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Analysis of Students' Computational Thinking Processes in Merdeka Curriculum Differentiation Learning using The Open-Ended Problem Based Learning Model

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Abstract

This research aims to evaluate the effect of implementing differentiated learning using the Open-Ended Problem Based Learning model on students' computational thinking abilities at the Batang State Tsanawiyah Madrasah. The research used mixed methods with a concurrent embedded model, which combines quantitative and qualitative approaches. Data was collected through computational thinking ability tests, interviews, and observations during the research period. The research results show a significant increase in students' computational thinking abilities after implementing differentiated learning. Quantitative data analysis shows significant differences between before and after learning, with visible improvements in aspects of computational thinking capabilities such as abstraction, algorithms, decomposition, and pattern recognition. These findings show that differentiated learning using the Open-Ended Problem Based Learning model can improve students' abilities in computational thinking and solving problems effectively.

Keywords: differentiated learning, open-ended problem based learning, computational thinking

INTRODUCTION

The development of the education curriculum in Indonesia continues to experience significant evolution, especially with the introduction of the Independent Curriculum concept (Kusuma et al., 2023). This new era demands a more innovative and adaptive approach to education, considering the complex challenges of educating future generations (Aho, 2012; Lya et al., 2024). One important aspect that needs to be considered is students' computational thinking (CT) abilities, which are the basis for a deeper understanding of technology and effective problem solving (Arumningsih et al., 2023).

Computational thinking provides a strong framework for developing students' problem-solving abilities (Fitri et al., 2022) (Yunianto, wahid;El-Kasti, Houssam; Lavicza, Zsolt; Prahmana, 2024). Computational Thinking (CT) is defined as an approach to thinking that allows a person to formulate problems and design solutions in a way that can be implemented by a computer (Wing, 2006). CT consists of several key elements that underlie the computational thinking process. These four elements are decomposition, pattern recognition, abstraction, and algorithms (Grover & Pea, 2013). By combining analytical, technological and collaboration skills, this approach prepares students to face real-world challenges with more confidence and a better ability to identify, analyze and solve complex problems (Mukhibin, et al, 2024).

Computational thinking is a core skill needed and is considered by experts to be able to support the education sector in the 21st century, therefore computational thinking is part of the independent curriculum (Fitriani, 2020). Salsabila & Yasfizham (2024) argued that integration of computational thinking in the implementation of the Independent Curriculum has great potential and is an important step to improve the quality of learning or education in Indonesia in order to prepare or give birth to the next generation who are creative, innovative, able to solve problems and can be competitive in the digital era (Gusteti & Neviyarni, 2022).

Anwar (2014) emphasize the importance of three main axes in successful learning, namely learners/students, teachers, and learning resources. However, the 2022 PISA results show that student numeracy literacy, including CT, is still not optimal in Indonesia (OECD, 2023). This can also be seen from the results of the 2023 Bebras Challenge which shows students' lack of understanding of CT concepts, especially in the algorithm, abstraction, decomposition and pattern recognition components (Haqq, 2016).

This condition creates an urgency to develop a learning approach that is able to accommodate students' CT needs more effectively (Maharani et al., 2020). One alternative proposed is the application of differentiated learning with the Open-Ended Problem Based Learning (PBL) model in the independent curriculum, the curriculum currently implemented in Indonesia for primary and secondary education (Pratiwi, G. L. & Akbar, 2022). Marlina (2019), Marlina (2020), Widayanti, R., & Nur'aini (2020) and (Purba et al., 2021) provide views on how differentiated learning can optimize student learning opportunities through adapting learning to individual learning styles. . In PBL, when students encounter a real-life problem, they should identify what they have already learned about the problem (i.e., activating their prior knowledge) and establish what they need to know in order to solve the problem (i.e., missing information) (Alreshidi & Lally, 2024). PBL methodology appear to offer benefits in the development of computational thinking (Moreno-Palma et al., 2024).

In this context, the research objectives are to describe the implementation of differentiated learning with PBL in the independent curriculum, analyze students' CT processes, and evaluate the effectiveness of PBL in supporting CT abilities. This research has significant benefits for developing curriculum and learning strategies that are more adaptive and effective in increasing students' numeracy literacy, especially in the context of the Independent Curriculum.

METHODS

This research uses a type of mixed methods research or combined research method, which combines quantitative and qualitative approaches simultaneously to obtain more comprehensive, objective, valid and reliable data (Sugiyono., 2016) The research was conducted at the MTsN Batang, which is located on Jalan Raya Pucungkerep No.48, Krikil, Sengon, Subah District, Batang Regency, Central Java, from April 25 to May 1 2024. The research target was all MTsN Batang students who had completed implementing an independent curriculum, with the research population including all students and samples taken using stratified sampling based on the results of computational thinking ability tests (Salsabila & Yahfizham., 2024) . The secondary research subjects are teachers who are involved to provide insight into the application of learning models in the classroom (Syamsidah & Suryani, 2012).

The research procedure includes several stages, namely preparation, implementation, data collection and data analysis. In the preparation stage, research instruments such as tests, interview guides and observation sheets are prepared. Furthermore, the research was carried out by implementing differentiated learning using the Open-Ended Problem Based Learning model in two meetings. Data was collected through three main techniques: tests to measure students' computational thinking abilities, interviews to analyze computational thinking thought processes, and observations to see the application of open-ended Problem Based Learning (Wulandari, 2022).

The research instruments used include tests covering aspects of abstraction, algorithm, decomposition, and pattern recognition, interviews with students from each category of computational thinking ability (high, medium, low) and teachers, as well as observations during the learning process. Data collection techniques were carried out through tests given before and after implementing the learning model, in-depth interviews, and direct observation (Fitriawan et al., 2023).

Data analysis was carried out quantitatively and qualitatively. Quantitative data analysis techniques use the Kolmogorov-Smirnov normality test to determine data distribution and paired sample t-test to compare computational thinking abilities before and after implementing open-ended Problem Based Learning (Taufiq, 2014). Hypothesis test results are determined based on the Sig value (2-tailed); if Sig (2-tailed) < 0.05 then there is a significant difference. Qualitative data analysis involves data reduction by categorizing the results of computational thinking skills, presenting data in the form of diagrams and interview transcripts, and drawing conclusions through triangulation of data sources. The validity of the instrument was tested by content validity and reliability was tested by the test-retest method to ensure consistency of results. This research was designed to provide a comprehensive overview of the application of the differentiated learning model with open-ended Problem Based Learning and its influence on students' computational thinking abilities.

The mix method research chart is described more clearly through Table 1.

Table 1. Embedded Mix Method Design

	Data Collection	Data Analysis	Conclusion Based on QUAN-QUAL Result
Mix Method (QUAN-QUAL)	QUAN Pre-test and post-testof Computational Thinking Ability Test	QUAN - Descriptive (Category) - Normality Test - Homogenity Test - Paired-sample t-test	- QUAN interpretation - QUAL interpretation - Clarify QUAN result by QUAL result - Conclusion by QUAN and QUAL result
	QUAL - Pre-test and post-testof Computational Thinking Ability Test - Interview	QUAL - Transcript of interview result - Content analysis	

RESULTS AND DISCUSSION

This research applies differentiated learning through an open-ended Problem Based Learning model, including process and product differentiation. The learning process includes preparation of open problems that are relevant to student competencies, formation of differentiated groups based on interests and abilities, presentation of problems through Student Worksheets (LKPD), investigation and independent learning in small groups, presentation and evaluation of results, as well as reflection and follow-up.

Some of the results and findings that occurred during differentiated learning with the open-ended Problem Based Learning model include:

a. Students study phenomena in the surrounding environment that are experienced and directly related to students' lives through the open-ended Problem Based Learning student worksheet presented.
b. Students are enthusiastic in conducting investigations related to the experiences and problems given.
c. Diversity of data analysis and interpretation to solve problems depending on the group (differentiation).

The results show that students are actively involved in investigating real-life problems and produce various analyzes and solutions based on their respective groups (Wahyuni et al., 2020). The application of this model succeeded in increasing students' computational thinking abilities, which were measured through pretest and posttest, and categorized into three levels: high, medium, and low (Wahyuningsih, 2021). The frequency distribution and percentage of students' computational thinking abilities are shown in Table 2.

Table 2. Frequency and Percentage Distribution of Computational Thinking Ability

Category	Pretest		Posttest	
	f	%	f	%
Low	10	30,3%	5	15,15%
Currently	22	66,7%	23	69,7%
Height	1	3%	5	15,15%

Before learning, 30.3% of students were in the low category, 66.7% in the medium category, and only 3% in the high category. After learning, the low category decreased to 15.15%, the medium category was relatively stable at 69.7%, and the high category increased to 15.15%. The increase in the average computational thinking ability score is also seen in Table 3.

Table 3. Description of Pre-test and Post-Test Data

Description	Pre-test	Post-test
Number of Respondents	33	33
Standard Deviation	13,248	15,009
Minimum Score	0	0
Ideal Maximum Score	100	100
Minimum Score Reached	16	92
Maximum Score Reached	86	28
Average	55,91	70,52
Category	Low	Currently

In the average score, it can be seen that it increased from 55.91 on the pretest to 70.52 on the posttest. Standard deviation shows an increase in variation in student results, from 13.248 on the pretest to 15.009 on the posttest, while the maximum score achieved increased from 86 to 92.

The results of computational thinking abilities are also presented based on each aspect as stated in Table 4.

Table 4. Computational Thinking Based on Each Aspect

Aspect	Ideal Maximum Score	Pre-test	Post-test
Abstraction	23	12,97	16,82
Algorithm	23	13,30	16,97
Decomposition	26	13,70	17,94
Pattern Recognition	28	15,94	18,79
Total	100	55,91	70,52

Further analysis shows improvements in all aspects of computational thinking, namely abstraction, algorithms, decomposition, and pattern recognition, although the abstraction aspect is not yet optimal. The normality test using Kolmogorov-Smirnov showed that the data was normally distributed, and the t-test results indicated that there was a significant difference between the pretest and posttest results ($p < 0.05$).

Table 5. The result of paired sample t-test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Pretest - Posttest	-14.606	6.923	1.205	-17.061	-12.151	-12.119	32	.000

The application of the open-ended Problem Based Learning model, with special LKPD material on Systems of Linear Equations in Two Variables (SPLDV), shows mixed results. Groups of students with below average mathematical abilities are more helped by LKPD which contain detailed steps, although the results are still less than optimal (Wanelly, 2020). On the other hand, the group with above average abilities showed better ability in formulating solving strategies without detailed guidance. Further analysis shows that the abstraction, algorithm, and decomposition aspects of students have improved overall, although pattern recognition still requires attention in certain groups. This shows that abstraction ability increases so that students focus more on important information only, and ignore details that are less relevant to solving the given problem (Israel-Fishelson & Hershkovitz, 2020). This is supported by one of the student's answers in Figure 1, which shows that the student's answer already shows known information from the existing problem and ignores other information that is not needed in solving the problem.

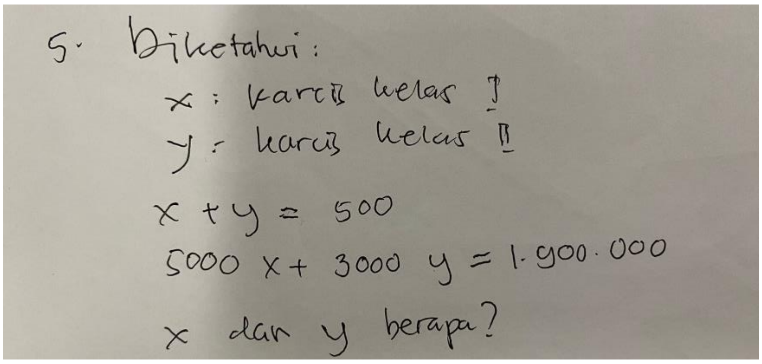

Figure 1. Abstraction Aspect

In addition, students are also more capable in compiling algorithms, namely being able to determine step by step solutions to overcome problems or procedures that must be carried out to solve problems. As seen in the example of student answers in Figure 2, which shows that students are able to choose solutions/steps to solve SPLDV using the elimination method.

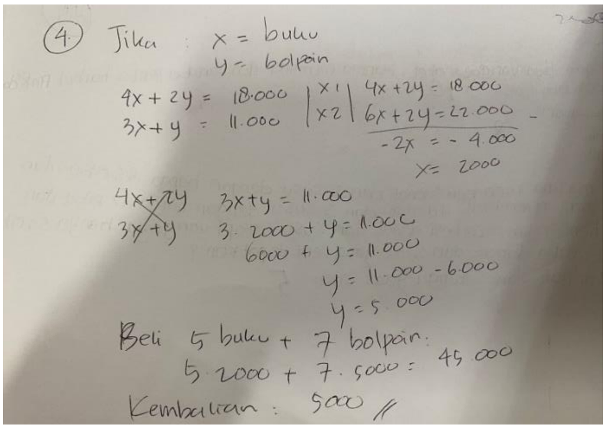

Figure 2. Algorthm Aspect

In the decomposition aspect, students are increasingly able to analyze or break down larger/complex problems into smaller/simpler parts so that they are easier to solve gradually. This is shown by students' answers which show that from the complex problems given, students can simplify the solution steps so that they are simpler as in Figure 3.

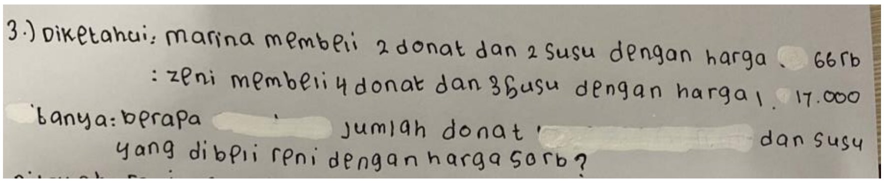

Figure 3. Decomposition Aspect

Meanwhile, in the aspect of pattern recognition, students in the low category showed a decrease in the ability to find/find patterns/similarities between problems or in the problem with other problems and solutions that have been raised including evaluation of the results of solutions that have been applied. As in the answer in Figure 4, students are still wrong in understanding the pattern in the problem. Students missed writing the variables x and y in the second equation.

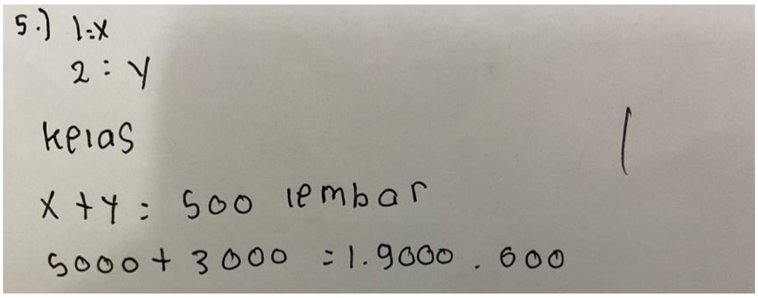

Figure 4. Pattern Recognition Aspect

This shows that the existence of differentiated learning with the open-ended Problem Based Learning model can facilitate students with different abilities, where the process of solving problems is given different treatment. In addition, the existence of open-ended problems also explores students' ability to do abstraction in solving problems, so that students' computational thinking abilities increase.

These results are in line with teacher interviews interviews conducted with teachers that in differentiated learning of the independent curriculum, there needs to be a special approach or learning method that can be used to develop Computational Thinking skills in the context of mathematics, including: Problem-Based Learning, Cooperative Learning, or Project-Based Learning. In addition, teachers also need to improve students' understanding of mathematical concepts by bringing up problems in everyday life.

CONCLUSION

This research shows that the application of the open-ended Problem Based Learning model in differentiated learning has succeeded in improving students' computational thinking abilities. This learning involves a preparation process, forming groups based on interests and abilities, presenting problems through Student Worksheet, as well as investigating and presenting results. The research results show a significant improvement in aspects of computational thinking, namely abstraction, algorithms, decomposition, and pattern recognition. The distribution of student abilities changed, with an increase in the high category and a decrease in the low category. The t-test analysis confirmed significant differences between the pretest and posttest, confirming the effectiveness of this approach. However, some aspects still require improvement, especially for students with lower abilities. These findings support the importance of applying contextual and differentiated learning in developing students' computational thinking skills.

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