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Do Eligible Teacher and Student Activities in Problem-Based Mathematics Learning Impact Critical Thinking?

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Abstrak

Penelitian studi kasus ini dilakukan dengan cross sectional desain. Partisipan sebanyak 32 siswa kelas V dan seorang guru. Penentuan partisipan siswa dan guru menggunakan teknik sampling jenuh (non-probabilitas). Teknik pengumpulan data melalui observasi, wawancara, dan tes. Tujuan penelitian menyelidiki apakah aktivitas belajar siswa dan guru yang eligible dalam model PBL dapat berdampak positif terhadap keterampilan berpikir kritis. Analisis data meliputi analisis resiko dan analisis dampak dari PBL. Temuan penelitian menunjukkan bahwa model problem based learning (PBL) mampu mengaktifkan potensi siswa dan guru melalui penciptaan aktivitas belajar yang tinggi. Aktivitas belajar siswa dan guru yang eligible dalam model PBL dapat berdampak positif terhadap keterampilan berpikir kritis. Dengan kata lain, kegiatan pembelajaran dalam PBL mempunyai pengaruh yang signifikan terhadap keterampilan berpikir kritis siswa. Dampak positif terhadap siswa ini tidak lepas dari peran guru sebagai fasilitator yang efektif dalam implementasi PBL.
Kata Kunci: aktivitas belajar; berpikir kritis; implementasi; problem-based learning.

Abstract

This case study research was conducted with a cross-sectional design. The participants were 32 fifth-grade students and a teacher. Determining student and teacher participants used saturated (non-probability) sampling techniques. Data collection techniques through observation, interviews, and tests. The research objective is to investigate whether the learning activities of eligible students and teachers in the PBL model can have a positive impact on critical thinking skills. Data analysis includes risk analysis and impact analysis of PBL. Research findings show that the problem-based learning (PBL) model can activate the potential of students and teachers through the creation of high-learning activities. The learning activities of eligible students and teachers in the PBL model can have a positive impact on critical thinking skills. In other words, learning activities in PBL have a significant influence on students' critical thinking skills. This positive impact on students cannot be separated from the teacher's role as an effective facilitator in implementing PBL.
Keywords: learning activities; critical thinking; implementation; problem-based learning.

I. Introduction

The increasingly rapid development of the global world and the rapid spread of information require individuals' critical thinking skills to understand and reason (Tajuddin et al., 2023). With this critical thinking ability, a person will verify their thoughts so that they produce the best point of view or decision. Therefore, education and learning in schools need to equip students with critical thinking skills so that students can behave rationally and make decisions in choosing the best alternative for themselves in facing the era of globalization (Turan et al., 2019).

Developing critical thinking skills in students is an important effort to prepare them for future challenges. By understanding and addressing existing challenges and obstacles, these efforts can be more effective and have a positive impact on student learning as a whole. By learning how to think critically, students will be better prepared to evaluate information and make informed decisions about themselves (ŽivkoviL, 2016; Sunaryo, Solihah, & Yulisma, 2024). In addition, critical thinking can increase intellectual curiosity and creativity (Suhirman & Ghazali, 2022). Critical thinking is an intellectual thinking process that involves assessing the quality of thinking, using reflective, clear, rational, and independent thinking. According to research by Dr. Peter Facione (2015, cited Mastuti et al., 2022) there are five indicators of critical thinking, namely: interpretation, analysis, evaluation, inference, explanation, and self-regulation. These critical thinking skills can be trained in students through active student-centred learning (Xhomara, 2022). Through continuous practice in learning, students will have increasingly mature critical thinking skills (Jirout, 2020).

To improve students' critical thinking skills, educators can apply appropriate learning models that are in accordance with the learning material (Noverli, Asih, & Juandi, 2024). A good learning model is a student-centred learning model, one of which is the application of problem-based learning in mathematics classes.

Problem-based learning is a contextual learning model that uses problems as the main focus of learning (Yew & Goh, 2016). The main purpose of implementing a problem-based learning model is to help students develop analytical and critical thinking skills from learning (Ningrum et al., 2021). This method is carried out with the aim of developing students' abilities in critical thinking, developing learning independence, and increasing students' self-confidence.

Problem-based learning (PBL) is one of the learning activities that is oriented towards active students. Active learning is intended to optimize the use of all the potential possessed by students. By optimizing potential, all students can achieve satisfactory learning outcomes according to their personal characteristics.

Several steps in PBL are outlined in five phases (Dewantara et al., 2023; Tursynkulova et al., 2023), namely: (a) student orientation to the problem, (b) organizing students to learn, (c) guiding individual and group investigations, (d) developing and presenting work results, and (e) analyzing and evaluating the problem-solving process. In PBL, the teacher plays a role in guiding and directing students in the problem-solving process. The application of PBL in mathematics classes requires teacher instructional skills in managing learning. Teachers as managers of the PBL environment are responsible for activating students' resources and potential into a critical thinking power for students in problem solving.

Activity is a characteristic of the learning process. Without someone's activity, the learning process is impossible. Learning activities are students' activities in the learning process, starting from physical activities to psychological activities (Dini et al., 2023). Physical activities are in the form of basic skills, while psychological activities are in the form of integrated skills. Learning activities are very important in learning mathematics in schools because they provide opportunities for students to interact with the objects being studied. Good learning activities can help students build better knowledge.

Student activity in undergoing the learning process is one of the keys to the success of achieving educational goals (Afriansyah & Arwadi, 2021). When students are actively involved in learning, they feel more motivated and interested in the material being studied. Student participation and involvement allow them to have direct experience, feel more involved, and see the relevance of the material in the context of their own lives.

In the last five years, many research results have been reported on the effect of PBL on students' critical thinking skills (Dakabesi & Luoise, 2019; Manuaba et al., 2022; Suhirman & Ghazali, 2022; Tursynkulova et al., 2023; Yu & Zin, 2023). In quantitative research, PBL can improve learning outcomes and critical thinking skills (Budi et al., 2023; Qomariah, 2019). However, there has been no qualitative research that focuses on investigating student and teacher learning activities in PBL. Therefore, this study is the first in terms of investigating eligible student and teacher learning activities in PBL so that it has an impact on critical thinking skills. We hope that this research can be useful for educators and stakeholders in managing effective PBL.

II. Method

This research is a case study with a cross-sectional design. Cross-sectional design is a research approach to study the dynamics of the correlation between risk factors and their effects, where observation or data collection is carried out simultaneously at one time (Wang & Cheng, 2020)

The research participants were 32 fifth-grade elementary school students and one teacher. Determination of student and teacher participants using the saturation sampling technique (non-probability). Saturation sampling was chosen because it is suitable for small populations by including all members of the population (Tight, 2024). The students have heterogeneous characteristics in terms of gender, initial ability level, and age (10 to 12 years). Considerations for selecting teachers who teach using the PBL model include teachers who have expertise in teaching mathematics. Teachers understand and have implemented the PBL model in mathematics classes.

Data collection techniques in this study were observation, interviews, and written test. Observations of student and teacher activities in PBL were carried out directly. Researchers recorded PBL activities in full from the beginning of the lesson, the core of learning, and the closing. The observation assessment instrument was guided by the observation sheet for student and teacher activities in PBL learning. The student and teacher activities observed were learning activities in the five phases of PBL. The observed student learning activities (Dewantara et al., 2023) included (a) visual activities, (b) oral activities, (c) listening activities, (d) writing activities, (e) motor activities, (f) mental activities, and (g) emotional activities. Meanwhile, the observed teacher activities (Zainuddin & Hardiansyah, 2023) included (a) opening the lesson, (b) explaining the lesson material, (c) guiding the discussion, (d) providing reinforcement, and (e) reflecting on and closing the lesson. Interviews were conducted in a semi-structured manner. The interview instrument contained questions to obtain data on student and teacher perceptions of the implementation of PBL in mathematics classes. The test instrument consists of 5 questions to measure students' critical thinking skills. The test instrument has been tested for validity with product moment correlation ($r_{xy} = 0.920 > 0.576$; $p < 0.01$) and reliability test with Cronbach's alpha ($r1 = 0.75 > 0.70$; $p < 0.01$) to ensure the test results are accurate and reliable (Wijaya & Kloping, 2021).

In this study, the teacher implemented PBL with the subject matter of quadrilateral planes. One of the problems discussed by students was squares and rectangles. The mathematical problems were packaged in the form of story problems and had to be solved by the following students:

- Farmer A has a square garden with an area of $36m^2$.
- Farmer B and Farmer C have rectangular gardens with the same area as Farmer A's Garden.
- How many meters are the possible length and width of Farmer B's and Farmer C's gardens? Discuss with your group members.

The implementation of PBL follows five phases according to the learning syntax in PBL. PBL syntax is the steps of problem-based learning consisting of (a) Orienting students to problems, (b) Organizing students to learn, (c) Guiding individual and group investigations, (d) Developing and presenting results, and (e) Analyzing and evaluating the problem-solving process (Hidayati & Wagiran, 2020). Each phase contains real student and teacher activities. The activities of students and teachers in each phase of PBL are carefully observed by researchers. At the end of the learning process, students complete 5 written tests to measure students' critical thinking skills. The written test is designed according to the critical thinking skills indicators to be measured.

The implementation of this research has received ethical clearance and is funded by a research institution at the university level. Informed consent has been given to students and teachers by providing complete and clear information, and asking for their approval verbally and voluntarily. The school or teacher has agreed that the results of the research will be published without mentioning affiliations, names of students, and teachers vulgarly. The study began with a discussion between researchers and class teachers. Researchers and teachers agree on the steps for implementing PBL. Researchers prepare observation instruments for learning activities and test. The implementation of PBL learning in mathematics classes is recorded on video. Student and teacher activities are observed and recorded by observers. Interviews with students and teachers were also conducted to obtain data on their perceptions of the implementation of PBL

The observation data were analyzed descriptively statistically and qualitatively. To calculate the percentage value of observed learning activities using the formula NP = (R: SM) x 100%. In the formula NP is the percentage value of learning activities obtained by students, R is the score of learning activities obtained by students, and SM is the maximum assessment score. The results of the calculation of the formula will be grouped into a certain range of values with learning activity criteria: high (75 - 100), medium (51 - 74), low (25 - 50) and very low (0-24) (Dewantara et al., 2023).

Researchers analyzed observation data (qualitative) including risk analysis and impact analysis of PBL (Sutton & Austin, 2015). Several steps were taken to analyze observation data: visualizing the data that had been analyzed and data analysis in context to identify patterns, themes, and relationships. After conducting the interview, make a transcript of the interview results by listening to the interview recording and writing down the words heard. Conduct data reduction by making abstractions then taking and recording useful information according to the research context. The critical thinking ability test result data was tested using one-sample t-test statistics (test value = 75). Simple linear regression analysis was used to test the effect of learning activities on critical thinking skills. In the final data analysis, the researcher used the data source triangulation method. The purpose of data source triangulation is to explore the truth of information with various data sources from more than one subject who are considered to have different points of view.

III. RESULT AND DISCUSSION

Student and teacher activities in PBL were observed when students were doing learning activities in each phase of PBL. Learning activities (students and teachers) while participating in PBL in mathematics class were observed directly and recorded in video form. The results of the video recording were replayed to be analyzed carefully and then presented in the following description.

A. Phase 1: Student Orientation on The Problem

In the problem orientation phase in PBL, students carried out several activities. We successfully observed student activities that emerged in phase 1, such as: listening to learning objectives, listening to motivation from the teacher, understanding the terms and concepts in the problem, and determining the problems that occurred in the form of questions.

The teacher's activities explained the learning objectives, explained the equipment needed, and motivated students to actively solve the selected problems. The activities of teachers and students when interacting in phase one learning are reported in the following conversation.

Teacher	:	*Do you understand the problem that needs to be discussed?*
S-01	:	*This is a problem of the differences in the shape of the land of farmers A, B, and C.*
Teacher	:	*What are the terms and concepts that you find in this problem?*
S-02	:	*We are trying to understand the concept of square and rectangular flat areas*
S-03	:	*Are we free to determine the shape of the land of farmers B and C?*
Teacher	:	*Your question is very good and critical. Of course, you can propose different shapes of garden land.*

B. Phase 2: Organizing Students To Learn

Student activities in the organizing phase of the PBL learning model are: forming study groups, choosing and solving different problems, defining and organizing learning tasks, and conveying information that is already owned. They discuss factual information and information that each student has.

The teacher's activities in phase 2 are that the teacher helps students define and organize learning tasks related to the selected problem. The activities of teachers and students when interacting in phase two learning are reported in the following conversation.

Teacher	:	*Have there been any divisions of tasks in your group? What are your tasks?*
S-04	:	*Andre is tasked with finding information about a square Romi is tasked with finding information about a rectangle What information can we share with your friends?*
Teacher	:	*A square has all sides of the same length.*
S-05	:	*A rectangular plane has two pairs of sides of the same length What facts did you obtain to develop this problem-solving strategy?*
S-06	:	*The area of a square plane = 36 so it can be written as 36 = 6 x 6*

C. Phase 3: Guiding Individual And Group Investigations

Student activities in individual and group investigations in the PBL model are: collecting appropriate information, conducting experiments, seeking explanations and solutions, recording data from investigations in worksheets, processing data obtained from their groups, answering questions on worksheets, and presenting the results of data processing in an agreed form. The role of the teacher in phase 3, the teacher monitor student involvement in collecting data and materials during the investigation process. The activities of teachers and students when interacting in phase three learning are reported in the following conversation.

Teacher : *What strategies did you use to solve the problem of the shape of farmer B and C's garden?*

S-08 : *We used grid paper to illustrate the area of farmer A's garden in the form of a square and then changed it into a rectangle*

S-09 : *We thought hard to investigate the problem of the shape of farmer B and C's garden by doing many experiments*

S-10 : *We found the idea that there is another form of multiplication where a x b = 36*

Teacher : *Wow…. I appreciate your efforts to solve this problem with pleasure.*

Teacher : *Have you reflected on the investigation and process used during the problem-solving activity?*

S-11 : *We have not checked the results of the problem-solving.*

S-12 *We are ready to re-check the investigation process from our group*

Teacher : *Have all group members agreed on the results of this problem-solving as a solution?*

S-13 : *All members of our group agree with the final results of this assignment*

S-14 : *We need to explain to group members to make decisions*

D. Phase 4: Develop and present the work

Student activities at the stage of developing and presenting group work results in the PBL model are: planning and preparing work to be reported and sharing tasks with friends to present the results of the discussion in front of the class. The role of the teacher in phase 4, the teacher guides the preparation of reports and helps students with various tasks to convey the results of their discussions to other groups in front of the class. The activities of teachers and students when interacting in phase four learning are reported in the following conversation.

Teacher : *Please have representatives from each group present the results of the discussion in front of the class.*

S-15 : *We report the results of the investigation from group 1 as follows.*

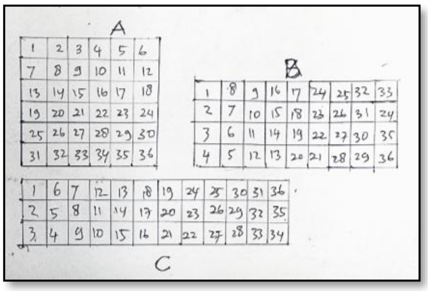

Figure 1. Results of Group 1 Investigation.

Teacher : *Please explain the results of the group discussion as in picture 1*

S-15 : *We agreed to make a picture of a square area by dividing it into 36 equal parts. Each box represents one square unit of 6 x 6 = 36 (see picture: A represents the area of Farmer A's Garden).*

S-16 : *We rearranged the 36 square unit boxes into rectangle B and rectangle C.*

S-17 : *We report the results of the investigation from group 2 as follows.*

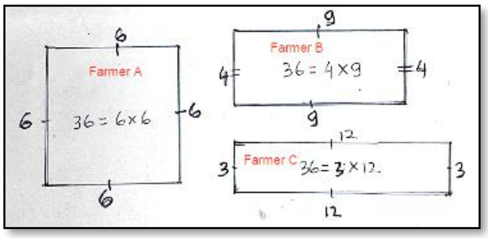

Figure 2. Results of Group 2 Investigation.

Teacher : *Please explain the results of the group discussion as in Figure 2*

S-17 : *The process of finding the size of farmer B and farmer C's gardens began with trial and error. We thought the number a x b = 36, what are the numbers a and b?*

S-18 : *We thought that 4 x 9 = 36 and 3 x 12 = 36. Then we drew it in the form of a rectangle according to the size.*

S-19 : *We report the results of the investigation from group 3 as follows.*

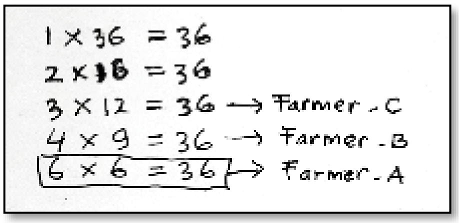

Figure 3. Results of Group 3 Investigation.

Teacher : *Please explain the results of the group discussion as in Figure 3*

S-19 : *We understand that the area of Farmer B and C's gardens is the same as the area of Farmer A's Garden but has different sizes. So, 36 is a base number, so we look for factors of the number 36.*

S-20 : *Based on Figure 3, we found the factors of the number 36 are 1, 2, 3, 4, 6, 9, 12,18, 36.*

E. Phase 5: Analyze and evaluate the problem-solving process

In the stage of analyzing and evaluating the problem-solving process in PBL, students can do activities such as: Reflecting on the investigation and evaluating the processes used. The teacher guides the presentation and encourages the group to give awards and input to other groups. The activities of the teacher and students when interacting in phase five learning are reported in the following conversation.

Teacher : *What do you think about Group 1's presentation?*

S-17 : *Wow... I understand from picture 1 like arranging tiles in different spaces but the number of tiles is the same as 36.*

S-18 : *Are there other arrangements?*

S-15 : *Of course, other shapes can still be arranged as different alternatives.*

Teacher : *Thank you. Group two's presentation is good and inspires other students to find solutions*

Teacher : *What do you think about group 2's presentation?*

S-19 : *The results presented by Group 2 are similar to Group 1, and their experiment was successful.*

S-20 : *I agree with group two's results. But, can you explain to us? Where did the idea come from?*

S-17 : *We think that half the area of the garden is 6 x 6 = (3 x 6) + (3 x 6).*

Teacher : *If we combine it, we get (3 x 6) + (3 x 6) = 3 x (6 + 6) = 3 x 12*
Thank you. Group three's presentation is good. Other students can use this strategy to find solutions

Teacher : *What do you think about group three's presentation?*

S-15 : *It seems that the strategy of finding factors of 36 is the best way.*

S-16 : *I am happy, it turns out there are*

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many alternative answers besides 4 x 9 and 3 x 12.

Teacher : *What distinguishes the land of farmers A, B, and C, besides their shapes?*

S-15 : *There are differences in the circumference of the land of gardens A, B, and C*

S-16 : *The circumference of the land of garden A = 6 + 6 + 6 + 6 = 24*
The circumference of the land of garden B = 4 + 9 + 4 + 9 = 26
The circumference of the land of garden C= 3 + 12 + 3 + 12 = 26

Teacher : *Thank you. Group 3's presentation was very good. Group three's explanation provided more alternative choices to find a solution. The conclusion is that the size of farmers A and B's gardens can vary, including 1 x 36 or 2 x 18, 3 x 12, or 4 x 9.*

Teacher : *I am very happy and proud of all your work. Your hard work is very persistent and never give up on completing this task. The cooperation between group members is very good. All members make useful contributions.*

Based on the results of observations of student activities during the PBL process, it can be reported in the form of descriptive statistics in Table 1. Student activities observed during the PBL process include: (1) visual activities, (2) oral activities, (3) listening activities, (4) writing activities, (5) motor activities, (6) mental activities, and (7) emotional activities. The category of student learning activities is measured using the criteria developed by Paul B. Diedrich (cited Dewantara et al., 2023).

Table 1.
Data on Observations of Student Activities in PBL

PBL Syntax	The real student's activity that observed							Mean Score (%)
	Act-1	Act-2	Act-3	Act-4	Act-5	Act-6	Act-7	
Phase 1: Orienting Students to the Problem	-	4.20	4.00	-	-	-	-	4.20 (84.0)
Phase 2: Organizing Students for Learning	-	4.30	-	4.00	-	4.00	4.15	4.11 (82.2)
Phase 3: Guiding Individual and Group Inquiry	4.30	4.00	3.70	4.20	4.30	4.00	3.90	4.04 (80.0)
Phase 4: Developing and Presenting Results	4.40	4.50	4.00	3.50	3.60	4.00	4.00	4.00 (80.0)
Phase 5: Analyzing and Evaluating the Problem-Solving Process	-	4.40	4.30	4.40	-	4.00	4.00	4.22 (84.4)
Mean Score (%)								4.12 (82,4)
Criteria								High

Information:
Act-1 = Visual activities; Act-2 = Oral activities; Act-3 = Listening activities;
Act-4 = Writing activities; Act-5 = Motor activities; Act-6 = Mental activities;
Act-7 = Emotional activities

Learning activities are one of the benchmarks for successful learning. Student learning activities in learning are considered good if the average percentage of learning activities has high criteria (see Table 1). In addition to observing student activities in PBL, researchers also reported the results of observations of teacher activities in PBL. Teacher activities in PBL that were observed included: opening lessons with apperception, explaining lesson materials, guiding discussions, providing reinforcement, and reflection in closing lessons (Arum & Hikmat, 2024). The results of observations of teacher activities are reported in Table 2 below.

Table 2.
Data on Observations of Teacher Activities in PBL

PBL Syntax	The real teacher activity					Mean Score (%)
	Act-A	Act-B	Act-C	Act-D	Act-E	
Phase 1: Orienting Students to the Problem	4.00	-	-	-	-	4.00 (80,0)
Phase 2: Organizing Students for Learning	-	4.00	5.00	-	-	4.50 (90.0)
Phase 3: Guiding Individual and Group Inquiry	-	-	5.00	4.00	-	4.50 (90.0)
Phase 4: Developing and Presenting Results	-	3.50	4.00	4.00	-	3.83 (76,6)
Phase 5: Analyzing and Evaluating the Problem-Solving Process	-	-	-	5.00	4.00	4.50 (90.0)
Mean Score						4.26 (85,3)
Teacher activity criteria						High

Information in Table 2:
Act-A = Opening the lesson with apperception; Act-B = Explaining the lesson material;
Act-C = Guiding the discussion; Act-D = Giving reinforcement:
Act-E = Reflection and closing the lesson

For sufficient research information, interviews were conducted with teachers and students. Interviews were conducted to obtain supporting data that strengthened the research findings. The following are excerpts from interviews with teachers and students at the school.

Researcher : *What do you think about student learning activities in PBL?*

Teacher : *Students are highly active and very enthusiastic in discussions. They work together to solve problems*

Researcher : *What are the obstacles that occur when implementing PBL in mathematics classes?*

Teacher *Factors of students' initial abilities, students have difficulty finding strategies to solve problems, level of thinking ability to the level of student confidence*

Researcher : *What are your challenges as a teacher when implementing PBL in mathematics classes?*

Teacher : *Teachers need to understand the learning model applied and prepare learning tools carefully.*

Researcher : *Selection of case studies that follow students' initial knowledge, carefully formulated, conducive to group discussions, and linked*

		to relevant learning outcomes.
S-01	:	*What is your impression after participating in problem-based learning in mathematics class?*
S-02		*I am very happy and have a challenging learning experience.*
Researcher	:	*I gain a better understanding of the teaching material*
S-03	:	*What skills do you gain when participating in PBL in mathematics class?*
S-04	:	*I become braver in asking questions and expressing opinions without fear*
S-05	:	*I can communicate better in discussions*

The following Table 3 is the data of the written test results of students' critical thinking skills. We present the data in the form of a concise statistical description.

Table 3.
Results of the Critical Thinking Test

Attributes	Statistical Data
Number of students	32
Highest score	96.0
Lowest score	65.0
Mean	83.7
Standard deviation	5.940
Score more than 75.0	29
Score less than 75.0	3

Based on the one sample t-test statistical test (test value = 75), the average value of a group of data (Table 3) obtained a Sig. (2 tailed) value of 0.015 < 0.05. This means that the average value of the students' critical thinking ability test is not equal to 75 or more than 75. Furthermore, the data values in Table 1 and Table 3 were subjected to statistical tests using regression analysis to test the influence of learning activities on students' critical thinking abilities (Table 4).

Table 4.
Linear Regression Coefficients

		Unstandardized B	Coefficients Std. error	Unstandardized Coefficients Beta	t	Sig.
Model	Constant	35.587	7.811		3.952	.007
1	Activity	.755	.194	.679	2.690	.029

*Dependent variable: Critical Thinking

In Table 4, the significance value of the activity variable is 0.029 <0.05 and the t value = 2.698 > 1.90 so that Ho is rejected and Ha is accepted, which means that there is an influence of learning activities on critical thinking skills. From the output of the summary model, the R Square value is 0.350. This value means that the influence of learning activities (X) on critical thinking skills (Y) is 35% through the regression equation Y = 35.587 + 0.755X. While 65% is influenced by other variables that are not studied.

F. Discussion

To answer the research question of whether student and teacher activities in PBL have an impact on critical thinking skills, we will discuss some research findings in depth. The results of observations of seven indicators of student learning activities in {BL (Table 1) and teacher strategies to activate students in mathematics PBL (Table 2) can be described through the following explanation. Table 1 reports that the average student activity is in the high criteria (82,4), and teacher competence in actualizing PBL (Table 2) is 85,3 (high) (Arum & Hikmat, 2024; Dewantara et al., 2023; Sutton & Austin, 2015). The first phase of PBL is student orientation to problems to improve students' critical thinking skills (Cholik et al., 2019). Students' visual activities are recorded while reading source books and paying attention to teacher explanations on the board and square pictures. Student activities in this first phase show students' ability to interpret the tasks that must be solved. Students read source books to get a lot of information about the material being studied so that students understand the problem.

In the second phase of PBL, observers noted that students carried out oral activities, namely discussing to understand and determine strategies for solving mathematical problems. In this second phase, the interpretation indicator (critical thinking) is clearly visible; students are in the process of understanding and expressing the intent or meaning of a problem. PBL starts from a problem that must be solved. Therefore, students are required to be skilled in problem-solving, creative thinking, and critical thinking. As stated by previous researchers (Bernstein & Isaac, 2018; Mulyanto et al., 2018; Tursynkulova et al., 2023), the second phase of PBL can take place effectively because of the continuous conditioning of the learning situation by the teacher, especially in group activities.

Motor activity is recorded in the third phase of the activity, namely, students investigating to find the size of a rectangle. They investigated whether the size of the rectangle was appropriate or not, with a square area of 36 (square meters). In this phase, students construct square and rectangle models. They compare the areas of squares and rectangles. In this third phase, students apply analysis indicators (critical thinking). Students are required to be able to identify the relationship between various statements, questions, concepts, descriptions and others. The role of the teacher in the third phase of PBL is to guide individual and group investigations. The teacher asks students critical questions about the results of their investigations (Yu & Zin, 2023). In this phase, the teacher provides structured scaffolding assistance so that students can construct their knowledge (Kusmaryono et al., 2021), Thus, students gain new knowledge from their critical thinking (Manuaba et al., 2022).

In the fourth phase, students' activities develop and present their work. Students actively present the results of group work in the form of representations of square and rectangular images complete with their dimensions (writing activity). They discuss by giving each other strong reasons for their work (oral activity). In the fourth phase, evaluation indicators (critical thinking) appear, and students are able to assess the credibility of a statement and the truth of a relationship between various statements, questions, concepts, descriptions and others. Based on their abilities, students want to put forward new ideas; this attitude is considered a critical thinking activity (Dakabesi & Luoise, 2019; Mulyanto et al., 2018). To encourage student activity, the teacher motivates students by giving further investigative questions. In the fifth phase, student activities are analyzing and evaluating the problem-solving process. Student activities at this stage are listening to presentations and criticizing the work of other groups (listening activity). They ask each other questions and evaluate their work (mental activity). The goal is for students to be able to re-check their solutions and draw conclusions as the right solution. Activities in this fifth phase characterize the achievement of inference indicators (critical thinking) and explanation and self-regulation (critical thinking), because students are required to be able to provide conclusions or provide reasons for the steps taken. The teacher acts as a facilitator providing space for reflection on the results of students' work and guiding students in drawing conclusions.

In the fifth phase, students' activities solve and complete the problem-solving process. Students' activities at this stage are listening to presentations and criticizing the work of other groups (listening activities). They ask each other questions and start their work (mental activities). The goal is for students to be able to re-check their solutions and draw conclusions about the right solution. Activities in this fifth phase characterize the achievement of inference indicators (critical thinking) and explanations and self-regulation (critical thinking) because students are required to be able to provide conclusions or provide reasons for the steps taken. The teacher acts as a facilitator who provides space for reflection on the results of students' work and guides students in concluding.

The PBL process through Phases 1 to 5 can invite students to actively think critically about existing problems and phenomena and create an enthusiastic learning atmosphere. The activeness of students in the PBL learning process can stimulate and develop the talents of students. Students can also practice critical thinking, and can solve problems in the learning process. In PBL, not only students are required to be active, but teachers must also be able to carry out strategies to activate students. In other words, students' critical thinking skills can be activated through the application of the PBL model.

Critical thinking skills can be improved through the process of phases 1 to 5 in PBL. PBL uses a learning approach to authentic problems. In PBL, students are not only asked to understand a problem but students must be able to work together to solve the problem, so that students are able to stimulate their critical thinking abilities and skills.

The results of interviews with students reported that after participating in the PBL process, there were changes and improvements in students' soft skills. Students have better communication skills than before. Students can lead discussions well (Putri et al., 2023); students become more confident in asking questions without fear (emotional activity). This positive impression from students cannot be separated from the role of teachers who are considered successful in implementing PBL in mathematics lessons. Students who have strong soft skills can improve their ability to solve mathematical problems and critical thinking skills, namely the ability to analyze facts logically and systematically to make the right decisions.

Soft skills are one of the personal supporting factors that allow someone to interact with others effectively in various situations and are useful in the world of work in the future. Meanwhile, the teachers feel that to be successful in PBL, they need to be prepared to understand the characteristics of PBL and to prepare the necessary equipment optimally. Teachers who implement PBL in mathematics classes face quite a tough challenge, but it is a valuable experience.

Learning activities are very important for students, where teachers provide students with opportunities to come into contact with the objects being studied as widely as possible. Eligible student and teacher learning activities in the PBL model can have a positive impact on students' critical thinking skills, namely (a) students can interpret tasks that must be solved by understanding the problem, (b) students are able to identify problems and analyze strategies that will be applied to solve problems, (c) students are able to evaluate the relationship between various statements, questions, and other concepts, and (d) students have the skills to make inferences and provide explanations in concluding by providing reasonable reasons.

Problem-based learning provides a real and challenging experience when students are active in the learning process. Table 4 shows that learning activities in PBL have a significant effect on students' critical thinking skills. With the implementation of PBL, students' critical thinking skills can develop, especially being trained to think critically about a problem. On the other hand, students' activities in identifying problems are related to the ability to make inferences and provide explanations. In identifying problems, critical thinking skills are needed, namely the ability to analyze to make inferences, and provide explanations, so that they can find the right solution to overcome the problem.

This positive impact on students cannot be separated from the role of teachers as effective facilitators in the implementation of PBL. In each phase (syntax) PBL allows students to have critical thinking skills). Thus, students' critical thinking skills can only be achieved and possessed by students if students successfully pass the stages (syntax) of PBL from phase 1 to 5 actively facilitated by the teacher.

The implications of this study are conveyed that in order to be successful in PBL in mathematics classes, teacher strategies are needed to activate the resources and potentials possessed by students. Some teacher strategies to increase student learning activities are: (a) motivating students to be active in learning and feel enthusiastic when facing problems, (b) designing effective learning media and posing realistic and challenging problems, (c) giving students the freedom to represent the results of their thinking, (d) using critical questions to develop research ideas, (e) managing the class conducively and facilitating students' learning needs with scaffolding, and (f) providing appreciation or rewards can motivate students to be active and contribute in class.

IV. Conclusion

The problem-based learning (PBL) model is able to activate the potential of students and teachers through the creation of high-learning activities. Eligible student and teacher learning activities in the PBL model can have a positive impact on students' critical thinking skills, namely (a) students can interpret tasks that must be solved by understanding the problems, (b) students are able to identify problems and analyze strategies that will be applied to solve problems, (c) students are able to evaluate the relationship between various statements, questions, and other concepts, and (d) students have the skills to make inferences and provide explanations in concluding by providing reasonable reasons. In other words, learning activities in PBL have a significant influence on students' critical thinking skills. The positive impacts that students have cannot be separated from the role of teachers as effective facilitators in the implementation of PBL.

The limitation of this study is that it only involved one observer of learning in the classroom so that the subjective nature of the observer is prone to bias. Although there is video recording documentation of learning activities, some student and teacher learning activities were not recorded in detail at certain PBL phases. In future research, researchers interested in PBL are advised to involve more than one observer so that the results of learning observations can be compared by involving video recordings of learning. Strategies that teachers can do to develop students' critical thinking skills are to provide opportunities to ask questions and collaborate and provide constructive feedback.

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