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Problem-Based Learning Materials Integrated with Differentiated Approaches to Enhance Elementary School Students' Learning Outcomes

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Abstract

The demands of the 21st century have reshaped the educational landscape, particularly in mathematics, requiring students to acquire relevant competencies. However, many elementary students find abstract mathematical concepts challenging, highlighting the need for effective instructional materials. This study employed a Research and Development (R&D) approach using the ADDIE model. Data were collected through questionnaires and multiple-choice tests, and the analysis was conducted using descriptive statistics and inferential analysis. Instructional materials integrating Problem-Based Learning (PBL) with a differentiated approach were designed and evaluated for validity, practicality, and effectiveness in teaching the perimeter and area of squares and rectangles to fifth-grade elementary students. Teacher and student feedback indicated that the materials were highly practical, and no significant obstacles were encountered. The analysis of student learning outcomes showed a significant improvement in mathematics achievement. These results imply that differentiated PBL materials can enhance students' learning experiences and outcomes, providing a viable solution for addressing individual learning needs in mathematics education. By providing relevant and tailored materials, educators can more effectively address abstract learning challenges and meet the demands of 21st-century competencies.

INTRODUCTION

Background of the Study

The challenges of the 21st century have significantly reshaped the educational landscape, particularly in mathematics education. To meet these challenges, students must develop robust 21st-century competencies. These competencies include critical thinking, problem-solving, creativity, independent learning, effective communication, collaboration, empathy, adaptability, and digital literacy. Mathematics, with its logical and systematic nature, is uniquely positioned to cultivate these essential skills. However, mathematics often presents abstract concepts that can be intimidating for elementary school students, who typically struggle to grasp these ideas. According to cognitive learning theory, children at this stage are in the concrete operational phase (Danoebroto, 2015), meaning they learn best through direct, hands-on experiences. Therefore, effective mathematics instruction should be designed to provide such experiences, fostering deep engagement, and understanding.

One effective method is the manipulative-assisted mathematical investigative approach, which enhances students' abilities to explore, hypothesize, and draw conclusions (Susanta, 2020). Elementary school students require well-structured learning resources and processes to fully comprehend mathematical concepts. Mastery of mathematics at the elementary level is crucial, as it lays the foundation for future academic success. The early introduction of key mathematical concepts at this stage is critical (Susanta et al., 2021). Thus, innovative, and carefully designed instructional strategies are vital for helping students build a strong understanding of mathematics.

Instructional materials play a crucial role in the learning process. To provide students with hands-on experiences, these materials are developed to present content that is both relevant and appropriate, which is then integrated into a problem-based learning (PBL) model. Research supports this approach, showing that problem-based learning, when combined with differentiated instruction, can significantly enhance students' learning outcomes (Robi’ah, 2023).

The PBL model leverages problems as the driving force for learning, transforming students from passive recipients of information into active problem-solvers who can expand their knowledge (Rahmania, 2021). The process begins with problem exploration and analysis, leading to solutions derived from student-led inquiry (Agus, 2018). Implementing PBL in elementary schools is particularly important because it involves a series of student-centered activities that improve comprehension of the material. This model not only fosters effective collaboration within groups but also actively engages students in solving problems (Afni, 2020). Moreover, it has been shown to have a significant positive impact on student learning outcomes (Adesta, 2017).

Instructional materials for problem-based learning (PBL) should be thoughtfully developed with students' learning needs in mind. A differentiated approach provides an effective strategy to accommodate the diverse learning profiles and characteristics of students. As Abdulloh (2020) notes, students learn most effectively when instruction is tailored to their individual learning profiles and needs. Consequently, it is crucial to offer students ample opportunities to develop their interests, talents, and creativity in alignment with their cognitive, physical, and psychological growth.

Differentiated instruction is a teaching methodology that delivers content in various ways to meet students' specific needs. This approach customizes instructional materials according to students' cognitive levels, ranging from Low Order Thinking Skills (LOTS) to Middle Order Thinking Skills (MOTS) and High Order Thinking Skills (HOTS). As Tomlinson (2001) explains, differentiated instruction is an effort to align classroom learning processes with students' needs, considering their readiness, learning profiles, interests, and talents (Aprima & Sari, 2022).

Integrating a differentiated approach into the development and application of PBL instructional materials on topics such as the perimeter and area of squares and rectangles represents a promising innovation to advance educational goals and enhance students' mathematics learning outcomes. This

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approach is expected to help students deepen their understanding of mathematical concepts, improve their critical thinking skills, and apply their knowledge in meaningful contexts (Felder & Brent, 2019).

Problem of The Study

The insufficient development of students' cognitive abilities is a key factor contributing to their struggles with mathematics. Data from the 2022 Program for International Student Assessment (PISA) shows that Indonesia ranked 68th out of 81 countries in mathematics, with an average score of 379, significantly below the global average of 500 (OECD, 2023). This underscores the urgent need for significant improvement in the mathematical competencies of Indonesian students.

Research suggests that students need a more interactive and engaging learning approach to improve their understanding of mathematics. Currently, education remains heavily textbook-centered, which often fails to actively involve students. These textbooks are typically brief, lack sufficient illustrations, and do not consider the diverse abilities and learning styles of individual students. Furthermore, the practice exercises provided are often homogeneous and do not adequately address the range of cognitive skills required for students to develop a deep and practical understanding of mathematical concepts (Radović, 2020). Teachers encounter significant challenges in developing instructional materials that are not only relevant and engaging but also tailored to the diverse needs of students, considering their varying learning styles and cognitive levels (LOTS, MOTS, and HOTS). To effectively support students' cognitive development, these materials must be carefully designed to address their specific needs (Tomlinson, 2019). The difficulty is compounded by the scarcity of resources that integrate ethnomathematics into elementary education, which is essential for enhancing student learning outcomes (Purwanto, 2020).

In response to these challenges, this research seeks to create Problem-Based Learning (PBL) instructional materials that integrate a differentiated approach for teaching the concepts of perimeter and area of squares and rectangles, while also embedding ethnomathematical contexts. This method is anticipated to improve elementary students' learning outcomes by situating mathematical concepts within local cultural contexts, thereby making learning more meaningful and motivating for students (Moust et al., 2019). By designing instructional materials that align with the needs and characteristics of students, it is expected that their mathematics learning outcomes will improve, and their cognitive abilities will develop more fully. This approach also aims to contribute positively to the future ranking and quality of mathematics education in Indonesia (Purba & Surya, 2020).

Research's State of the Art

Educational materials are crucial components of the education system, meticulously designed to align with the curriculum and achieve specific learning outcomes. When structured effectively, these materials become powerful tools for conveying educational content to students (Berharu & Sheferaw, 2022). High-quality and relevant educational materials support teachers in creating and executing a more organized and efficient learning process, while also aiding students in meeting the competencies specified by the curriculum.

In mathematics education, the significance of educational materials is profound for both instructors and learners. Research by Lestari et al., (2021) highlights that using suitable and contextually relevant materials can substantially improve student learning outcomes. These materials not only facilitate a deeper understanding of mathematical concepts but also allow teachers to present content in a more engaging and interactive manner. Effective educational materials serve not just as sources of information but also as tools for fostering critical thinking and problem-solving skills among students.

Appropriate educational materials enhance the quality of mathematics instruction by presenting content that resonates with students' real-life experiences. Fundamental mathematical concepts, such as the perimeter and area of geometric shapes, can be applied to various practical scenarios, including calculating land area, estimating materials for constructing a fence, or dividing a cake equitably. Ethnomathematics, particularly as practiced in Bengkulu Province, offers a concrete way to present these concepts. Abi (2017) suggest that incorporating ethnomathematics into the curriculum can make mathematics learning more contextual and meaningful. By linking mathematical concepts with local cultural practices, students are more likely to perceive the relevance of the material in their daily lives, thus enhancing their motivation and comprehension.

Differentiated instruction is a pedagogical approach that customizes teaching methods to match students' cognitive development levels. This approach is particularly effective in meeting the diverse learning needs of students (Tomlinson, 2020). By allowing teachers to adapt their instructional strategies to fit each student's unique abilities and requirements, differentiated instruction is exceptionally well-suited for the Merdeka Curriculum. When incorporated into a Problem-Based Learning (PBL) framework, differentiated instruction significantly enhances the ability to cater to varying cognitive development among students. According to research by Yew and Goh (2016di), a PBL model that integrates differentiated instruction can substantially boost students' critical thinking and problem-solving skills. This integration enables students to engage in problem-solving tasks that are pertinent to their real-life contexts, facilitating not only theoretical understanding but also practical application of concepts.

Based on the preceding discussion, employing Problem-Based Learning (PBL) models alongside differentiated instruction represents a promising approach for enhancing students' conceptual understanding and critical thinking skills. However, there is a notable paucity of research integrating these two approaches within mathematics education, especially in the development of instructional materials for teaching the perimeter and area of squares and rectangles, while incorporating ethnomathematics as a contextual element. This presents a significant research gap. This study seeks to address this gap by developing PBL-based instructional materials that integrate differentiated instruction, focusing on the perimeter and area of geometric shapes, with Bengkulu ethnomathematics as the contextual content. It is anticipated that these instructional materials will enhance students' understanding of mathematical concepts, improve their problem-solving abilities, and boost their motivation to learn, particularly for students from diverse cultural backgrounds.

Gap Study & Objective

The challenges in achieving mathematics learning outcomes in elementary schools highlight the necessity of developing instructional materials that address individual differences in understanding the concepts of perimeter and area for squares and rectangles. Although existing research has demonstrated the effectiveness of Problem-Based Learning (PBL) models in improving conceptual understanding, studies often focus on more general approaches. This research aimed to create PBL-based instructional materials that integrate differentiated instruction, designed not only to enhance problem-solving skills but also to cater to the diverse learning needs of students. It is anticipated that this approach will foster greater motivation, deeper conceptual understanding, and improved problem-solving abilities, specifically in relation to the perimeter and area of geometric shapes like squares and rectangles.

Previous studies have shown that the Problem-Based Learning (PBL) model is effective in improving students' conceptual understanding, particularly in developing problem-solving skills. However, most of these studies implement a more general approach without considering the diverse learning needs among students. In the studies conducted by Novalinda et al. (2023) and Kardipah & Wibawa (2020), the importance of flipped learning in enhancing understanding and learning motivation was emphasized, but these studies did not explicitly address the integration of differentiated instruction with PBL in basic mathematics topics, such as geometry (the area and perimeter of squares and rectangles). Meanwhile, other research, such as that by Horvath et al. (2023)

and Zhao & Li (2022), shows that the STEAM model and project-based approaches support the development of information literacy and problem-solving skills. However, although the existing literature highlights the importance of differentiation within the context of project-based learning (PBL), specific studies that integrate PBL with differentiated approaches in basic geometry concepts in elementary schools remain limited.

This research aims to develop PBL-based teaching materials integrated with a differentiated approach, designed not only to enhance problem-solving skills but also to meet the diverse needs of students. Performance-based tasks in PBL allow for content differentiation, where the depth of understanding and application of concepts can be adjusted to students' abilities. It is hoped that through this approach, students will be more motivated and will also have a deeper conceptual understanding and improved problem-solving skills, particularly related to the area and perimeter of squares and rectangles. This study aims to: 1) Develop PBL-based instructional materials integrated with a differentiated approach that align with students' cognitive levels (LOTS, MOTS, HOTS) on the topic of area and perimeter of flat shapes; 2) Test the effectiveness, practicality, and validity of these instructional materials in improving elementary students' mathematics learning outcomes, specifically on the geometry of squares and rectangles.

METHOD

Type and Design

This study adopted a Research and Development (R&D) approach, focusing on educational research and development to create Problem-Based Learning (PBL) instructional materials that incorporate differentiated instruction for teaching the perimeter and area of squares and rectangles. The development process follows the ADDIE model, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2019).

In the Analysis phase of the ADDIE model, the emphasis is on collecting and organizing information relevant to the research objectives (Reiser & Dempsey, 2023). This phase includes three primary steps: (1) analyzing the curriculum; (2) assessing the needs of students and teachers; and (3) evaluating the characteristics of the target audience. The collected data are then reviewed to ensure they align with the research objectives. During the Design phase, the researcher meticulously plans the development of the instructional materials. This involves: (1) creating a curriculum map; (2) selecting formats based on criteria set by the National Education Standards Agency (BSNP), adapted to the needs of PBL-based materials with differentiated instruction (Hannafin & Peck, 2019); and (3) drafting the initial design of the instructional materials integrating PBL and differentiated instruction.

In the Development phase, the researcher constructs and revises the instructional materials based on the initial design draft (Richey & Klein, 2020). After completing the design, the materials are validated by designated experts, and revisions are made in response to the feedback received.

The Implementation phase of the ADDIE model focuses on validating the development draft and revising it based on expert feedback (Morrison et al., 2020). During this phase, the instructional materials are utilized in a learning setting to evaluate their impact on educational quality. This involves assessing the practicality of the materials through feedback from teachers and students, as well as measuring their effectiveness in enhancing students' mathematics learning outcomes. The goal of this implementation is to collect feedback to refine and improve the draft product.

In the Evaluation phase, the developed materials undergo both limited and extensive testing. The limited trial is conducted at Public Elementary School X1 Bengkulu City, while the extensive trial is carried out across three additional schools: Public Elementary School X2, Public Elementary School X3, and Public Elementary School X4 Bengkulu City. This evaluation includes the collection of both qualitative and quantitative data to assess the effectiveness, efficiency, and overall appeal of the instructional materials.

Data and Data Sources

This development research primarily focuses on detailing the research product through the use of both quantitative and qualitative data. The qualitative analysis encompasses an evaluation of the implemented curriculum and a review of the instructional materials from the perspectives of both teachers and students. Concurrently, the quantitative data collection involves distributing assessment sheets that measure product validity and conducting surveys to gauge student responses. The overall evaluation of the product is conducted through tests aimed at assessing students' learning outcomes in mathematics, particularly concerning the concepts of perimeter and area of squares and rectangles.

The study is carried out in the Penggerak Public Elementary Schools in Bengkulu City, which are institutions applying the Merdeka Curriculum and receiving financial support from the Ministry of Education and Culture of the Republic of Indonesia. Table 1 provides a list of these schools.

Table 1. List of Penggerak Public Elementary Schools in Bengkulu City

School Name	Status
Public Elementary School X1 Bengkulu City	Public
Public Elementary School X2 Bengkulu City	Public
Public Elementary School X3 Bengkulu City	Public
Public Elementary School X4 Bengkulu City	Public

(Source: Office of Education and Culture of Bengkulu City)

The research subjects were selected from fifth-grade classes, based on the identification of challenges in mathematics content and the need for supplementary instructional materials as noted by elementary school teachers. Of the four schools, Public Elementary School X1 was designated for the limited-scale trial, while Public Elementary School X2, Public Elementary School X3, and Public Elementary School X4 were selected for the extensive-scale trial. Classes within each school were chosen randomly. The study sample comprised a total of 212 students across the four schools, with a detailed breakdown provided in Table 2.

Table 2. Research Sample Distribution

School Name	Activity	Number of Students	Teacher
Public Elementary School X1 Bengkulu City	Limited-Scale Trial	25 students	2
Public Elementary School X2 Bengkulu City	Extensive-Scale Trial	Experimental: 32 students Control: 31 students	2
Public Elementary School X3 Bengkulu City		Experimental: 25 students Control: 26 students	2
Public Elementary School X4 Bengkulu City		Experimental: 24 students Control: 22 students	2
Total		212 students	8

Data Collection Technique

The data collection phase in the development of Problem-Based Learning (PBL) instructional materials, integrated with a differentiated approach, employs a range of techniques. First, document analysis is conducted to inform the design of instructional materials by examining the curriculum, student textbooks, and learning objectives. Second, interviews with fifth-grade teachers at Public Elementary School X1 Bengkulu City are carried out to gain insights into the instructional needs and to gauge student responses to various pedagogical approaches. Semi-structured interviews are used, providing the flexibility for more open and in-depth discussions. Third, questionnaires are administered to validate the instructional materials and to collect feedback from both teachers and students. Finally, pretest and posttest assessments are implemented to measure students' comprehension before and after the instructional intervention, serving as an indicator of the effectiveness of the developed materials.

Research instruments are essential tools for measuring observed natural or social phenomena, as represented by the research variables. In this study, the instruments include document analysis sheets, interview guides, questionnaires to assess user characteristics, validation forms, student response surveys, evaluations of instructional material practicality, and assessments of cognitive learning outcomes. The validation forms employ a five-point rating scale: excellent (5), good (4), adequate (3), poor (2), and very poor (1).

Data collection focuses on assessing students' spatial abilities in solving mathematical problems. The test instrument comprises 10 multiple-choice questions, specifically designed to align with the concepts of perimeter and area of squares and rectangles. The questions are distributed evenly across three key indicators: knowledge, application, and reasoning. The instrument underwent rigorous review by two experts, who evaluated the relevance of the content and the construction of the questions. The instrument's logical validity was confirmed through Aiken's analysis, with all items exceeding an Aiken's V index value of 0.5, and its reliability was established through interrater reliability, which demonstrated a very strong level of agreement.

Table 3. Interpretation of Rater Agreement

Value	Percentage of Data Reliability	Level of Agreement
0 – 0,20	0 – 4%	No Agreement
0,21 – 0,39	5 – 14%	Weak Agreement
0,40 – 0,59	15 – 34%	Fair Agreement
0,60 – 0,79	35 – 63%	Moderate Agreement
0,80 – 0,90	64 – 81%	Strong Agreement
Di atas 0,90	82 – 100%	Very Strong Agreement

(McHugh, 2012)

Based on Table 3 the instrument was subsequently administered to a sample of 22 sixth-grade students at Public Elementary School X2 Bengkulu City. The reliability analysis yielded a Cronbach's alpha coefficient of 0.83, exceeding the commonly accepted threshold of 0.7. This result underscores the instrument's robustness and reliability in alignment with established standards.

Data Analysis

Data analysis is a critical phase in the research process, serving as the foundation for interpreting findings and drawing meaningful conclusions. This phase encompasses the transformation of qualitative data into quantitative formats and involves a comprehensive set of activities, including preliminary data analysis, validation and questionnaire evaluation, practicality testing, as well as normality, homogeneity, and hypothesis testing, culminating in the N-Gain hypothesis analysis. Homogeneity and hypothesis testing are conducted using the SPSS statistical software, adhering to a 5% significance threshold. These analytical procedures are designed to assess differences in students' average learning outcomes before and after the intervention, as well as to evaluate the extent of improvement in their performance. In parallel with quantitative analysis, qualitative data analysis is performed to assess the quality of students' responses derived from interviews and documentation, with a particular focus on evaluating responses within the cognitive levels of LOTS, MOTS, and HOTS. This dual approach ensures a robust understanding of both the statistical and qualitative dimensions of the research findings.

RESULTS

Development of Problem-Based Learning Materials Integrated with a Differentiated Approach

This study successfully developed instructional materials rooted in Problem-Based Learning (PBL) and integrated with a differentiated approach, specifically designed for teaching the concepts of perimeter and area of squares and rectangles to 5th-grade elementary students. The development process was rigorously evaluated for validity, usability, and effectiveness in the classroom setting. Formative assessments were conducted at each stage, while summative evaluations took place during small-scale field trials (prototype 2), which informed revisions before the larger-scale trials. The final iteration, prototype 3, represents the high-quality, refined product.

The development process began with an analysis phase, marking the foundational step in creating PBL-based teaching materials integrated with a differentiated approach. This phase focused on the curriculum currently in use, identified as the "Merdeka" curriculum, and concentrated on the specific topics of perimeter and area of squares and rectangles. The learning objectives, aligned with the curriculum, stipulated that by the end of 5th grade, students should be able to calculate the perimeter and area of various plane figures (triangles, quadrilaterals, and polygons) and their combinations. The developed materials include two core learning modules: 1) the perimeter and area of squares, and 2) the perimeter and area of rectangles.

An initial blueprint for the development of teaching materials was crafted, guided by the results of the needs analysis. This design process involved mapping out the content to be developed and selecting an appropriate format for integrating a differentiated approach into Problem-Based Learning (PBL) materials. The content, language, and visual elements were meticulously designed to meet criteria adapted from the National Education Standards Agency (Badan Standar Nasional Pendidikan, BSNP). The materials were structured to include components such as real-world problems relevant to students' everyday lives, elements of ethnomathematics, and learning experiences utilizing a PBL model integrated with a differentiated approach, ensuring these elements formed a cohesive whole. The language employed in these materials was specifically tailored to the linguistic characteristics of elementary school students, particularly 5th graders. It adhered to BSNP criteria by using clear, communicative language that avoids ambiguity, multiple meanings, and follows correct grammar. The overall design of the teaching materials also followed BSNP guidelines, with careful attention to font selection, layout, and the use of illustrations in both the cover and content. The materials were designed to align with the characteristics of 5th-grade students, with the standard book size being A4, and the cover was designed to be visually appealing, providing a general overview of the book's content.

In the subsequent development stage, the researcher prepared the necessary materials and tools to bring the initial design to life. The teaching materials were developed and designed using Canva Premium, ensuring a unified and polished final product. The process began with creating a foundational layout design, which served as the template for the teaching materials. This product is based on PBL and incorporates a differentiated approach for teaching the concepts of perimeter and area of plane figures. Furthermore, this product is provides an exposition on the concept of ethnomathematics, supplemented by a reference to the Tabot Bengkulu tradition, which can be explored further via a QR code linking to a YouTube video, also presents instructional material on the perimeter and area of squares and rectangles, accompanied by additional resources for each topic, accessible through QR codes.

The Problem-Based Learning (PBL) instructional materials, integrated with a differentiated approach, incorporate Student Worksheets (LKPD) meticulously crafted to accommodate the diverse cognitive levels of students—namely, Lower-Order Thinking Skills (LOTS), Middle-Order Thinking Skills (MOTS), and Higher-Order Thinking Skills (HOTS). The structure and design of these worksheets. During the implementation phase, the initial development draft underwent rigorous validation and subsequent revisions, guided by expert feedback. The validity of the materials was assessed using Aiken's Index, as detailed in Table 4.

Table 4. Validity Test Results of the Instructional Materials

Aspect	Aiken's Index	Validity
Material Presentation	0,81	Highly Valid
Language Usage	0,77	Moderate
Media Usage	0,88	Highly Valid

Upon achieving a high standard of validity and reliability, expert validators provided suggestions for improvement on the material aspects: stimulus questions were designed using mathematical language that was easy to understand; in terms of language, the use of capital letters in sentences had to follow writing conventions; on the design aspect, illustrations on the front cover were adjusted to match the title of the instructional material; the layout design of the instructional material had to be consistent from beginning to end; and the positioning of images in the instructional material was adjusted and presented systematically to make it easier for students to read. The final stage of development focused on evaluating the teaching materials. This evaluation stage included the practical implementation of the developed material in the classroom to determine its impact on the quality of learning. Specifically, the evaluation included teacher and student response tests to assess the practicality of the material, as well as effectiveness tests to measure its influence on students' mathematics learning outcomes.

A preliminary trial was conducted on a limited scale at SDN X1 Bengkulu City, involving 25 students. During this trial, Teacher A delivered lessons employing the PBL model integrated with the instructional materials. Student responses were meticulously analyzed to evaluate the practicality and usability of the materials. Based on the feedback received during this trial, the instructional materials were refined.

Following these revisions, a broader-scale trial was implemented across three elementary schools: Public Elementary School X2 Bengkulu City, Public Elementary School X3 Bengkulu City, and Public Elementary School X4 Bengkulu City. The results of this trial were overwhelmingly positive, with an average response rate of 98% from teachers, classified as highly practical, and 95% from students, also categorized as highly practical. These findings underscore the conclusion that the Problem-Based Learning instructional materials, designed with a differentiated approach, are highly practical for instructional use, with no significant obstacles encountered during their implementation.

Student Learning Outcomes Using Problem-Based Learning Instructional Materials Integrated with a Differentiated Approach

Furthermore, after the researcher carried out data analysis on the practicality of teaching materials, in the extended trial phase the effectiveness of the instructional materials was evaluated by analyzing the difference between students' pretest and posttest scores after engaging in Problem-Based Learning (PBL) sessions that utilized PBL-based materials integrated with a differentiated approach. The analysis of learning outcomes, based on multiple-choice assessments, demonstrated that these instructional materials significantly improved students' mathematics performance. This conclusion is further corroborated by the N-Gain test results presented in Table 5, which show that the improvement in learning outcomes is classified as high.

Table 5. N-Gain Test Results for Pretest and Posttest in Experimental and Control Classes

Class	N-Gain Score	N-Gain Criteria
Experimental	0,7014	High
Control	0,4479	Moderate

The marked improvement in student learning outcomes can be attributed to the instructional materials used in the experimental class, which organized students into groups according to their cognitive levels—LOTS, MOTS, and HOTS. These students engaged in investigative or experimental activities that enabled them to explore and understand the concepts of area and perimeter of geometric shapes as outlined in the instructional materials. Below is an example of an investigative activity included in the materials for the LOTS, MOTS, and HOTS groups.

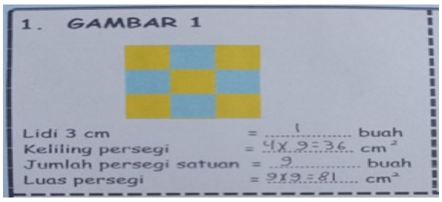

Figure 1. Student Responses in the LOTS Group Investigative Activity

Based onFigure 1 depicts the responses from students in the LOTS group as they engaged with a worksheet problem on calculating the area and perimeter of a square. The LOTS group determined the perimeter by counting the number of matchsticks surrounding the square and calculated the area by counting the unit squares that filled the square's surface. These responses were further clarified in the following interview excerpt:

Teacher (T): How did you calculate the perimeter of the square?
Student (S): We counted the number of matchsticks along the sides of the square, ma'am.
T: And what did you determine the perimeter to be?
S: It's 12 matchsticks long, and each matchstick is 3 cm, so the perimeter is 36 cm, ma'am.

This dialogue reveals that while the students understood the concept of perimeter, they had not yet utilized the formal mathematical formula for calculating it. In the subsequent investigative activity, the MOTS group was given a different approach: they arranged unit squares on the square's surface and derived the formulas for area and perimeter through this hands-on experience. Below is an excerpt from the students' responses in the MOTS group.

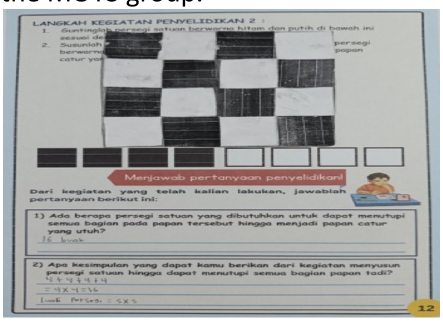

Figure 2. Student Responses in the MOTS Group Investigation Activity

Based on Figure 2 illustrates the responses of students in the MOTS group as they worked to derive the formula for the area of a square. These responses were further clarified through the following interview exchange:

Teacher: "*How did you determine the area of the square?"*
Student: "*First, we arranged the available unit squares to completely cover the area. Then, we concluded that the area could be calculated by multiplying the lengths of its sides*"
Teacher: *"So, what is the area of the square?"*
Student: *"4 x 4 = 16 square units"*

This transcript demonstrates that the MOTS group students reasoned out the formula for the area of a square by multiplying the side lengths. Following this, the HOTS group was provided with a word problem related to the area of a square for their investigation activity. Below is an excerpt from the responses of the HOTS group.

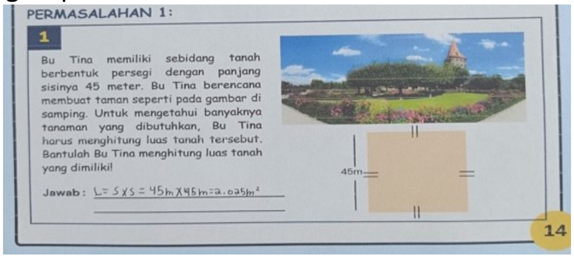

Figure 3. Student Responses in the HOTS Group Investigation Activity

Based on Figure 3 the responses of students in the HOTS group as they solved a problem related to the area of a square. These responses were further clarified through the following interview exchange.

Teacher: *"How did you determine the area of the square?"*
Student: *"Since the garden is square-shaped, each side measures 45 meters"*
Teacher: *"So, what is the area of the square?"*
Student: *"45 m x 45 m = 2,025 m²"*

The teaching materials also include evaluation questions tailored to each student group, with problems designed to match their respective cognitive levels. Below is an excerpt of the assessment tasks provided in the teaching materials for the LOTS, MOTS, and HOTS groups. For the LOTS group, students were tasked with calculating the area of a square, given the length of its sides. Their responses are presented as follows:

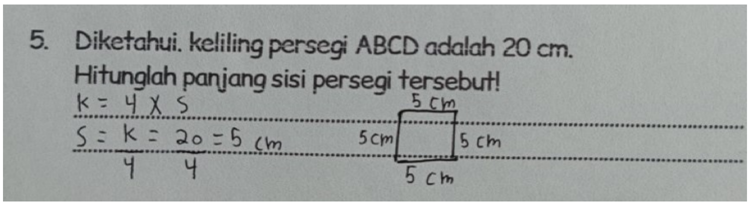

Figure 4. Student Responses in the LOTS Group Assessment

Based on Figure 4 shows the responses of students in the LOTS group as they solved a routine problem related to the area of a square. These responses were clarified through the following interview exchange.

Teacher: *"How did you determine the length of the sides of the square?"*
Student: *"We used the perimeter formula, ma'am-4 times the side length"*
Teacher: *"So, what is the length of one side of the square?"*

Student: *"20 cm ÷ 4 = 5 cm"*

This conversation transcript indicates that the students in the LOTS group applied the formula for the area of a square by multiplying the length of its sides. For the MOTS group assessment, students were given a more challenging word problem in which the area was provided, and they were asked to determine the length of the sides of the square. Below is an excerpt of the responses from the MOTS group.

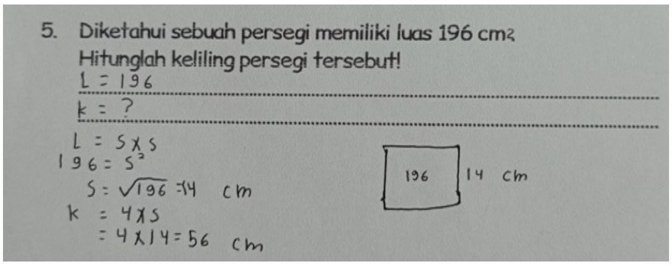

Figure 5. Student Responses in the MOTS Group Assessment

Figure 5 presents the responses of students from the MOTS group as they worked on a problem concerning the area of a square. The following explanation is derived from an interview conducted to clarify their answers.

Teacher: *"What is the objective of this problem?"*
Student: "*The problem provides the area of the square, ma'am. We were asked to first find the length of the square's side, and then to calculate its perimeter"*
Teacher: *"How did you determine the length of the square's side?"*
Student: *"We used the formula for the area of a square, ma'am. The side length is equal to the square root of the area. So, the side length is 14 cm"*
Teacher: *"Was the problem fully solved after that?"*
Student: *"Not yet, ma'am. After that, we calculated the perimeter, which is 4 x 14 cm = 56 cm"*

This dialogue indicates that the students in the MOTS group were capable of solving a more complex problem. They demonstrated the ability to apply the formula for the area of a square to accurately determine the side length. Following this, the HOTS group was given an assessment involving a more challenging word problem set in the context of "Tabut." This problem was designed to be more difficult than the one presented to the MOTS group. In the task, the area of the square is provided, and students are required to determine the perimeter of the square. Below is an excerpt of the responses from the HOTS group.

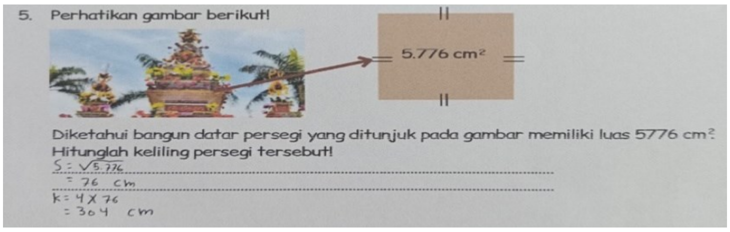

Figure 6. Student Responses in the HOTS Group Assessment

Based on Figure 6 the responses of students in the HOTS group as they worked on a routine problem involving the area of a square. The following clarification is based on an interview conducted with the students.

Teacher: *"Were you able to solve this problem?"*

Student: *"Yes, ma'am"*
Teacher: *"How did you go about solving it?"*
Student: *"First, we drew the square, ma'am. Then, we noted that the area was given as 5,776 cm². We started by determining the side length of the square and then calculated its perimeter"*
Teacher: *"Did you find this problem difficult?"*
Student: *"Somewhat, ma'am"*

This exchange demonstrates that the students in the HOTS group successfully solved the problem, though it required more than one attempt. The students exhibited a preference for engaging with non-routine and challenging problems. This differentiated instructional approach ensures that the diverse learning needs of all students are effectively met.

DISCUSSIONS

Development of Problem-Based Learning Materials Integrated with a Differentiated Approach

The final product of this instructional material, grounded in Problem-Based Learning (PBL) and integrated with a differentiated approach, was developed through a Research and Development (R&D) process using the ADDIE model. This research included both limited and large-scale trials to refine the material, ensuring it is optimally suited for mathematics instruction at the elementary school level. Analysis of the curriculum, student and teacher needs, and target characteristics identified significant challenges in mathematics instruction. Specifically, students exhibited a lack of interest in mathematics, primarily due to the absence of engaging and comprehensive learning resources and the repetitive nature of classroom activities. Effective instruction depends on several key components: selecting a teaching model that aligns with both the content and the developmental stages of students, implementing appropriate instructional strategies, and providing accessible and engaging teaching materials. The development of instructional materials is a critical strategy for achieving desired educational outcomes, as it facilitates the integration of suitable instructional models and approaches tailored to specific subject matter, particularly in mathematics. The creation of PBL-based teaching materials, integrated with a differentiated approach, represents a promising solution to these instructional challenges.

Teaching materials come in various forms, including printed resources that systematically organize content to foster a learning environment aligned with school curriculum objectives. The development of culturally-based mathematics teaching materials, utilizing a Problem-Based Learning (PBL) model and integrating a differentiated approach, involves a series of processes aimed at producing printed resources that adhere to established developmental theories while meeting the needs of educators and students, particularly at the elementary school level.

Differentiated instruction in elementary mathematics emphasizes accommodating individual differences within the classroom. This approach is designed to provide learning experiences tailored to the students' levels of understanding and specific needs. While differentiated instruction has a positive impact on student learning outcomes, it requires considerable effort, time, and thoughtful planning (Aguanda et al., 2023). A study by Nepal et al., (2021) noted that in differentiated instruction, "Participants drew upon multiple sources of knowledge when thinking about differentiation; however, they relied heavily on course units, prescribed textbooks, and their supervising teachers." In contrast, the PBL model emphasizes active problem-solving and the application of mathematical concepts in real-world contexts (Gusteti & Neviyarni, 2022).

The integration of differentiated instruction with the PBL model in elementary school mathematics is complementary but still requires the development of teaching materials as essential learning resources. In this context, educators can use differentiation to tailor instruction to the diverse needs and abilities of elementary students. This aligns with findings by Gheyssens et al. (2022), who observed that "Teachers in primary education generally have a mindset oriented towards the differentiation approach, and they report implementing differentiated practices more frequently. For example, adaptive teaching in accordance with students' readiness, interests, and learning profiles occurs regularly in primary classrooms." Differentiated instruction also fosters teachers' commitment to providing emotional support, thereby creating more meaningful learning experiences for students (Zerai et al., 2023; Smets et al., 2022). The PBL model can be effectively integrated into differentiated instruction by aligning it with students' varied cognitive levels, including LOTS (Lower-Order Thinking Skills), MOTS (Middle-Order Thinking Skills), and HOTS (Higher-Order Thinking Skills).

During the design phase, the instructional materials for this project were developed to focus on the concepts of perimeter and area for squares and rectangles. After identifying the content and creating a content map, the researcher selected and organized the format of the instructional materials. This format follows the guidelines established by the National Education Standards Agency (BSNP) and includes essential components such as the title, basic instructions, learning outcomes, learning objectives, subject matter, exercises, student worksheets, and assessment/evaluation. These elements are comprehensively integrated into the PBL-based instructional materials, which also incorporate a differentiated approach.

The researcher then created an initial draft of the PBL-based instructional materials, ensuring that all components were systematically organized into a cohesive unit. This draft was designed to arrange the summarized content and supplementary components, such as the preface, table of contents, learning outcomes and objectives, matrices, integration of the PBL model, and mind maps. This systematic approach facilitated the development of a coherent and comprehensive overall design for the instructional materials. In the development phase, the researcher finalized the design of the instructional materials, from the front cover to the back cover, using Canva-a graphic design platform that offers various templates for posters, presentations, and instructional materials. Canva enabled the creation of visually appealing materials that feature vibrant colors, animations, and engaging layouts. Such attractively designed instructional materials are likely to increase students' enthusiasm and motivation for learning, thereby positively influencing their academic outcomes (Salimi et al., 2023).

These PBL-based teaching materials, enriched with a differentiated approach, effectively integrate mathematical content into the instructional framework of the PBL model. The integration of mathematical concepts, the PBL model, and differentiated instruction within these materials is structured as follows;

1. Orientation to the Problem: The materials introduce images and essential questions designed to spark students' curiosity, help them recall prior experiences, and connect their existing knowledge to the lesson topic. These key questions are presented at the beginning of each subchapter.
2. Organizing Students for Learning: The materials are crafted to be both engaging and comprehensive, fostering students' knowledge development. They include exploratory activities that encourage students to seek information from additional sources, such as websites and YouTube, thereby promoting interaction between students and diverse learning resources.
3. Guiding Individual and Group Investigations: The teaching materials and student worksheets (LKPD) facilitate scientific inquiry, such as deriving formulas for the perimeter and area of squares and rectangles.
4. Developing and Presenting Results: The materials and LKPD emphasize collaboration among students as they work together to solve problems. This collaborative approach is designed to support and enhance students' problem-solving skills.
5. Analyzing and Evaluating the Problem-Solving Process: The materials include activities that allow students to present their problem-solving outcomes, providing opportunities to showcase their

projects and creative works (such as posters) to peers, teachers, and other members of the school community. This process encourages students to develop and express their creativity.

The learning activities embedded in these PBL-based teaching materials, combined with a differentiated approach, are designed to improve student learning outcomes. This is supported by research from Rohmah & Wijayanti (2002), which demonstrates that a PBL model integrated with a differentiated approach has a positive impact on student achievement. In the implementation phase, following the development of the PBL-based teaching materials integrated with a differentiated approach, the researcher submitted the product, along with instruments for assessing the content, language, and media aspects, to expert validators. Based on their feedback, the product was revised and deemed appropriate in all three areas. The instructional materials developed in this resource are distinguished by their unique presentation of mathematical content, language use, and media integration.

After the PBL-based teaching materials with an integrated, differentiated approach were created at the implementation stage, the researcher submitted the product and the appropriateness instruments for material, language, and media aspects to the expert validator. This product has been revised based on the validation results and meets the appropriate material, language, and media standards. The material developed in this teaching material is unique in presenting mathematical, linguistic, and media material. The feasibility and practicality of PBL-based teaching materials with an integrated, differentiated approach were obtained from research conducted on limited-scale and wide-scale trials. PBL-based teaching materials integrated with a differentiated approach are suitable for use in learning activities. In the research results, it is explained that students and teachers agree that PBL-based teaching materials integrated with a differentiated approach are very practical to use in learning activities, so that these exciting and meaningful teaching materials have a positive impact on improving student learning outcomes.

The final stage in developing PBL-based teaching materials integrated with this differentiated approach is the evaluation stage. This stage is carried out after the teaching materials are implemented in learning. At this stage, the researcher provided questionnaires and tests as well as observations to obtain data on student learning outcomes and determine the effectiveness of using PBL-based teaching materials integrated with a differentiated approach, which were analyzed using the t-test. The suitability of these PBL-based teaching materials, integrated with a differentiated approach, was confirmed through research conducted in both limited and large-scale trials. The materials were categorized as highly appropriate for use in instructional activities. The research findings revealed a consensus among students and teachers that the materials were engaging and compelling, significantly enhancing student learning outcomes.

The final stage in developing these PBL-based teaching materials is the evaluation phase, which occurs after the materials have been implemented in the classroom. During this stage, the researcher administered questionnaires and tests and conducted observations to gather data on student learning outcomes. This data was then analyzed using a t-test to assess the effectiveness of the PBL-based teaching materials integrated with a differentiated approach. The development of instructional materials based on Problem-Based Learning (PBL) and integrated with a differentiated approach constitutes an innovative model that can significantly enhance the effectiveness of educational activities within the *Merdeka Belajar* program in elementary schools. The implementation of the *Merdeka Belajar* curriculum has been supported by schools through extensive teacher training programs aimed at elevating the quality of instruction (Zulinto et al., 2023). The integration of PBL with a differentiated approach in instructional materials is expected to provide valuable new perspectives for both educators and students.

This study successfully developed mathematics instructional materials based on PBL and integrated with a differentiated approach, specifically designed to elucidate concepts, and offer assessments that reinforce the understanding of the perimeter and area of squares and rectangles among fifth-grade elementary students. The distinctive features of the developed instructional materials are as follows:

1. Integration of a Differentiated Approach: The instructional materials incorporate a differentiated approach, carefully tailored to accommodate the varying academic abilities of students through customized learning content, activities, and assessments. Notably, the learning activities, particularly the experimental tasks, include worksheets (LKPD) that are designed according to different cognitive levels: LOTS, MOTS, and HOTS. For instance, students with higher academic capabilities are provided with more challenging tasks that stimulate critical and creative thinking.
2. Adoption of the PBL Model: The instructional materials are structured using the PBL model, chosen for its effectiveness in engaging students in learning activities that address real-world problems, foster higher-order thinking skills, develop problem-solving abilities, encourage independent learning, facilitate information-gathering skills, promote teamwork, and enhance communication skills (Sani, 2014).
3. Incorporation of Diverse Learning Resources: The instructional materials are enriched with various learning resources, including teaching aids, images, YouTube videos, and PowerPoint presentations. This diverse array of resources aims to create more meaningful learning experiences by offering students access to a broad spectrum of relevant information.

The integration of the differentiated approach with the PBL model within these instructional materials presents an optimal combination, as it places the student at the center of the learning process. This approach allows students to actively participate in their learning journey and to fully realize their potential. Through the experimental activities embedded in the materials, students are encouraged to develop critical thinking skills by analyzing information, formulating solutions, and testing those solutions.

These findings corroborate prior research demonstrating that learning activities structured around the PBL model and a differentiated approach significantly enhance student learning outcomes (Manggalastawa et al., 2023). The instructional materials developed in this study also contribute to the cultivation of creative thinking skills and the mathematical learning autonomy of elementary students, owing to their integration of a differentiated approach (Deswita et al., 2024). Moreover, the development of PBL-based mathematics instructional materials that incorporate a differentiated approach offers valuable insights and practical experiences for educators in designing mathematics instructional resources across a variety of topics (Susanta et al., 2023).

Student Learning Outcomes Using Problem-Based Learning Materials Integrated with a Differentiated Approach

The effectiveness of mathematics instruction through problem-based learning (PBL) materials integrated with a differentiated approach was evaluated using data from both limited-scale and broader-scale trials. The limited-scale trial involved 5th-grade students at Public Elementary School X1 in Bengkulu City, where achievement tests were administered to assess the improvement in student learning outcomes following the use of these PBL-based instructional materials. The findings from the limited trial revealed that educators effectively implemented each step of the PBL model integrated with a differentiated approach throughout the learning activities. This effectiveness is clearly reflected in the substantial improvement in students' mathematics test scores, with the average pretest score rising from 41.6 to an average posttest score of 82.4.

Following the limited-scale trial, the instructional materials were revised based on feedback from respondents, after which a broader-scale trial was conducted. This broader trial involved fifth-grade students at three public elementary schools: Public Elementary School X2, Public Elementary

School X3, and Public Elementary School X4 in Bengkulu City. The results from this trial led to the conclusion that the use of Problem-Based Learning (PBL) instructional materials, integrated with a differentiated approach, significantly enhances student learning outcomes.

The test questions included within the instructional materials were designed with ethnomathematics as a local context. As students engaged with these questions, they recalled prior knowledge of ethnomathematical objects they had previously encountered, such as the Tabot of Bengkulu, which positively influenced their comprehension of the problems presented. This finding is consistent with the research of Susanta et al., (2023), which suggests that designing test instruments in alignment with local content has a positive impact on students' understanding. Similarly, research by Susanta et al., (2022) demonstrated that mathematics problems framed within the Bengkulu context aid students in grasping the questions more effectively. Furthermore, Putri (2023), found that PISA-style questions set within an Asian context contribute to making the learning process more meaningful and accessible. Additionally, the use of ethnomathematical content in mathematics problem design has been shown to positively influence student creativity (Ifana et al., 2023).

The aggregated student learning outcomes across the schools involved in the study indicated highly positive results from using PBL-based instructional materials integrated with a differentiated approach. These findings align with those of Dharmaji and Astuti (2023), who observed that instruction using a differentiated approach combined with the PBL model leads to improved student learning outcomes. This conclusion is further supported by Pozas et al., (2020), who stated that "peer tutoring within the differentiation approach has a significant positive effect on student achievement and further fosters positive interactions between students."

he implementation of the Problem-Based Learning (PBL) model within these instructional materials has proven to significantly enhance students' understanding of mathematical concepts. Utilizing PBL to delve into and expand students' conceptual knowledge is crucial for cultivating 21st-century skills, including communication, collaboration, critical thinking, and creativity (Nasution et al., 2023). This perspective is echoed by Riyanto et al., (2023), who contend that learning activities incorporating the PBL model positively influence students' comprehension of concepts. The PBL model effectively nurtures students' critical and creative thinking abilities, which are essential for addressing the challenges of the 21st century.

During the initial phase of the PBL model, where problems are first introduced, students are encouraged to develop curiosity and engage in critical thinking as they work to uncover the underlying concepts necessary for solving the presented problems (Susanto & Susanta, 2022; Setiawan, & Islami, 2020). This approach not only strengthens students' mathematical critical thinking skills Suhirman dan Ghazali, (2022); Lapuz dan Fulgencio, (2020) also creates a learning environment that begins with real-world problems, stimulating higher-order thinking and creativity as students seek solutions and resolve the challenges posed (Astuti et al., 2021). Additionally, there is a noticeable increase in students' emotional, cognitive, and behavioral engagement when learning through PBL (McQuate, 2020).

The development of these instructional materials has also proven beneficial for educators. In designing and implementing problem-based learning activities, educators are required to refine their creative thinking skills to develop mathematics problems aligned with higher-order thinking skills (Widiatsih et al., 2020). Furthermore, these materials support the concept of "Merdeka Belajar" (freedom to learn), allowing students to engage with content according to their cognitive levels—LOTS, MOTS, and HOTS. The effectiveness of the PBL-based instructional materials, integrated with a differentiated approach, is evidenced by the significant improvements in student learning outcomes, as demonstrated by the pretest results from both limited and broader-scale trials. The instructional materials developed in this study are considered effective if they successfully achieve the intended goal of enhancing the mathematics learning outcomes of fifth-grade students in public elementary schools in Bengkulu City.

The success of developing PBL-based instructional materials integrated with a differentiated approach is assessed by evaluating students' understanding of the concepts and their ability to solve problems related to the mathematical topics of perimeter and area of squares and rectangles. These concepts were taught and measured through carefully crafted test questions designed as word problems, tailored to match the students' academic abilities. The goal of these word problems is to hone students' problem-solving skills, as solving mathematical word problems enhances analytical, critical, and creative thinking abilities (Nurdahwati et al., 2023). This enhancement is facilitated by instructional materials that provide problem-based learning activities (Susanta & Koto, 2021).

CONCLUSION

This study has demonstrated the effectiveness of integrating Problem-Based Learning (PBL) with a differentiated approach in enhancing students' understanding of the concepts of perimeter and area of geometric shapes. The innovative aspect of this research lies in the application of PBL combined with a differentiated approach to address the challenges of learning abstract mathematical concepts. This method not only deepens students' conceptual understanding but also fosters critical thinking, creativity, and collaboration—skills essential for success in the 21st century. The development of PBL-based instructional materials tailored to diverse learning profiles represents a significant advancement in mathematics education, offering a practical solution to the challenges faced by educators. Despite its effectiveness, this study is limited to the context of teaching perimeter and area of geometric shapes. Future research should explore the application of this instructional model across various mathematical topics and in different educational settings. Additionally, investigating the role of teachers in facilitating PBL and differentiated instruction could provide further insights into optimizing the effectiveness of these approaches. The findings of this study have important implications for mathematics education. Educators are encouraged to adopt and adapt PBL-based materials that incorporate differentiated instruction to improve student engagement and learning outcomes. Future studies should focus on broadening the scope of this approach and examining its impact on other areas of mathematics, as well as its application in diverse student populations.

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