

Implementation of Differentiated Mathematics Learning in Quadratic Functions at Senior High Schools

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Abstract

This article discusses differentiated learning in mathematics at SMAN 4 Surakarta, focusing on how this approach is implemented in the quadratic function material. The research uses a qualitative methodology with a single-anchored approach, employing triangulation of data sources and methods to ensure data validity. Data collection was done through document analysis, in-depth interviews, and observations. The findings reveal that mathematics teachers initially used differentiated learning strategies to develop and implement math modules. In the learning process, differentiation is applied through varying content, processes, and products in the quadratic function material. Teachers also use assessments based on cognitive, affective, and psychomotor guidelines for evaluation. The study concludes that differentiated learning enhances students' critical and creative thinking skills in mathematics, although challenges such as limited facilities, infrastructure, and insufficient learning time are noted. This research provides implications for improving instructional strategies and educational practices to foster a more inclusive and effective learning environment.

Keywords: *differentiated learning, Mathematics learning, learning outcomes*

Introduction

The Merdeka Curriculum uses a new approach to education and evaluation (Ultra Gusteti, 2022; Wijyaningputri et al., 2024). (1) Learning is developed by taking into account the stages of growth in achievement levels, learning needs, characteristics, and development of various students so that learning is more relevant and enjoyable. These learning principles are what is called the "new learning paradigm". (2) education aims to develop the ability to learn continuously throughout life. (3) The development of student character and competence is supported holistically by the learning process. (4) Relevant learning. (5) Education that pays attention to sustainability (Dasar & Menengah, 2021; Sari et al., 2023). Differentiated learning can be designed and implemented by educators to meet these learning principles.

The explanation above suggests that to prepare students to face the dynamics of a future life full of challenges, education needs to be oriented in such a way that it can accommodate various potential differences for the sake of developing and optimizing the competencies and character of students (Astuti & Afendi, 2022; Haryadi Santoso & Istiyono, 2022). Differentiated learning is one of the goals that must be realized to fulfill these expectations, which requires critical and equitable revitalization of education. The concept of diversified learning was first proposed by Carol Ann Tomlinson in 1999. It is defined as teaching that considers each student's readiness, interests, and learning preferences while accommodating, serving, and recognizing their diversity. Meanwhile, content differentiation learning focuses on what is taught to students (Tomlinson, 2017; Trinanda & Yaswinda, 2022).

Tomlinson (2017) argues that teachers in differentiated classrooms do not use standardized, mass-produced teaching methods that are considered appropriate for all students, as they recognize that each student is an individual. Instead, differentiated instruction allows teachers

to effectively teach according to content standards while addressing the diverse needs of all students. In this model, teachers adopt a flexible approach to teaching, adjusting the curriculum and how it is presented, rather than expecting students to adjust themselves (Hall et al., 2014). This approach involves modifying content, processes, products, and learning environments for each student, taking into account their individual readiness, interests, and learning profiles (Tomlinson, 2017).

Teachers in today's classrooms have the same challenges as teachers in one-room schools years ago (Graham et al., 2020). Teachers compete by effectively meeting students' learning needs which revolve around learning readiness, interests and cultural views and experiences (Pozas et al., 2023). Differentiated teaching is not new as it is based on best practices in education (Singh & Singh, 2014). This approach offers educators an effective model based on the belief that all students can learn, with strategies that can be used in a discriminatory and purposeful manner based on standards, content and student needs (Woodcock et al., 2022). One of them is through learning mathematics. To maximize mathematics learning and improve students' abilities in learning mathematics, teachers must be able to differentiate between different learning instructions in the classroom (Simanjuntak et al., 2023).

Mathematics learning is a process of connecting different learning elements to improve students' critical thinking and problem-solving abilities (Kamarulzaman et al., 2022). Students who study mathematics can build mathematical concepts using their abilities in encouraging student initiative and involvement in the learning process is the goal of mathematics learning (Chamberlin & Powers, 2010). Mathematics is a tool for solving problems, thinking, and communicating. Mathematics can be used to improve reasoning, logic, creative thinking, problem-solving, and other mathematical skills (Hery Murtianto, 2013). To improve their mathematical skills, students can be actively involved in class, express opinions, and ask questions. Using various learning models, techniques, and tactics that are adapted to the subject matter and student needs (Ultra Gusteti, 2022).

Mathematics learning needs to involve student activity, both physical activity and mental activity, and focus on students, based on daily experiences. While studying, students will have meaningful learning experiences so that at this stage students are able to develop the values of mathematics learning (Chamberlin & Powers, 2010; Evendi et al., 2023).

However, despite the availability of effective strategies, there remains a gap in the implementation of differentiated learning in mathematics. While mathematics education is vital for developing critical thinking and problem-solving skills (Kamarulzaman et al., 2022), and despite its potential to promote logical reasoning and creativity (Hery Murtianto, 2013), the active involvement of students in the learning process is not always guaranteed. The gap is particularly evident in how students engage with mathematical concepts and whether the teaching approach truly addresses individual student needs. Moreover, even though differentiated learning models could enhance engagement and understanding, there is still insufficient integration of these approaches in many classrooms, particularly where facilities and infrastructure may be lacking. This observation was particularly evident during initial assessments of the mathematics learning process at SMAN 4 Surakarta. Here, the uniqueness of the differentiated learning implementation, despite the challenges of inadequate facilities, sparked the researcher's interest to further explore how this model is applied in this setting.

The initial observations revealed a unique approach in the implementation of differentiated learning in mathematics for class X at SMAN 4 Surakarta. Despite the limited facilities and infrastructure, the mathematics teacher was able to effectively apply differentiated learning strategies. This distinct practice in mathematics teaching at SMAN 4 Surakarta sparked the researchers' interest to explore and investigate further the implementation of differentiated

learning in this particular setting. The research aims to gain deeper insights into how differentiated learning can be effectively carried out in a classroom with minimal resources..

Method

This research uses a descriptive-analytical method with a qualitative approach (Miles et al., 2013).. In this method, the researcher not only describes events that have occurred but also analyzes the meaning of the phenomenon. Analysis in descriptive research can be divided into activity analysis and content or document analysis. Activity analysis is an analysis that aims to analyze the activities carried out during the implementation of tasks. Content or document analysis is an analysis that aims to collect and analyze official documents, both legal and policy documents, and research results. Data collection is the most important step in this research because the main aim of the research is to obtain valid data (Naeem et al., 2023).

Qualitative research design requires careful planning of the research management framework, including the research stages. The research stages carried out were preparation, implementation, and data processing (Creswell, 2014). The data collection techniques used in the research were interviews, observation, and document study using tools in the form of interview guides, observation guides, and recording equipment. The stages in this research help to collect as much data as possible and describe the data accurately and systematically about the research. Research instruments are tools needed or used to collect data. Written guidelines and observations function as research tools and are processed through observation, interviews and documentation. Data analysis is organizing data, presenting data, and drawing conclusions.

This research was conducted at SMAN 4 Surakarta, a school chosen due to its unique challenges in implementing differentiated learning in mathematics, despite limited facilities and infrastructure. The researcher, being a teacher at the same school, had direct access to the classroom environment and the opportunity to observe and engage with both students and teachers. This case study employs a qualitative research approach, which is suitable for exploring the intricacies of classroom practices. In qualitative research, ensuring the validity of data is crucial. This study addresses four key criteria of data validity: construct validity (ensuring the research measures what it intends to), internal validity (confirming that the findings are attributable to the variables being studied), external validity (examining the extent to which the findings can be generalized to other settings), and reliability (ensuring consistency and dependability of the research process). In this research, data were analyzed through triangulation of sources and methods, combining observations, interviews, and document analysis to provide a comprehensive understanding of the differentiated learning process at the school.

Results

Learning planning

In implementing differentiated learning planning in Mathematics, the process begins with a collaborative meeting among Mathematics teachers at SMAN 4 Surakarta. Based on interviews with the teachers and analysis of documentation, it was found that this meeting serves to align the perceptions and teaching strategies of the Mathematics faculty. The meeting takes place at the start of the academic year, typically between late June and early July 2023. The outcomes of this collaborative process include key teaching documents such as modules, annual programs (Prota), semester programs (Prosem), assessments, and teaching materials.

The modules developed by the Mathematics teachers are guided by the Learning Outcomes (CP) from the Ministry of Education and Culture, available through the Merdeka

Belajar Platform. Through teacher interviews and document analysis, it was revealed that the responsibility for creating these modules is entrusted to the subject teachers to ensure that the content is aligned with students' needs and the specific context of the school. This process begins with reducing the CP into Learning Objective Flows (ATP), followed by designing steps for differentiated learning based on student characteristics. Interviews and observations confirmed that teachers assess students' learning styles and prior knowledge through surveys and trigger questions to adjust their teaching methods accordingly.

The modules used in the classroom are customized to address the needs of students, incorporating technology-based resources, particularly for topics on sequences and series. Documentation of the lesson plans reveals that the modules include barcodes that students can scan to access instructional videos related to the material. Additionally, the modules emphasize the Pancasila Student Profile, fostering critical and creative thinking. Teachers encourage students to solve problems related to sequences and geometric series by reasoning critically and developing creative solutions, such as constructing formulas and recognizing patterns in the material.

Observations and interviews further revealed that teachers plan their lessons systematically, developing detailed lesson plans, activities, and assessments. The planning process aligns with the Merdeka Belajar curriculum and involves interactive methods such as question-and-answer sessions and group discussions. The teachers begin each lesson by distributing links to videos and reading materials on sequences and series, followed by engaging discussions and a post-test to assess comprehension. Lesson documentation shows that the objectives are crafted to develop students' critical thinking skills, helping them analyze and interpret the material in meaningful ways. Teachers ensure that students understand the relevance of the lesson by linking series and number concepts to real-life applications (EH, Teacher Interview, 2024).

the findings of this study show that the planning and implementation of differentiated mathematics instruction at SMAN 4 Surakarta have been effective, despite limitations in facilities and time. The collaboration among mathematics teachers at the beginning of the academic year to align perceptions and plan instructional materials that meet students' needs has proven to be an effective step. The planning process, which involves creating modules tailored to students' learning styles and characteristics, demonstrates that differentiated learning can adapt the content to individual needs, thereby enhancing students' understanding and engagement in learning. Additionally, the use of technology and the principles of the Pancasila Student Profile, as reflected in the use of videos and barcodes in the modules, supports the development of students' critical and creative thinking skills.

Through observations, teacher interviews, and document analysis, it was found that learning activities involving group discussions and project-based learning have been particularly effective in improving students' critical and creative thinking skills. Mathematics learning not only focuses on understanding the material but also on applying mathematical concepts in real-life situations, allowing students to become more actively involved in the learning process. However, time and facility constraints remain the main challenges in the implementation of this differentiated learning approach, affecting the optimization of the learning process. These findings suggest that differentiated mathematics instruction has great potential to enrich students' learning experiences, although attention is needed to address the existing barriers.

Implementation of Learning

In implementing differentiated learning, three key components are emphasized: (1) content (input), which refers to what students learn; (2) process, or how students gather information and formulate ideas about what they learn; and (3) product (output), or how students present

what they have learned. Based on observations, interviews, and documentation, these components are tailored and adjusted according to students' levels of readiness, areas of interest, and learning profiles. These adjustments ensure that each student can engage meaningfully with the learning process and maximize their learning potential.

1. **Content:** Content directly connects to students' prior knowledge, understanding, and learning goals. Teachers adjust how students access or engage with the subject matter based on their individual readiness levels and interests. Classroom observations revealed that teachers provided differentiated materials, such as visual aids for visual learners and simplified texts for students requiring additional support, ensuring that all students could access the content effectively.
2. **Process:** The process refers to how students acquire knowledge and skills. Teachers facilitate varied learning activities that allow students to interact with information in ways suited to their needs. Interviews with teachers revealed that methods such as group discussions, peer teaching, and independent tasks were used to support students in exploring and processing concepts. Documentation, including lesson plans and student worksheets, illustrates how activities were designed to accommodate different learning profiles and foster deeper engagement with the material.
3. **Product:** The product is the tangible outcome students create to demonstrate their learning. Students are encouraged to present their knowledge in ways that align with their strengths, such as written reports, oral presentations, or creative projects. Based on observations and teacher interviews, students were given the flexibility to choose the format that best represented their understanding, enhancing their motivation and engagement in the learning process.

In the Mathematics subjects, differentiated learning was implemented in classes X.3 to X.6 by two Mathematics teachers. Documentation of the lesson schedule shows that the learning process was conducted over three meetings, each lasting 6 JP (lesson periods). Observations of classroom practices revealed that the teachers employed a project-based learning model, supported by discussion methods, differentiated media, and varied learning resources. The teachers utilized tailored instructional tools and materials to meet the diverse needs of their students, as evidenced in student assignments and assessment records.

Differentiated learning in mathematics classrooms has proven to be an effective teaching strategy. It helps accommodate the diverse learning needs and preferences of students through varied teaching approaches. Additionally, differentiated learning shifts the paradigm of traditional, often monotonous, mathematics instruction to a more engaging and enjoyable experience, thereby increasing student enthusiasm in the classroom (EH, Teacher Interview, 2024).

In implementing the lesson, the teacher shares links in the form of videos and reading texts among:

1. **Videos.** The results showed that the videos were created in a way that met students' needs visually. The videos used by teachers vary depending on the material being taught. The video comes from YouTube, then students pay attention to the video. When the teacher gave a discussion sheet, it turned out that the students were able to complete it well.

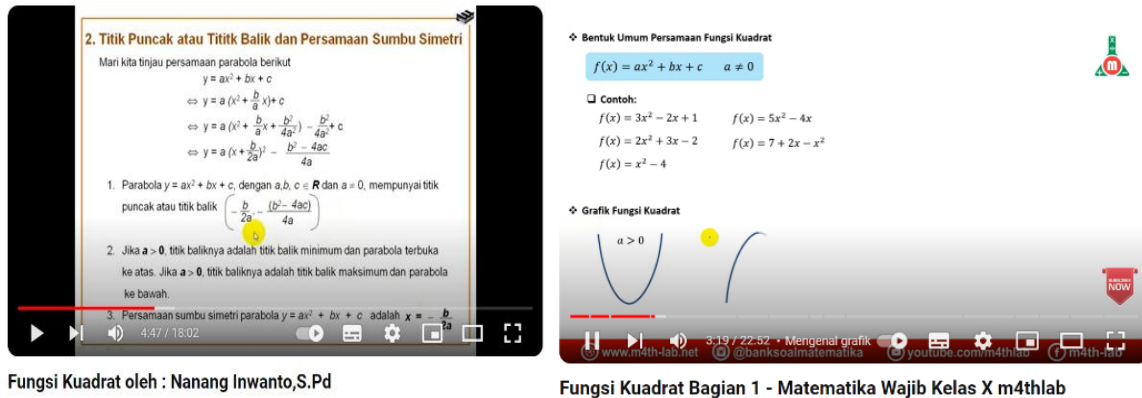


Figure 1. Learning video taken from YouTube

2. Reading Material/Text. The research results showed that the reading materials/texts were adapted to the needs of students with a visual learning style using the flipbook application. Reading materials are equipped with pictures that explain the learning. The reading material contains material about series and numbers. At the end of the reading material, students answer questions and practice questions. These practice questions function as a measuring tool to determine students' understanding of the material in this subject. Reading materials are made by the teacher in printed and book form. After finishing the teacher asks the students; It turns out that students know how to answer correctly.



Figure 2. Reading material with the Flipbook application

Evaluation Stage

The final step in the learning process is the assessment phase. During this stage, both educators and students collaborate to evaluate the learning activities that have been completed collaboratively. The assessment is crucial as it helps identify markers of learning achievement from both the perspective of the educators and the students. Although assessments in the mathematics classes have been conducted, the quality of these assessments is not yet optimal. A new assessment approach was introduced, allowing students to present their group projects in front of the class and share their findings. However, students have not yet had the opportunity to express their thoughts on the teaching methods used or suggest ideas for future learning activities.

Differentiated learning in mathematics at SMAN 4 Surakarta has shown several significant impacts. Some of the key outcomes observed during the research include:

1. Improvement in critical thinking skills: Critical thinking in mathematics education is particularly evident in learning activities that involve discussions. The variety of material presented by the teacher made group discussions lively, with many students actively participating. Visual learners engaged with textbooks and videos that appealed to their learning style, while kinesthetic learners appreciated the group discussion activities, which incorporated hands-on and progressive tasks. From the interviews, students reported that differentiated learning helped them better understand series and numbers. They were motivated to seek out additional learning resources that were easier for them to understand (KR, Student Interview, 2024). This indicates that differentiated learning facilitated critical thinking, particularly in terms of researching and processing learning materials from diverse sources to deepen their understanding of the subject matter.
2. Enhancement of creative thinking skills: Creative thinking skills were prominently developed as students were given the freedom to create projects and decide how to approach problem-solving related to series and numbers. Students recognized that differentiated learning positively influenced their ability to think creatively, as it allowed them to respond to questions fluently and explore alternative methods of finding solutions (KR, Student Interview, 2024). This highlights that differentiated learning plays a significant role in fostering creativity, especially when students are encouraged to create products and solutions that align with their individual characteristics and learning preferences.

Obstacle

The implementation of differentiated learning in Mathematics subjects follows three main stages: the initial stage, the core stage, and the final stage. Based on observations, teachers begin the initial stage by identifying students' needs, abilities, and learning preferences through diagnostic assessments and direct observation of classroom activities. Additionally, interviews with teachers revealed that this stage is critical to ensuring that the learning process aligns with the individual characteristics of students. Documentation, such as lesson plans (RPP) and assessment tools, further supports the planning process, showing how teachers design strategies to accommodate the diversity of students' learning needs from the outset.

During the core stage, differentiation is applied in three key areas: content, process, and product. Classroom observations demonstrated that teachers used a variety of instructional materials, such as visual aids and manipulatives, to address the different levels of students' understanding. The learning processes also varied, including group discussions, peer teaching, and individual assignments, ensuring active participation from all students. Based on interviews with teachers, it was noted that implementing these differentiated strategies requires careful planning and adjustments to meet each student's needs. Moreover, documentation of student work highlighted how differentiated learning allows students to demonstrate their understanding through various forms, such as written assignments, verbal presentations, or creative projects.

However, there are challenges in implementing this approach. Based on observations, limited instructional time was identified as a major obstacle, as the allocated 2x45-minute sessions were often insufficient to fully execute all stages of differentiated learning. Interviews with teachers confirmed that time constraints frequently forced them to simplify or reduce certain activities planned for differentiation. This was further supported by lesson schedule documentation, which showed a mismatch between the complexity of differentiated strategies and the available instructional time. These findings emphasize the need for improved time management or extended instructional periods to ensure the successful implementation of differentiated learning.

Discussion

The findings of this study align with previous research on differentiated learning in Mathematics. According to Aini, Rendy, and Handoyo (2023), differentiated learning is an essential approach in addressing diverse student needs. This is reflected in the implementation at SMAN 4 Surakarta, where Mathematics teachers collaboratively design learning modules based on students' readiness and interests. The structured approach allows teachers to accommodate varying levels of understanding within the classroom. Similar approaches have been highlighted by Tomlinson (2000), who emphasized that differentiated instruction enhances student engagement and understanding. By tailoring instruction to individual learning needs, students are more likely to grasp complex mathematical concepts effectively. This research confirms that differentiation plays a significant role in improving student outcomes in Mathematics.

The process of developing teaching modules observed in this study is also consistent with previous research. Bal (2016) found that designing modules tailored to students' learning profiles improves academic performance. The Mathematics teachers at SMAN 4 Surakarta follow a similar methodology by using the Learning Outcomes (CP) from the Ministry of Education and reducing them into Learning Objective Flows (ATP). This structured approach ensures that learning materials cater to various student abilities, as suggested by Simanjuntak et al. (2023). By aligning instructional content with learning objectives, teachers create a more personalized learning experience. Additionally, this method provides flexibility in addressing different learning styles within the classroom. The findings indicate that a well-planned module development process enhances overall student comprehension and performance.

Incorporating technology in Mathematics learning, as observed in this study, corresponds with the findings of Kamarulzaman et al. (2022). Their research demonstrated that integrating digital tools enhances mathematical thinking skills. The use of barcode-enabled instructional videos in the Mathematics modules at SMAN 4 Surakarta supports this claim, making learning more interactive and accessible. Technology integration allows students to engage with content beyond the traditional classroom setting. This approach aligns with the principles of the Pancasila Student Profile, which encourages critical and creative thinking in problem-solving. By leveraging digital tools, teachers facilitate a more dynamic and engaging learning environment. These findings suggest that technology-enhanced learning strategies contribute to improved student participation and understanding in Mathematics.

The implementation of differentiated learning strategies observed in this study is supported by prior research. Chamberlin and Powers (2010) highlighted that effective differentiation involves modifications in content, process, and product. At SMAN 4 Surakarta, differentiation is applied by adjusting instructional content to students' prior knowledge, using varied teaching methods, and allowing students to present their understanding through diverse formats. This supports the findings of Singh and Singh (2014), who emphasized the importance of flexible learning pathways. By incorporating multiple instructional strategies, teachers accommodate diverse learning preferences and abilities. Students benefit from tailored learning experiences that align with their individual needs. These findings reinforce the significance of differentiation in fostering a supportive and inclusive learning environment.

Furthermore, the interactive learning methods applied in the study align with previous research on effective instructional strategies. Graham et al. (2020) found that active learning approaches, such as group discussions and peer teaching, improve student engagement. Similarly, Mathematics teachers at SMAN 4 Surakarta facilitate discussions and collaborative activities, enhancing student participation. Engaging students in interactive learning fosters a

deeper understanding of mathematical concepts. This approach aligns with the findings of Pozas, Letzel-Alt, and Schwab (2023) regarding the benefits of differentiated instruction on student motivation. By promoting student collaboration, teachers create a more stimulating and supportive learning environment. These findings highlight the effectiveness of active learning strategies in improving Mathematics instruction.

The findings on assessment methods in differentiated learning also relate to previous studies. According to Evendi et al. (2023), varied assessment formats allow students to showcase their learning outcomes effectively. The assessment at SMAN 4 Surakarta includes group presentations and alternative assessment formats, catering to different learning preferences. These varied approaches support the claim that differentiated assessments contribute to deeper learning (Woodcock et al., 2022). By incorporating multiple assessment methods, teachers can evaluate student progress more comprehensively. This strategy ensures that students have diverse opportunities to demonstrate their understanding. These findings suggest that flexible assessment practices enhance overall learning outcomes in Mathematics.

Despite the benefits, this study also identified challenges in implementing differentiated learning, particularly regarding time constraints. This challenge is consistent with the findings of van Geel, Keuning, and Safar (2022), who noted that time limitations often hinder teachers from fully executing differentiation strategies. Teachers at SMAN 4 Surakarta encountered similar issues, requiring careful planning and prioritization of activities to optimize instructional time. Effective time management is crucial in ensuring that differentiation strategies are implemented successfully. Additionally, teachers may require additional support and resources to address time-related challenges. These findings highlight the need for structured planning to maximize the benefits of differentiated instruction. Addressing these challenges can lead to more effective implementation of differentiation strategies in Mathematics education.

In conclusion, the findings of this study corroborate existing research on the effectiveness of differentiated learning in Mathematics education. By implementing structured differentiation strategies, integrating technology, and employing varied assessment methods, Mathematics teachers at SMAN 4 Surakarta enhance students' critical and creative thinking skills. These approaches contribute to a more inclusive and effective learning environment. However, challenges such as time constraints highlight the need for further improvements in planning and execution. Addressing these issues can help maximize the impact of differentiated learning in Mathematics instruction. Future research may explore additional strategies to overcome these challenges and further enhance student learning outcomes.

Conclusion

Differentiated learning in Mathematics at SMAN 4 Surakarta has been proven to be effective in accommodating diverse student learning needs. The process includes an initial evaluation of students, followed by activities that differentiate content, process, and product, and culminates in final activities designed to assess student learning. This approach has not only focused on student-centered learning but has also successfully shifted the paradigm of Mathematics education from a traditionally difficult subject to a more engaging and enjoyable experience for students. However, the research also identified some limitations, primarily the lack of time, which hinders the optimal implementation of differentiated learning. This time constraint affects the depth and breadth of activities, preventing full engagement from all students.

The findings of this study have several implications for educators. Differentiated learning can significantly improve student engagement, critical thinking, and creative problem-solving in Mathematics. It emphasizes the need for teachers to adopt more flexible, student-centered

approaches to teaching that can cater to the individual needs of each student. However, for differentiated learning to be fully effective, schools should address the issue of time constraints by providing adequate planning time for teachers and creating a more supportive learning environment.

Based on these findings, recommendations for future practice include: (1) schools should consider allocating more time for lesson preparation and implementation of differentiated learning activities, (2) teachers should receive continuous professional development in differentiating instruction to further refine their teaching strategies, and (3) future research could explore how other factors, such as school infrastructure and resources, impact the successful implementation of differentiated learning.

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