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A comparison of computational thinking skills: PBL model vs traditional learning

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Abstract
Computational thinking abilities assist students in solving complex problems, enhancing productivity, and preparing them to face challenges in various fields. The problem-based learning (PBL) model was chosen because it is believed to improve students' computational thinking skills, as well as their critical and creative thinking abilities, which are often difficult to achieve through conventional learning. This research aims to determine the differences in students' computational thinking abilities through the application of problem-based learning and traditional learning methods. The research method was an experiment involving a population of all 2020 Mathematics Education students who took six linear program courses at Medan State University. Sampling was conducted using a random sampling technique, focusing on the PSPM 20B and PSPM 20C classes, totaling 60 students. This study employed a pretest–posttest control group design. Results from previous research indicated that the average computational thinking ability of students in the experimental class was higher than that of the control class, with scores of 82.67 for the experimental class and 69.00 for the control class. From the results of the average difference test, it can be concluded that there is a significant difference in the computational thinking abilities of students taught using the problem-based learning model compared to those taught using the traditional learning model, with PBL being more effective.

Keywords: Computational thinking, Conventional learning, Problem based learning

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Introduction

Education involves various resources, such as human resources, funding, as well as infrastructure and facilities. Each of these resources consists of numerous variables and elements. To improve the quality of education, a substantial approach (content approach) is required that directly relates to the quality of education and student behavior. This approach should emphasize student-centered learning rather than teacher-centered learning, ensuring that students truly master the material or skills being taught, ultimately providing a strong foundation for future learning.

In education, there are various essential elements to enhance the quality of human resources, one of which is proficiency in mathematics. Mathematics plays a crucial role both in daily life and in the development of science and technology. It possesses a strength that can be applied in various aspects, including technology. Since its inception, mathematics has been a supporting force for technological advancement. It is even referred to as the root of science due to its significant role. The immense role of mathematics as a fundamental science is evident in the high demand for mathematical skills, particularly in facing the 21st century.

With the advancement of information technology driving global competition in the 21st century, the formulation of a strategic educational framework has become a challenge in the curriculum. Considering the current condition of the education system in Indonesia, the results are deemed unsatisfactory. This is evident from Indonesia's ranking in the 2018 Programme for International Student Assessment (PISA), where it placed 62nd out of 70 countries. Furthermore, Indonesia achieved a reading score of 371, compared to the average score of 487, a mathematics score of 379, compared to the average score of 489, and a science score of 396, compared to the average score of 489. Based on the data presented above, the scores of Indonesian students are lower than the average scores of students from Organisation for Economic Co-operation and Development (OECD) countries that participated in the PISA test in mathematics, science, and reading skills (Widiyastuti & Jazuli, 2019).

In the (OECD, 2022) ranking results, it can be seen that Indonesia's ranking has increased. However, the average student performance scores in reading or literacy is 359, compared to the global average of 469. In mathematics, Indonesia scored 366, compared to the global average of 358, and in science, the score is 383, compared to the global average of 384 (Lorenceau et al., 2019). It is evident that the scores obtained by Indonesian students have declined since 2018. However, this decline is also observed in other countries in the PISA 2022 survey, attributed to the impact of these countries' unpreparedness in facing the effects of the Covid-19 virus spread, which has adversely affected the education sector (Indarta et al., 2022).

The questions tested in PISA require participants to have problem-solving and reasoning skills. Based on the questions tested, Indonesian students are able to solve up to level 3 problems, and only a few manage to complete level 4. Students struggle with solving PISA questions at the content change and relationship level 4, where students are required to identify information and transform it into a simpler mathematical model (In the PISA 2021 framework, the concept of mathematical literacy, which previously focused only on basic calculation skills, now involves the rapid development of technology (Lorenceau et al., 2019), leading to the inclusion of computational thinking in its assessment. Mathematical literacy must demonstrate the relationship between mathematical thinking and computational thinking. Considering this, mathematics education in Indonesia should be directed towards both abilities so that Indonesian students can compete at the international level.

Computational thinking (CT) is a critical skill that individuals must master (Maharani et al., 2021) CT is a fundamental skill that enables individuals to solve problems systematically and logically. (Wing, 2006) defines computational thinking as a problem-solving approach involving techniques and concepts from computer science, including problem decomposition, pattern recognition, abstraction, and algorithms. Computational thinking involves two major steps: the reasoning process followed by decision-making or problem-solving (Pratiwi & Akbar, 2022) thinking encompasses a series of thought patterns, including understanding problems with appropriate visualization, reasoning at multiple levels of abstraction, and developing automated solutions (Lee et al., 2012) This skill is not only relevant in the field of information technology but also has broad applications across various disciplines and everyday life. It is evident that the gradual use of digital computing tools is becoming a basic life skill for modern individuals (Chen et al., 2021). The importance of computational thinking extends beyond information technology and into various disciplines. This capability helps individuals analyze data, make better decisions, and develop creative solutions. Computational thinking also plays a crucial role in enhancing critical and logical thinking skills, which are highly necessary in today's workforce (Adelia et al., 2024; Juldial & Haryadi, 2024).

Computational Thinking (CT) has garnered significant attention among educators and education researchers worldwide, and it has even been incorporated into the curricula of several countries (Van Borkulo et al., 2021), including the UK, the USA, Japan, and Singapore. CT has become a core competency in the era of integrated STEM-based education (Rehmat et al., 2020) In Indonesia, CT is not yet a mandatory component of the curriculum and has not gained significant attention in the educational landscape. However, in 2020, the Ministry of Education and Culture (Kemendikbud) planned to include two essential skills in the Indonesian curriculum, one of which is Computational Thinking (Abidin et al., 2023). This initiative indicates that Indonesia is beginning to recognize the potential of CT to significantly aid Indonesian children in addressing complex problems.

For university students, computational thinking skills are particularly crucial due to various reasons related to technological advancements, job market demands, and the ability to tackle and solve complex problems. With these skills, students not only become more competitive in the job market but also better prepared to adapt to rapid technological changes and contribute significantly across various disciplines.

In conjunction with the implementation of curriculum reforms, the learning process has also evolved from students being told information to students discovering it for themselves. Therefore, a learning model is needed that can support students in actively finding concepts that are the objectives of learning. A learning model is required that not only leads students to think mechanically in problem-solving but also guides them to think analytically in formulating and resolving issues. The current learning models are transforming from conventional approaches to new models that meet contemporary needs and demands (Syahrullah, 2024). To create an engaging learning process that fosters higher-order thinking in students, a well-designed learning concept is essential. One of the effective learning models for training students to solve problems independently and connect lesson material with everyday life is the Problem Based Learning (PBL) model. The PBL learning model is based on problem-solving (Ariandi, 2016)

(Rasto & Pradana, 2021) state that the Problem Based Learning (PBL) model is a group learning model that originates from a problem, enabling students to become trained in problem-solving. PBL trains students to think critically, analyze, and solve problems. These skills are crucial in facing challenges in the information era (Nurhidayat & Nana, 2020). To enhance higher-order thinking skills, teachers can use the problem-based (Masduriah, 2020; Novianti et al., 2020) learning (PBL) model, which trains students to recognize problems and find their solutions Based on this, it is evident that problem-solving skills are one of the 21stcentury skills, enabling students to understand complex issues, connect information, and ultimately find solutions to the problems they face (Nana, 2021).

Suratno et al. (2020) state that the focus of learning in the Problem Based Learning (PBL) model is on the selected problem, enabling students not only to learn the concepts related to the problem but also to use scientific methods to solve it, thereby fostering higher-order thinking skills. Problem-based learning is not designed to help teachers provide as much information as possible to students; rather, it is developed to help students enhance their thinking abilities. This can be seen from the PBL syntax, which consists of five stages of learning: (1) orienting students to the problem, (2) organizing student learning, (3) guiding investigation, (4) developing and presenting the work, and (5) analyzing and evaluating the problem-solving process (Rawash et al., 2023).

Research on the Problem Based Learning (PBL) model has been widely conducted, but it has mostly been limited to secondary schools and has only implemented the PBL model without comparing it to traditional learning, even though the results have shown an improvement in students' computational thinking skills (Jannah et al., 2023; Putra & Muqoyyidin, 2019). Therefore, further research is needed to prove that the PBL model is effective in optimizing, enhancing, and directing students' thought processes towards computational thinking abilities within a learning process. Thus, it is very feasible to address students' needs in computational thinking by applying the PBL model.

Based on the above explanation, this research aims to (1) determine whether there are differences in students' computational thinking abilities when taught using the Problem Based Learning model compared to traditional learning, and (2) identify which learning model is more effective in improving students' computational thinking skills.

Methods

This research uses a quantitative approach, as it analyzes numerical data processed with statistical methods. Once the results are obtained, they are described by outlining conclusions based on the data processed using these statistical methods. The research is conducted at the Department of Mathematics, Medan State University. The population consists of all 2020 cohort Mathematics Education students who took six classes of linear program courses. Sampling was conducted through random sampling, selecting PSPM 20B with 30 students and PSPM 20C with 30 students, making a total of 60 students.

This study employs a pretest–posttest control group design, consisting of two groups of students for comparison. The PBL model is used in the first group, while the second group follows the traditional learning model. Data collection techniques involve tests in the form of essay tests. To observe the differences in the application of the problem-based learning model compared to traditional learning in enhancing students' computational thinking skills, data analysis uses the independent sample t-test, ensuring that normality and homogeneity assumptions are met. The normalized gain (N-Gain) formula is used to determine the extent of improvement before and after the learning process, following the identification of differences in the treatment provided.

Result

Before conducting hypothesis testing using the IBM SPSS Statistics 25 application, the research data undergoes normality and homogeneity tests. The Kolmogorov-Smirnov and Shapiro-Wilk statistics are used for testing the normality of data distribution, while the Levene's statistic is used for testing the homogeneity of variances. The results of the normality test are shown in Table 1 below.

Table 1. Results of the Posttest Normality Test

	Class	Shapiro-Wilk		
		Statistic	**df**	**Sig.**
Score	Post-Test (Experimen)	,936	30	,073
	Post-Test (Control)	,934	30	,061
Lilliefors Significance Correction				

From Table 1 above, the results of the posttest normality test of students' computational thinking abilities in the experimental and control classes show a Shapiro-Wilk significance value greater than 0.05. This indicates that all data are normally distributed. Therefore, parametric statistical analysis can proceed. The results of the homogeneity test are presented in Table 2 below.

Table 2. Results of the Homogeneity Test

		Levene Statistic	df1	df2	Sig.
Score	Based on trimmed mean	1,441	1	58	,235

Based on Table 2, it can be seen that the results of the posttest homogeneity test of students' computational thinking abilities in the experimental and control classes show a significance value (sig.) of 0.235. With $\alpha = 0.05$, it indicates that the significance value (0.235) is greater than 0.05, thus it can be concluded that the posttest data for computational thinking abilities are homogeneous or have the same variance. After confirming through prerequisite tests that the sample is normal and homogeneous, the hypothesis test is conducted using the mean difference test or t-test, and the results are shown in Table 3 and Table 4.

Table 3. Statistics Group

	Data	N	Mean	Std. Deviation	Std. Error Mean
Score	Control	30	69.00	7.474	1.365
	Experimen	30	82.67	8.976	1.639

Table 4. Independent-Sample T Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		T	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
Score	Equal variances assumed	-6.409	58	.000	-13.667	2.133	-17.935	-9.398
	Equal variances not assumed	-6.409	56.158	.000	-13.667	2.133	-17.938	-9.395

Based on Table 4 above, it shows that the significance value (sig. 2-tailed P) is 0.000. Because the sig. 2-tailed P (0.000) is less than α (0.05), so H_o is rejected and H_a is accepted. This means that there is a significant difference in the average computational thinking abilities between students who received PBL learning and those who received traditional learning. With this identified difference, it is indicated that the PBL model has an effect on students' computational thinking abilities. To determine the extent of the improvement before and after PBL learning, the normalized gain (N-Gain) formula is used. The results can be seen in Table 5 below.

Table 5. N-Gain Pretest and Posttest

	N	Minimum	Maximum	Mean	Std. Deviation
Experimental Class, N-Gain_percentage	30	0,00	100,00	56,2088	22,19963
Controlled Class, N-Gain percentage	30	16,67	53,85	35,1135	10,11727
Valid N (*listwise*)	30				

From Table 5, it is evident that the experimental group has a higher average N-Gain (56.2088) compared to the control group (35.1135). This indicates that students who learned using the Problem-Based Learning (PBL) model experienced a greater increase in abilities compared to those who learned using the traditional learning model. Based on the N-Gain score calculation results, it shows that the average N-Gain score for the experimental class (PBL model) is 56.2088 or 56.21%, which falls into the "moderately effective" category according to the N-Gain score categorization table. Meanwhile, the average N-Gain score for the control class (traditional learning) is 35.1135 or 35.11%, which falls into the "ineffective" category. Thus, it can be concluded that the use of the PBL learning model is more effective in enhancing computational thinking abilities compared to the traditional learning model.

Discussion

Overall, based on the two classes studied, it is evident that the Problem Based Learning (PBL) model is able to enhance student engagement in the learning process compared to traditional learning methods. In the PBL model, students feel challenged by real-world problems presented at the beginning of the lesson. The PBL syntax guides the discussion process smoothly. Students find information through discussion and solve problems based on the information they gather. These results are consistent with the findings of Isabela et al. (Isabela et al., 2021) who also found that the implementation of the PBL (Problem Based Learning) model could improve students' learning outcomes. This is evident when students present the results of their discussions, with each group eager to be the first to present. Individually, students also appear enthusiastic about the learning process. In the experimental class, students actively ask questions while working on practice problems to find solutions.

Based on the responses of students in the experimental class, it can be seen that they have mastered computational thinking skills. Each indicator was addressed effectively: (1) Decomposition: Students were able to identify the known information from the given problems, as evidenced by the information they obtained from the provided problems. (2) Pattern Recognition: Students were able to recognize patterns or similarities/differences in solving the given problems in order to construct a solution, as seen from the information they discovered, which was formed into a linear problem pattern. (3) Algorithmic Thinking: Students were able to develop the steps used to formulate a solution to the given problems, as shown by the standard form and initial simplex table obtained. (4) Pattern Generalization and Abstraction: Students were able to form general patterns from the similarities/differences found in the given problems and draw conclusions, as evidenced by the iterations carried out until the final answer was obtained.

In contrast, the responses of students in the control class were less focused and not systematic. The PBL learning model aligns with the processes of computational thinking, thereby significantly enhancing students' abilities. The relationship between PBL and aspects of computational thinking can be analogized as: (1) Decomposition: In PBL, students are often confronted with complex problems that they need to break down into smaller, more manageable parts. This is similar to decomposition in computational thinking (Manullang & Simanjuntak, 2023). (2) Pattern Recognition: PBL encourages students to recognize patterns and relationships in the data and information they encounter while solving problems. This is in line with pattern recognition skills in computational thinking (Pratiwi & Akbar, 2022). (3) Abstraction: PBL teaches students to focus on the key elements of a problem, disregard irrelevant details, and formulate general concepts that can be applied in various contexts. This is akin to the abstraction process in computational thinking. (4) Algorithm Design: PBL involves designing steps or procedures to solve problems, which is at the core of algorithm design in computational thinking

Similar results were found in the research conducted by Pratiwi and Akbar (2022) which demonstrated that at the stages of problem orientation and student organization in learning, students' abilities to describe known and asked-for information in the given problems were enhanced through group discussions. This was evident as students engaged in reading activities to capture information and find ideas or solutions to problem-solving. During the investigation guidance stage, students took on a more active role in collaborating to solve problems, which fostered a high level of curiosity and motivation in problem-solving. This could be seen from students asking questions about aspects they did not yet understand. Additionally, at the stages of developing and presenting results, as well as analyzing and evaluating outcomes, students' confidence increased, and they, along with the teacher, evaluated and reflected on their discussion results. Pratiwi and Akbar (2022) found that the mathematical computational thinking abilities of students taught using the PBL model were higher than those of students taught using conventional learning models, indicating that the PBL model positively impacts students' mathematical computational thinking abilities.

Other studies also support that the PBL model can influence students' mathematical computational thinking abilities. Among them, Setiani et al. (2020) state that various stages or phases within the PBL model help students understand concepts more effectively, thereby positively impacting their problem-solving abilities. Specifically, the initial stage, known as problem orientation, fosters critical thinking and enhances computational skills by presenting relevant problems at the beginning of the lesson (Ramadhani, 2019)

Computational thinking offers a more active and in-depth approach to learning (Juldial & Haryadi, 2024). Unlike traditional learning, it is challenging to create a more effective and relevant learning environment that meets the needs of 21st-century students. In traditional classrooms, students often wait for information from the lecturer, are not introduced to relevant real-world problems, rarely interact with peers, and are less active in independently seeking information. This leads to low levels of critical thinking skills among students, especially in computational thinking. In traditional learning, problem-solving skills appear to be dependent on what is presented by the lecturer, who employs a teacher-centered approach, resulting in students being less creative and innovative (Syamsidah et al., 2019).

In the implementation of the PBL learning model, researchers have identified a weakness, namely the limited instructional time, which impacts the optimal results of the research. The application of the PBL model requires a considerable amount of time for students to fully engage in each learning process, especially in answering questions that train their mathematical computational thinking skills. This is consistent with the findings of Auliah et al. (2023) that limited time is a barrier for teachers in implementing the PBL model in the classroom. On the other hand, the weakness of traditional learning is that, in addition to requiring a long time, some students are less serious about learning due to a learning environment that focuses on a relaxed, comfortable, and leisurely atmosphere.

Conclusion

Based on the research findings described above, the average computational thinking ability of students in the experimental class is higher than that in the control class, with scores of 82.67 for the experimental class and 69.00 for the control class. The results of the average difference test indicate that there is a difference in computational thinking abilities between students taught using the Problem-Based Learning (PBL) model and those taught using traditional learning methods, with PBL being superior to traditional learning. This difference indicates that the PBL model has an effect on students' computational thinking abilities. To determine the extent of improvement before and after PBL learning, the normalized gain (N-Gain) formula is used. The N-Gain score calculation results show that the average N-Gain score for the experimental class (PBL model) is 56.2088 or 56.21%, which falls into the "moderately effective" category according to the N-Gain score categorization table. Meanwhile, the average N-Gain score for the control class (traditional learning) is 35.1135 or 35.11%, which falls into the "ineffective" category. Thus, it can be concluded that the implementation of the PBL learning model is more effective than traditional learning models in enhancing students' computational thinking abilities in the BIG-M method linear programming material.

Declarations

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