Effectiveness of differentiated learning in mathematics: insights from elementary school students

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ABSTRACT

This study looked at the effectiveness of differentiated learning in enhancing students' mathematical outcomes by incorporating varied content, processes, and products. Employing a mixed-methods experimental design, the research hypothesized that differentiated instruction significantly influences students' performance in mathematics exams. The differentiation strategy involved altering the level of support in group discussions (process), adjusting the material's difficulty (content), and modifying the nature of student tasks (products). The participants comprised sixty-five fifth-grade students from public elementary schools. Data collection utilized interviews, document analysis, observations, and test questions, with the t-test and paired sample t-tests comparing pretest and post-test scores to assess the impact. The findings revealed that differentiation in content, process, and product significantly enhances student mathematical achievements, thereby supporting the initial hypothesis. This suggests that teachers should tailor instruction by varying the structure, support, and autonomy of task completion and product creation. Future research should expand the application of content, process, and product differentiation to a broader sample, including different mathematical materials and extending to high schools, to further validate these results and explore additional educational contexts.

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1. INTRODUCTION

The diversity of students and their distinct qualities present significant challenges for teachers in the classroom, especially in executing the learning process. Teachers are often required to multitask and confront daily hurdles. Observations from Indonesian primary schools indicate that only 18% of students reach a minimum of level 2 proficiency in mathematics, substantially below the Organization for Economic Co-operation and Development (OECD) average of 69% [1]. This gap is largely attributed to students' difficulties in comprehending explicit instructions and mathematical representations of basic concepts. Additionally, the prevalence of a teacher-centered learning approach, which has been long-standing in various countries, hampers the adoption of differentiated learning strategies [2]. Traditional educational models tend to view student diversity as a drawback, focusing mainly on intellectual intelligence and neglecting individual interests or learning profiles. Such models use assessments merely to identify students who have mastered the material, with teachers resolving issues and setting uniform assessment standards for the entire class [3], [4]. The persistence of conventional teaching strategies often leads to student disengagement and inattention [5], [6]. When implementing differentiated learning, it's crucial to consider various aspects, with learning readiness, interests, and student profiles standing out as key reference points [6].

To improve student learning results, differentiated instruction is advised. This method addresses the requirement for a learning strategy that is customized to the unique needs and development of each student. According to Tomlinson and Jarvis [7], differentiated learning involves customizing the classroom setting and teaching strategies to each student's specific needs [8]. This approach involves a series of efforts that consider the specific learning profiles, interests, and abilities of students [5]. Differentiated learning focuses on three key factors to ascertain the needs of every student: their learning profiles, interests, and readiness [9]. It is well known that students who participate in activities that make use of their prior knowledge and abilities demonstrate their readiness to learn-are more likely to succeed [8]. Differentiated learning entails a continuous cycle of understanding students' unique needs and adjusting teaching methods accordingly [10]. When educators commit to continuously learning about and acknowledging the diversity of their students, they facilitate professional, effective, and successful learning experiences [11].

Differentiated learning stems from thoughtful decisions educators make, considering the unique needs of their students [12]-[14]. These choices include modifying lesson plans to fit the unique requirements of students based on the teacher's comprehension of those needs and customizing the curriculum, which establishes the learning objectives [15]. In this approach, continuous assessment plays a crucial role, utilizing data from formative assessments to pinpoint students who may be lagging or those who have already achieved the set learning objectives [10]. The key benefits of differentiated learning include its proactive nature, focus on quality over quantity, and the incorporation of diverse methods of content, processes, and products [7]. The initial step in crafting differentiated instruction involves evaluating students' readiness, creating engaging learning scenarios that capture their interest, and accommodating their preferences for learning environments [8], [16].

When math learning techniques, content, and outcomes are strategically integrated into the classroom and customized to meet the individual needs of each student, differentiated learning results [17]. This approach involves varying the organization and presentation of content, which encompasses the ideas, knowledge, and skills students are expected to master according to the curriculum [18]. Product differentiation is a method of distinguishing between the outputs of student learning and the outcomes of applying and further developing the acquired knowledge [19]. Meanwhile, process differentiation entails adopting various strategies to modify the learning processes students engage in, enabling them to practice and internalize the content more effectively [20]. All students will have access to learning options that are most beneficial to their unique development and comprehension thanks to this all-encompassing approach.

The differentiation learning developed in this study is in the mathematics learning of elementary school students. Differentiated learning aims to enhance life skills-particularly those related to creativity, critical thinking, teamwork, and communication-and it can aid in the development of mathematical learning competencies [21]. These are skills that are essential for 21st-century employment [22]. To support other cross-disciplinary and non-cognitive skills as well as the development of values, norms, and ethics (soft skills), the development of mathematical competencies also emphasizes proficiency or skills in using technological devices to perform technical calculations (computing) and presentations in the form of images and graphics (visualization) [23]. Learning mathematics is the formation of a mindset for understanding and reasoning in a relationship [24]. The scope of elementary mathematics includes numbers, geometry, measurement, and statistics. Area and perimeter flat building materials are essential materials in learning geometry in elementary schools. Instructors can engage pupils in discovering broad concepts of flat wake using media that students can find in everyday life [25]. The learning stage is implemented by varying support through group discussions (processes), varying the level of difficulty of the material (content), and varying the work or assignments of students (products) in learning mathematics flat material materials [21].

Differentiated learning is first implemented by determining the needs, interests, and starting skills of students concerning flat construction material [26], [27]. Fifth graders in the experimental class use application in their study of mathematics. The results of this identification show that some children are already familiar with the concept of becoming flat. The next stage of learning is implemented through various techniques, namely large group discussions and small group discussions to investigate flat wake problems. The flat wake material learned is divided into materials to recognize flat wakes around, identify the type of flat wake, and draw flat wakes (content). Student work or output from flat wake learning includes question assignments from student worksheets, flat wake type works created on paper, and flat wake type drawings (products).

Various differentiated learning studies have been carried out in science learning [28], in improving students' reading comprehension and literacy skills [29], and which is a learning solution for student diversity in inclusive classrooms [30]. This study investigates how the differentiation of learning processes, products, and content affects primary school students' learning outcomes in mathematics. Although studies have previously looked at the effectiveness of differentiated learning, they have not specifically addressed the content, procedures, and end products of this approach and how they affect student learning. By combining content, processes, and products in mathematics education, this study aims to determine the improvement of student learning outcomes. Using a hypothesis test, we assume that varied, differentiated instruction affects students' math exam results.

2. METHOD

In this study, a mixed-method approach was employed, utilizing a complex mixed-method design with a focus on mixed-method experimental (intervention) design. Researchers gathered and analyzed both quantitative and qualitative data, integrating them into experiments or intervention trials. This means that to investigate before experimenting, qualitative information data is gathered beforehand. To put it another way, qualitative research done before an intervention can assist researchers in determining whether it is necessary and in identifying potential factors that could increase or decrease its effectiveness [31]. This methodology was implemented in one school during the even semester of the 2022-2023 school year. Over 14 weeks, teachers used differentiated instruction in mathematical learning, specifically varying content, processes, and products of flat building materials within the classroom environment to collect data [32].

The quasi-experiment employed a one-group pre-test and post-test design, lacking significant control over external variables [33]. Initially, researchers administered a pre-test (O1) to the experimental class to establish their baseline understanding. The experimental group then underwent treatment (X), engaging in the mathematical learning process through differentiated content, processes, and products of flat building materials. Subsequently, the experimental group completed a post-test (O2) to measure the impact of the differentiated learning approach on their math outcomes. Purposive sampling, a non-random technique, was used to select participants. In particular, students in high school 5, specifically those in grades 11 and 13, were selected based on the common traits of students in that age range, such as self-perception, social anxiety, attachment orientation toward peers, and interpersonal skills in friendships [34]. The study involved 65 fifth-grade students from public elementary schools 11 and 36 in Lubuklinggau City (n=60).

The study utilized various tools, including test questions, study materials, observation sheets, and interview sheets. Ten essay test questions were found to be valid after analyzing trial data from thirty respondents, with correlation values exceeding the Rtable values at both the 1 and 5% significance levels of 0.105 and 0.080, respectively. However, all question items had dependency values (Cronbach's Alpha) below 0.7. Both quantitative and qualitative data analysis techniques were applied. Quantitative analysis involved calculating the proportion of student involvement, and the average learning outcomes, and conducting pretest and posttest paired t-tests using a statistical package for the social sciences (SPSS). Qualitative data was collected through observations conducted either before or during each cycle of the learning process. The stages of qualitative data analysis included data reduction, data presentation, and drafting conclusions [35].

3. RESULTS AND DISCUSSION

3.1. Results

The initial stage of this research's implementation was gathering qualitative information about the instructional strategies employed in Lubuklinggau City's public elementary schools 11 and 36. The following are the findings from the researchers' observations and interviews conducted in schools: "The learning activities' strategies are still traditional, involving lectures and assignments, and there are barriers to learning, such as students who follow the process and pay less attention to teachers or who tend to take up too much space in the classroom, low student enthusiasm in learning, continued reliance on whiteboards and visual media in instructional materials, low student activity and learning outcomes are the result of the teacher's inability to manage the classroom to meet the needs of children. Furthermore, the teaching tactics have not taken into account the pupils' interests, readiness, or learning profiles."

Qualitative data findings empirically guide the preparation of lesson plans. Diverse learning materials are used to carry out the process, which involves student participation through the use of teaching aids, questions and answers, group discussions, tiered assessments, content creation linked to the knowledge gained, creation of procedures to aid in the understanding of concepts and information, and product demonstrations that are a result of the knowledge gained. Before starting the learning process, researchers provided a preliminary test (pretest) to determine the initial ability of students before they were given a course. A final exam called a posttest, was given after the learning process to evaluate the learning outcomes of the students following an intervention that used differentiation of content, processes, and products. The data on student learning outcomes in Table 1 showed an average score of 69.06 students completing the pre-test or 69.06% of the total. The average number of test results increased to 78.73, with a percentage of 78.73% at the time of the post-test. The following table provides a summary of the learning outcomes.

Table 1. Recapitulation of learning outcomes differentiation of content, process, and product

No	Test	Number of students	Average	Percentage (%)
1	Pre-test	60	69.06	69.06
2	Post-test	60	78.73	78.73

Teachers incorporated various content related to the circumference of flat shapes into their lesson plans, resulting in students demonstrating a high level of understanding of the material. Students were drawn in by visually captivating and memorable picture media, which inspired them to create student work on the subject. Corrective actions were necessary when teaching mathematics courses in the fifth grade using materials on flat shapes to achieve learning objectives. These actions pertained to teacher performance, student activities, and learning outcomes in these pre-cycle activities. Figure 1 offers more information on the improvement of students' mathematics learning outcomes from the pre-test to the post-test.

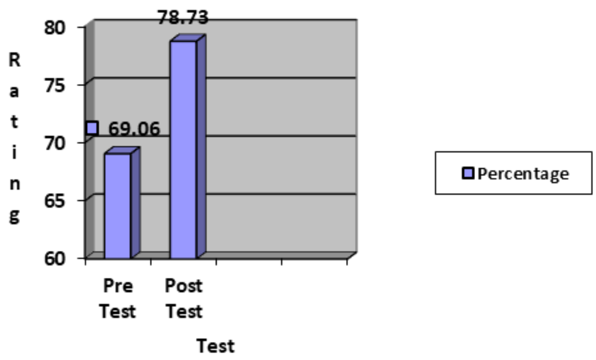

Figure 1. Comparison of pre-test and post-test student learning outcomes

The quantitative findings presented in Table 2 were derived from collecting test question data from grade 5 students at public elementary schools 11 and 36 in Lubuklinggau City. Using SPSS, the analysis computed the paired sample t-test on the pretest and post-test values. This statistical test was employed to compare the average scores before and after a specific intervention, determining whether the treatment had a significant effect. The following are the findings from the paired samples t-test for the pretest and post-test values.

Table 2. Analysis of paired t-test recapitulation on pretest and post-test values

Paired differences							
Pair 1 Pre-Test - Post Test							
			95% Confidence interval of the difference				
Mean	Std. Deviation	Std. Error means	Lower	Upper	t	df	Sig. (2-tailed)
-9.66667	6.20734	.80136	-11.27019	-8.06314	-12.063	59	.000

Using SPSS to compute a paired samples t-test on the data from Table 2, the analysis produced a computed t-value of -12.063, with a crucial t-value (t-table) of 2.000. The obtained significant (Sig.) value was 0.000, indicating a value below the 0.05 alpha threshold. As a result, the alternative hypothesis (H1) is accepted and the null hypothesis (H0) is rejected. Therefore, it can be concluded that varied learning strategies significantly impact students' mastery of mathematics, specifically in the context of using flat and roving content. This supports the argument that differentiating the content, processes, and products in teaching fifth-grade elementary school mathematics leads to improved student learning outcomes.

3.2. Discussion

This research looked into the effect of the use of processes, content, and product differentiation in teaching mathematics using flat building materials on student learning outcomes with qualitative and quantitative data. Conducted in Public Elementary School 11 and Public Elementary School 36 in Lubuklinggau City, it aimed to enhance the educational experience for fifth-grade students. Differentiated learning strategies were employed as interventions to rectify the reported inadequacies in student involvement that existed before these measures. Observational data highlighted a significant lack in student learning activities, attributed to a monotonous approach by teachers, resulting in diminished student interest [29]. Furthermore, it was noted that teachers had not sufficiently explored the backgrounds of their students concerning their previous learning experiences and skill development. The inadequate instructional design that resulted from failing to match the learning process with the student's interests, readiness, and learning profiles was a serious worry. The average student learning results as a result of this mismatch fell short of the predetermined standards, highlighting the necessity of specialized teaching strategies to raise student proficiency and engagement in mathematics.

During the intervention, there was a noticeable increase in student activity within the classroom, marking an improvement over the previous state of learning. Students began to engage more by asking questions, using teaching aids for demonstrations, participating actively in discussions, and presenting their discussion results. However, areas for further enhancement remain, including diversifying the content learned, ensuring students fully grasp ideas and information, making image media more engaging and memorable to foster learning interest and addressing the issue of some students not focusing on the material or demonstrating learned outcomes [19]. Initially, students' pre-test scores were relatively low, with an average of only 69.06. Post-intervention, there was a notable increase in test scores, with the post-test average rising to 78.73. Significant results from the hypothesis test supported the introduction of differentiated learning methodologies, which was credited with these gains in the classroom. This analysis allows for a partial conclusion that differentiated learning strategies have a positive impact on the mathematics learning of flat shapes [2]. This aligns with research by [28], which suggests that tailored instruction can significantly enhance children's academic performance and interest in mathematics.

The study revealed a significant correlation between the differentiation of content, process, and product and math learning outcomes, demonstrating a notably high level of enhancement in student comprehension tailored to their abilities. It was discovered that students participate in projects that require them to create a variety of things. These projects vary in terms of difficulty, length, and amount of scaffolding that professors or peers offer. These activities leverage essential skills and knowledge to grasp key concepts or address significant questions [20]. Further research [27], [36] has shown that differentiated learning implemented by teachers should encompass the development of diverse media, targeted student assessments, effective classroom management, and the application of differentiation strategies without compromising curriculum content. The significance of enhancing teacher-student engagement through diversified learning techniques across content, processes, and products is emphasized by these findings, which are consistent with earlier studies. In addition to promoting individualized problem-solving support and extra attention for students in need of specialized teaching, this technique guarantees full student engagement in the learning process.

Furthermore, the research demonstrated that differentiation in content, processes, and products, without compromising the diverse abilities of students, provided information that improved students' capacity to learn, think, and produce work independently, critically, and with greater enthusiasm in adherence to mathematics learning outcomes on flat materials. Students were better able to learn, think, and produce work independently, critically, and more enthusiastically in participating in learning outcomes. This aligns with findings [37], indicating that when students received differentiated instruction tailored to their needs, a pivotal transformation was achieved [38]. Furthermore, the practice of inclusive education played a crucial role in enabling teachers to establish a positive learning environment [39]. To be more selective in applying methods or strategies in learning activities, teachers needed to navigate how students choose, obtain, process, and remember new information, as highlighted by findings [21], [40], [41]. This demonstrated how important it is for educators to concentrate more on helping students in an effective way through differentiation, especially when it comes to meeting the requirements of high achievers who have greater learning potential through the use of tactics that incorporate a variety of teaching modalities [42].

The study made clear that educators need to modify how students approach tasks and turn in products, as well as the structure and amount of support they receive. The fact that learning materials can be tailored to students' interests in mathematics and other subjects was emphasized. Additionally, the task's level of difficulty should be adjusted to accommodate the different preparedness levels of the pupils in the class. The study stressed the value of teachers in related areas working together to create better learning opportunities. Schools are urged to provide support for teachers to openly share the challenges and hurdles faced during the learning process [43]. Through the differentiation of content, processes, and products, this inquiry focused on the comprehensive learning outcomes of students in mathematics education. Nevertheless, it identified the necessity for more in-depth research to verify its strategies, content, and outcomes, especially about intricate and distinct mathematical topics. The findings suggest that there is an increased resilience in learning outcomes when differentiation is applied across content, procedures, and products in mathematics education. Future inquiries might explore various mathematical materials, include high school environments, and incorporate larger sample sizes.

4. CONCLUSION

This study's results revealed that applying differentiation learning strategies in fifth-grade mathematics education, particularly with flat material instruction, significantly improves student learning outcomes. It was evident that varying instruction, procedures, and end products had succeeded in satisfying students' varied requirements and promoting an inclusive learning environment. Such an approach not only increased teacher engagement but also ensured active participation from all students, providing additional support and tailored instruction for those needing extra help with problem-solving. These findings offer valuable insights for educators, especially teachers, aiming to refine their teaching methods. By developing mathematical curricula that address individual student needs, teachers can significantly enhance learning outcomes. Future investigations are anticipated to expand on these strategies, employing a broader sample size, exploring different educational settings, and extending into other academic disciplines.

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