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APPLICATION OF DIFFERENTIATED LEARNING USING A PROBLEM-BASED LEARNING MODEL TO IMPROVE STUDENTS' MATHEMATICS LEARNING OUTCOMES

Rizky Hidayatul Muslim[a*], Febrian[b], Ibnu Yazid[c]
E-mail: rizkyhidayatul123@gmail.com

[a*,b] *Pendidikan Profesi Guru, Universitas Maritim Raja Ali Haji, Tanjungpinang, Indonesia*
[c] *SMA Negeri 2 Tanjungpinang, Tanjungpinang, Indonesia*

Abstract
This study aims to improve students' mathematics learning outcomes by combining problem-based learning strategies with differentiated teaching. The action research was conducted using the Kemmis and McTaggart model in two cycles, each consisting of planning, implementation, observation, and reflection stages. The study involved 47 students from SMAN 2 Tanjungpinang, with data collected through assessment. The results showed a significant improvement in students' mathematics skills: the pre-cycle classical learning completeness rate of 29.78% increased to 57.44% in cycle one and further to 82.97% in cycle 2. Thus, the application of differentiated teaching within a problem-based learning framework improves students' mathematics learning outcomes.

Keywords: differentiated learning, problem-based learning, mathematics.

Abstrak
This study aims to improve students' mathematics learning outcomes by integrating customized teaching with problem-based learning techniques. The action research conducted using the Kemmis and McTaggart approach was carried out in two cycles, each consisting of planning, implementation, observation, and reflection stages. The study involved 47 students from SMAN 2 Tanjungpinang, with data collected through assessment. The results showed a significant improvement in students' mathematics skills: the pre-cycle classical learning completeness rate of 29.78% increased to 57.44% in cycle one and further to 82.97% in cycle 2. Thus, implementing customized teaching within a problem-based learning framework improves students' mathematics learning outcomes.

Kata Kunci: pembelajaran berdiferensiasi, *problem-based learning*, matematika.

INTRODUCTION

Mathematics, a fundamental science, is crucial in education as it equips students with essential critical and scientific thinking tools. It encompasses operations, numbers, symbols, and various patterns constituting its core concepts (Marfu et al., 2022; Nurhikmayati, 2019; Sinaga et al., 2021). Due to its frequent application in daily life, mathematics is an exceedingly essential science. Nevertheless, students' achievements in mathematics often need to improve in practical terms (Budiyani et al., 2021; Ndraha et al., 2022). The 2018 PISA (Programme for International Student Assessment) findings highlight that Indonesian students scored lower than their global peers, averaging just 379 in mathematics, compared to the global average of 489 (Firdaus et al., 2023; Nugraha, Harum, et al., 2023).

The low mathematics learning outcomes among students at SMAN 2 Tanjungpinang stem from their dependence on teacher explanations and their lack of engagement in learning activities, as highlighted in observations and interviews with mathematics educators. Formative assessments reflect this trend, showing a low classical completion percentage of 29.78% against a minimum completeness criterion (KKM) of 70. This underscores a significant challenge in mathematics education: the measurable mastery of learning materials by students.

To improve student learning outcomes, educators must analyze emerging issues and utilize these insights to refine their teaching approaches (Angraini & Fathiyyah Firdaus, 2022). Educators must choose strategies, methods, or techniques that facilitate students' proficiency in mathematics (Habibi & Suparman, 2020; Masfufah & Afriansyah, 2021; Muzaki & Masjudin, 2019). Applying suitable techniques is expected to influence students' educational outcomes, improving mathematics learning outcomes for children with diverse characteristics.

Students have different characteristics and learning needs. The diversity of students brought to the school environment has different things. These differences can be in abilities, experiences, interests, culture, learning styles, etc. Therefore, with differentiated learning, efforts are made to facilitate students' diversity based on their characteristics (Handiyani & Muhtar, 2022; Saputri et al., 2023; Sarnoto, 2024). Differentiated learning provides various methods for acquiring knowledge, understanding concepts, and producing outcomes to optimize learning for each student. Therefore, it is logical to introduce differentiated learning in classrooms that encompass diverse student characteristics.

Differentiated learning aims to simplify the learning process, enhance efficiency, and increase student engagement (Aldila & Mukhaiyar, 2020). Differentiated learning strategies are expected to elevate classroom engagement among students (Avivi et al., 2023; Fitriana et al., 2024; Tilamsari et al., 2023). These students' engagement will improve their learning outcomes. Therefore, differentiated instruction can be effectively integrated with various learning models, including the well-known Problem-Based Learning (PBL) paradigm (Gusteti & Neviyarni, 2022).

The educational approach known as Problem-Based Learning can assist students in developing their problem-solving abilities (Khakim et al., 2022; Sari et al., 2022; Zulfa et al., 2022). Problem-Based Learning (PBL) aims to enhance students' comprehension of the material by engaging them in solving real-world problems. This approach involves several steps: introducing the issue, organizing the classroom, supervising individual and group research, developing and presenting solutions, and evaluating the problem-solving process (Nugraha, Purwati et al., 2023). Previous research has demonstrated that employing the PBL method can enhance students' educational achievements (Akhmad et al., 2023; Isma et al., 2021; Langitasari et al., 2021; Nurkomaria et al., 2022; Priyanti & Nurhayati, 2023).

The statement above reflects the researcher's intention to conduct classroom action research (PTK) to improve students' mathematics learning outcomes by implementing customized instruction rooted in the Problem-Based Learning approach.

METHOD

Teachers employ Classroom Action Research (PTK) to investigate classroom issues and develop strategies to enhance teaching and learning. This research methodology follows the Kemmis and McTaggart models, which consist of four stages: preparation, action, observation, and reflection (Nalowati, 2022; Ngatiyem, 2021; Widiyanto & Farida, 2022).

This classroom action research project comprises three phases: pre-cycle, Cycle 1, and Cycle 2. According to the Kemmis and McTaggart PTK model, each cycle includes four stages: action, observation, reflection, and preparation. Data from the pre-cycle, Cycle 1, and Cycle 2 are compared to evaluate the effectiveness of combining Problem-Based Learning with tailored instruction in improving students' mathematics learning outcomes.

The study focuses on 47 students from class X.8 at SMAN 2 Tanjungpinang. The dependent variable (outcome) is the students' learning achievements in mathematics. The independent variable (intervention) is the implementation of differentiated learning within the Problem-Based Learning model. The research is specifically delimited to the quadratic equation topic covered in the grade 10 second-semester curriculum.

This study utilizes an experimental approach to gathering data. Each cycle concludes with administering a learning outcome test to assess student performance related to the learning objectives on quadratic equations. The Minimum Completeness Criteria (KKM) for mathematics topics is set at 70, serving as the threshold for categorizing and analyzing student performance data from the outcome tests. Table 1 outlines the completeness criteria used in the analysis.

Table 1. Minimum Completeness Criteria (KKM)

No	Test scores	Category
1	70 – 100	Complete
2	< 70	Incomplete

The classification of completeness is then used to calculate the percentage of completeness of classical learning outcomes with the formula.

$$PS = \frac{\sum students\ complete}{many\ students} \times 100\% \quad (1)$$

Description:
PS = Percentage of Students

The mathematical learning results in this study serve as a measure of success; pupils attain a classical learning completeness of at least 70%. If these indicators have been met, the cycle can be broken.

RESULTS AND DISCUSSION

Pre-cycle activities will be held on February 20 and 21, 2024. The pre-cycle is carried out using conventional learning methods. Students are given cognitive and non-cognitive diagnostic tests at the beginning of learning. The results of these tests will be used to design differentiated learning for the next cycle.

Following traditional instruction, students take a formative exam on quadratic equations. The results of these pre-cycle formative assessments, representing the student learning outcomes, are analyzed as shown in Table 2.

Table 2. Analysis of Formative Test Results or Pre-Cycle Learning Outcomes

Test Score	Many Students	Percentage of Student	Description
70 – 100	14	29,78 %	Complete
< 70	33	70,22 %	Incomplete
Total	47	100 %	

Table 2 illustrates that 14 students achieved a completion percentage of 29.78%, while 33 did not meet the minimum completeness criterion, resulting in a completion percentage of 70.22%. This data indicates that the classical standard for completeness of student learning outcomes, set at 29.78%, remains below the minimum completeness criterion benchmark of 70%. Cycle 1 activities will be held on February 27 and 28, 2024. They have four stages: planning, action, observation, and reflection.

A teaching module is developed during the planning phase by integrating differentiated instruction within the Problem-Based Learning (PBL) model. The initial step involves analyzing the outcomes of diagnostic tests, both cognitive and non-cognitive, conducted during the pre-cycle. Subsequently, the student's learning needs are mapped based on these diagnostic findings. Following this, formative assessments or learning outcome assessment tools are created, and learning materials are the teaching module and student worksheets (LKPD). Consultation with peers and teachers follows the development of teaching modules and learning resources. The final step entails incorporating feedback and suggestions from peers and teachers to make necessary adjustments.

In the action stage for cycle 1, the previously designed teaching module is implemented. The Problem-based Learning approach is used to carry out differentiated learning activities. A 10-minute preliminary activity begins with opening greetings and prayers, checking students' attendance, providing motivation regarding the material to be taught, conducting interviews related to prerequisite materials, giving trigger questions to students, and informing the learning objectives to be learned that day.

The Problem-Based Learning (PBL) model comprises five phases: (1) introducing students to the problem; (2) preparing them for learning; (3) guiding individual and group investigations; (4) developing and presenting solutions; and (5) evaluating and analyzing the problem-solving process. The model utilizes student worksheets and includes scaffolding to help students navigate challenges within the student worksheets. The final step involves reinforcing the day's lessons.

In the closing activity, students were given a formative test that was useful for assessing how well they understood the material learned that day. Furthermore, the students reflected on the learning that had been passed, ending with information about the material at the next meeting and closing with prayers and greetings.

Differentiated learning applied in cycle 1 is a differentiated learning environment where students are divided into several groups to solve a problem in student worksheets. The group division was conducted heterogeneously based on the results of non-cognitive diagnostic tests, with each group comprising 5 to 6 students.

During the observation stage, which runs concurrently with the action stage, observations are conducted on the ongoing learning process. The findings from these observations are carefully analyzed to inform the development of a follow-up strategy for the next cycle.

After completing the observation stage of cycle 1, the next step involves analyzing the gathered data to evaluate the progress of the research. This phase is referred to as the reflection stage. It aims to refine and improve the existing learning process in preparation for cycle 2.

Table 3 presents the results derived from data analysis on formative test scores or student learning outcomes in cycle 1.

Table 3. Analysis of Formative Test Results or Cycle 1 Learning Outcomes

Test Score	Many Students	Percentage of Student	Description
70 – 100	27	57,44 %	Complete
< 70	20	42,56 %	Incomplete
Total	47	100 %	

Table 3 indicates that 27 students achieved a completion percentage of 57.44%, while 20 students did not meet the minimum completeness criterion, resulting in a completion percentage of 42.56%. These findings demonstrate that the classical standard for completeness of student learning outcomes, at 57.44%, remains below the minimum completeness criterion benchmark of 70%.

Next, some inputs to learning activities in cycle 1 include: (1) there is no class agreement, which makes the class less conducive; (2) poor time management so that there is some syntax that is less than optimal due to running out of time; (3) Reflection activities carried out by all class members, not carried out individually by students.

Based on the reflection stage that has been carried out, student learning outcomes in cycle one have increased compared to the pre-cycle. However, based on the indicators of research success in cycle 1, the research objectives cannot be said to have been achieved because the completeness of learning outcomes has not reached or is equal to 70%. So, cycle two will be continued in this class's action research. Cycle 2 activities will be held on March 5 and 6, 2024. Like cycle 1, cycle 2 activities consist of four stages: planning, action, observation, and reflection.

Cycles 1 and 2 share similarities in their planning stages, focusing on developing teaching modules and applying differentiated learning using the Problem-Based Learning (PBL) model. The initial step involves enhancing instructional materials and learning resources based on reflections from Cycle 1. The second step entails mapping students' learning requirements, derived from cognitive and non-cognitive diagnostic test analyses. The third step is to compile a teaching module by adding class agreement activities between students and educators, creating student worksheets, creating learning outcome assessment instruments or formative assessments, and designing learning media. The fourth step is to consult with teachers and peers. The fifth step is to make improvements based on suggestions and inputs from teachers and peers in the previous step.

The action stage of cycle 2 is not much different from cycle 1. However, there is a slight addition to cycle 2. The preliminary activity began with saying greetings and praying, followed by checking students' attendance, then conveying class agreements so that learning activities were more conducive, then providing motivation about the material taught, making perceptions, asking triggering questions, and informing the learning objectives to the students who will be studied that day.

In the core activities, learning in cycle 2 continues to apply differentiated learning with a learning model, namely Problem-based Learning. Educators continue to provide scaffolding to students according to their level so that students can solve problems given through student worksheets. Next, in the closing activity, students were given a formative test and asked to complete a reflection sheet. So that educators know how far students understand the material that has been learned. In addition, each syntax is also timed so that activities can be carried out optimally.

Differentiated learning applied in cycle 2 is a differentiated learning environment in which students are divided into several groups to solve a problem in student worksheets. The division of groups was carried out heterogeneously based on the results of non-cognitive diagnostic tests. Each group consists of 4 to 5 students. This allows educators to provide process differentiation, which provides scaffolding to students according to their abilities. In addition, students with weak abilities will also be assisted by their group friends who have high abilities.

This observation stage is carried out at the same time as the action stage and is not much different from the observation stage in cycle 1. Observations are made on the learning process that has been carried out. The results of the observation stage will be used as a reflection and design of a follow-up plan.

During the reflection stage of cycle 2, the task involves analyzing the collected data to evaluate the success of the research. This stage also aims to refine and replicate the established learning process.

The entire learning process appears to have been executed successfully, achieving time efficiency and effectively implementing each syntax. Table 4 presents the findings from the data analysis of formative test scores or student learning outcomes in cycle 2.

Table 4. Analysis of Formative Test Results or Cycle 2 Learning Outcomes

Test Score	Many Students	Percentage of Student	Description
70 – 100	39	82,97 %	Complete
< 70	8	17,03 %	Incomplete
Total	47	100 %	

Table 4 reveals that eight students, accounting for 17.03%, did not meet the completion criterion, while 39 students achieved a completion rate of 82.97%. These results indicate that 82.97% of student learning outcomes were completed, meeting or exceeding the minimum completion requirement of 70%.

The reflection stage revealed that students' mathematics learning outcomes improved in Cycle 2 compared to Cycle 1 and the pre-cycle. Then, based on the research indicators, cycle two achieved the research objectives because the students achieved learning completeness, 82.97%, with 39 out of 47 students completing it. Based on these results, the cycle in this class action research can be stopped.

The researcher compared the learning outcomes of students starting from pre-cycle, cycle 1, and cycle 2, as shown in Table 5 and Figure 1 below.

Table 5. Comparison of Percentage of Classical Learning Outcomes Between Cycles

Test Score	Percentage of Learning Outcomes		
	Pre-Cycle	Cycle 1	Cycle 2
70 – 100	29,78 %	57,44 %	82,97 %
< 70	70,22 %	42,56 %	17,03 %

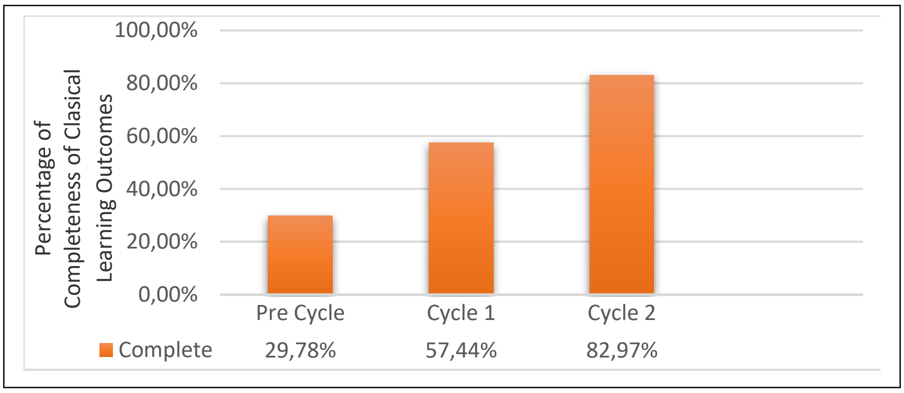

Figure 1. Increase in the percentage of classical learning outcomes between cycles

Table 5 and Figure 1 illustrate the progression of student learning outcomes across each cycle. The completeness of classical learning outcomes improved by 27.66%, rising from 29.78% in the pre-cycle to 57.44% in cycle 1. Subsequently, there was a further increase of 25.53%, from 57.44% in cycle 1 to 82.97% in cycle 2. Notably, the completeness percentage in cycle 2 surpassed the minimum completeness criterion benchmark of 70%.

When differentiated learning is implemented alongside the Problem-Based Learning (PBL) model, student engagement in the learning process increases, leading to improved learning outcomes. Research by Ahmad et al. (2023), Isma et al. (2021), Langitasari et al. (2021), Nurkomaria et al. (2022), and Priyanti & Nurhayati (2023) supports the idea that differentiated learning enhances students' mathematics performance. Moreover, differentiated learning effectively addresses diverse learning needs, improving overall learning outcomes (Purnawanto, 2023; Sarie, 2022). Incorporating tailored instruction within the PBL framework further enhances student learning outcomes.

Based on the description above, which references the research findings, it is possible to conclude that differentiated learning presents learning in a way that enables students to enhance their learning outcomes in mathematics. Thus, students in class X.8 at SMAN 2 Tanjungpinang can achieve better learning outcomes in mathematics through tailored instruction based on the Problem-Based Learning approach.

CONCLUSION

Students' mathematics learning outcomes increased, according to the findings and wetting of the classroom action research conducted on the research participants, class X.8 students at SMAN 2 Tanjungpinang. The percentage of classical learning outcomes in the pre-cycle to cycle one has increased by 27.66%, from 29.78% to 57.44%, indicating a rise in students' mathematics learning outcomes. Subsequently, the percentage of completeness of classical learning outcomes increased by 25.53%, from 57.44% to 82.97%, between cycle 1 and cycle 2. The cycle 2 classical learning outcomes percentage of completeness is 82.97%, which is higher than the standard value indicator of the minimal completeness requirement of 70. Therefore, when applied to varied learning, the problem-based learning model can enhance students' learning results in mathematics.

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