B_2
B_2 (high)	A_1B_2	A_2B_2

Research Target/Subject

The population in this study were students at Public Middle School 1 Tanjung Jabung Timur. The sampling technique in this research used simple random sampling. The sample obtained in this research was 50 students who were made into two class groups. Each group conducts learning in the same room and environmental conditions at Public Middle School 1 Tanjung Jabung Timur. Each group consists of 25 students.

Research Procedure

The experiment consisted of 4 meetings in a series of activities, namely the first was pre-learning preparation and group division and determining group leaders. Next, each group underwent a metacognition knowledge questionnaire test and a learning outcomes test (pretest). At the next meeting, each group was given treatment according to the planned learning plan. The treatment will be carried out over 4 meetings of 2 x 45 minutes each (2 class hours). The experiment ended by holding 1 meeting at the end to carry out a post-test, namely an essay test.

Instruments, and Data Collection Techniques

The instruments in this research used a metacognitive knowledge questionnaire and learning outcomes tests. The experiment ended by holding 1 meeting at the end to carry out a post-test, namely an essay test.

Data analysis technique

After the pretest average similarity test (one way ANOVA) was completed, namely $t_{count} < t_{table}$ so that H_0 was rejected, meaning there was no difference in initial ability between the experimental class and the control class or both classes had the same initial ability. Then proceed with testing the research hypothesis, namely testing the difference between the independent variable and the dependent variable using posttest-pretest difference data (Prabawati et al., 2020). There are assumptions that must be met before carrying out the ANOVA test, namely that the data is normally distributed in each class and the variance is the same. Based on this, an assumption test was carried out first for each class (upper and lower in the experimental and control classes), including: 1) Lilliefors normality test; and 2) Barlett's Homogeneity Test, each of which was calculated manually using Microsoft Excel.

RESULTS AND DISCUSSION

The results of the table calculate the average mathematics learning outcomes from the pretest-posttest scores for the four testing groups. Recap the data in the following table.

Table 2. Recapitulation of Average Values for Mathematics Learning Results

Average	Learning model		Average
Metacognition Level of Knowledge	PBL	Row Totals	Total Baris
Low	52.188	52,032	52.032
High	31.875	29,219	29.219
Column Totals	39.219	Total Row Column	Total Baris Kolom 40.626

Next, calculate the F value with two-way Anova to test hypotheses 1, 2 and 5.

Table 3. Comparison of the calculated F value with the Two Way Anova F table

No.	Hypothesis	$F_{Calculated}$ value	F_{Table} values	Conclusion
1	H_{01} : $\mu A_1 = \mu A_2$ H_{a1} : $\mu A_1 > \mu A_2$	36,467	2,78	Ho was rejected
2	H_{02} : $\mu B_1 = \mu B_2$ H_{a2} : $\mu B_1 > \mu B_2$	36,467	2,78	Ho was rejected
5	H_{03} : A X B = 0 H_{03} : A X B $\neq$ 0	8,165	2,78	Ho was rejected

Next, calculate the Tukey value to test hypotheses 3 and 4, which are presented in table 4 below:

Table 4. Tukey value to test hypotheses 3 and 4

Hypothesis	Group	Class Size (N)	Sample Average	Difference Value
3	µA1B1	25	51.875	25.312
	µA2B1	25	26.563	
4	µA1B2	25	52.188	20.313
	µA2B2	25	31.562	

These results are interpreted as follows. If in the interval there is a value of 0, at the significance level α= 0.05, then $\mu i \neq \mu j$. Thus the conclusions obtained for the entire hypothesis are:

1). Hypothesis 1 with A_1 is the PBL model and A_2 is the conventional model

H_{01} : $\mu A_1 = \mu A_2$

H_{a1} : $\mu A_1 > \mu A_2$

Decision: The statistical test shows that the Fcount is 1744.939 with a probability of 0.000. Because the probability <0.05 then H_0 is rejected. In other words, there is an influence of the PBL model on higher order thinking skills.

2). Hypothesis 2 with B_1 being low metacognitive knowledge and B_2 being high metacognitive knowledge:

H_{02} : $\mu B_1 = \mu B_2$

H_{a2} : $\mu B_1 > \mu B_2$

The statistical test shows that the F_{count} is 14.602 with a probability of 0.000. Because the probability <0.05 then H_0 is rejected. In other words, there is an influence of metacognitive knowledge on students' mathematics learning outcomes.

3). For hypothesis 3, using the Tukey test, there is no value 0, so $\mu_i = \mu_j$, then $\mu A_1B_1 = \mu A_2B_1$ in other words, there is an influence of the PBL model on the mathematics learning outcomes of students in the group of students who have high metacognitive strategies.

4). Hypothesis 4, the results of the Tukey value calculation, interpret that there is no value of 0, so $\mu_i = \mu_j$, then $\mu A_1B_1 = \mu A_2B_1$ so H_0 rejected, or in other words there is an influence of the PBL model on the mathematics learning outcomes of students in the group of students who have low metacognitive knowledge.

5). Hypothesis 5: Looking at the interaction between PBL learning model variables and metacognitive knowledge:

H_{03} : $A \times B = 0$

H_{03} : $A \times B \neq 0$

The statistical test shows that the Fcount is 8.165 with a probability of 0.06. Because the probability is > 0.05 then H_0 rejected. In other words, there is an interaction between the PBL model and metacognitive knowledge on mathematics learning outcomes.

Table 5. Factor analysis results

Row factor	Column Factor		Row average
	PBL model (A1)	Conventional approach (A2)	
High Metacognitive Knowledge (B1)	52.188	51.875	52.032
Low Metacognitive Knowledge (B2)	31.875	26.563	29.219
Column Average	39.219	42.032	40.626

Based on table 5, it is discussed that students with high metacognitive knowledge have a difference in scores that is not much different whether taught with a problem-based learning model or taught with a conventional model. In the sense that students who have high metacognitive knowledge have no problem being taught with any learning model because these students are able to control, monitor and control themselves in learning, these students are independent in learning. Meanwhile, students with low metacognitive knowledge are better taught using a conventional model, because if taught using a problem-based learning model, students with low metacognitive knowledge are not yet able to understand problems and solve problems, these students need teacher direction and guidance, students are not yet able to learn independently.

The learning process using conventional methods has weaknesses in improving learning outcomes, in this research it is metacognitive knowledge. The weaknesses include that students are less able to develop their minds (lazy to think), tend to be passive, have difficulty working together and are individual, and are less motivated in learning activities in class. Students' weaknesses in learning are thought to be from the habits carried out by teachers in the learning process which places more emphasis on teacher-centred where learning is teacher-centred, resulting in students' potential and thinking abilities not being "activated" to the maximum, students are only listeners during the learning process. This causes students to tend to be passive and less skilled at communicating in learning activities in the classroom.

Learning is a necessity to face the problems that occur in this world, so it is appropriate for students to be able to solve problems that occur, especially those related to mathematics. In response to this, the appropriate model is the PBL learning model. The PBL learning model is a learning model with a student approach to authentic problems (real problems), so that students are able to develop their own knowledge, develop higher skills and inquiry, make students independent and increase their self-confidence, so that students learn, especially in mathematics lessons. one of the characteristics is that it is abstract and becomes real because it is connected to problems that occur in the student's environment (contextual).

PBL is built on the theory of constructivism, brought by researchers such as John Dewey, Lev Vygotsky, Jean Piaget, Jerome Bruner, who rely on the belief that all humans have the ability to build knowledge in their thinking through the process of discovery and problem solving. If discovery is the goal of learning, students must be able to develop their thinking abilities. To develop students' willingness to think, educators must first be able to develop a good perception of what is being learned. The teaching and learning process of mathematics subjects will run smoothly if students and teachers are both active in carrying out activities. Success in the teaching and learning process is one of the responsibilities of the teacher/instructor, while other elements function as supporters. Good metacognitive knowledge about mathematics will be able to encourage students' interest and motivation to take learning seriously.

Various efforts have been made to optimize mathematics learning outcomes. First, the mathematics learning material measured only consists of 3 basic competencies, so this research is only able to rely on basic competencies which are used as measuring tools in improving mathematics learning outcomes. Second, the implementation of the PBL model in this research is only limited to one subject for students at Public Middle School 1 Tanjung Jabung Timur class VII, even semester for the 2021/2022 academic year. Third, controlling for covariates, in this case students with high metacognitive knowledge will be enthusiastic about learning, while those with low metacognitive knowledge or lack of preparation before studying mathematics will be lazy to learn, let alone think about solving problems.

There are many ways to improve mathematics learning outcomes and metacognitive knowledge, one of which is by using the PBL model. The PBL model is proven to be superior both in terms of learning outcomes and other aspects such as attitudes and behavior. This is supported by the results of previous research that the problem-based learning model provides students with the opportunity to search for and understand the material presented through problem solving activities in order to provide a deeper understanding so that cognitive learning outcomes increase (Irmawati. H et al., 2023). The difference is that previous research was conducted on class VII students in the Sulawesi Region.

The results of this research have important implications in the context of developing more effective mathematics learning. The finding that students with high metacognitive knowledge do not show significant differences in scores, whether taught with a problem-based learning model or a conventional model, shows that these students have the ability to learn independently. However, for students with low metacognitive knowledge, it is better to be taught using the conventional model because they still need teacher guidance and direction in understanding and solving problems. This highlights the importance of developing metacognitive knowledge in improving mathematics learning outcomes.

In addition, these findings also show that the use of the PBL model has the potential to improve mathematics learning outcomes and students' overall metacognitive knowledge, especially through authentic approaches to problems and increasing student involvement in the learning process. Therefore, this research provides a strong foundation for developing more innovative and inclusive mathematics learning strategies, with an emphasis on using the PBL model to improve students' thinking skills as well as their metacognitive knowledge. The limitations of this research include a limited sample of class VII students, only considering the influence of the PBL model and metacognitive knowledge on mathematics learning outcomes, and limited time and resources.

CONCLUSION

Based on research on the use of the PBL model in class VII students at Public Middle School 1 Tanjung Jabung Timur, it can be concluded that the PBL model has a positive effect on students' mathematics learning outcomes, with a higher level of achievement compared to the conventional approach. In addition, metacognitive knowledge also influences mathematics learning outcomes, where students with high metacognitive knowledge show statistically significant differences compared to students who have low metacognitive knowledge. The interaction between the use of the PBL model and metacognitive knowledge has also been proven to influence students' mathematics learning outcomes, indicating that the superiority of the PBL model in mathematics learning can be influenced by the variable of students' metacognitive knowledge. Recommendations for further research are to further explore the mechanisms of how the PBL (Problem-Based Learning) model and metacognitive knowledge interact to influence students' mathematics learning outcomes.

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