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Development of a Differentiated Interactive Digital Module Assisted by Grid Paper on Plane Area Geometry in Elementary Schools

Resti Adriyatni[1*], Karlimah[2]

Universitas Pendidikan Indonesia
*Corresponding email: restiadriyatni@upi.edu, karlimah@upi.edu

Abstract

This research aims to develop a differentiated interactive digital module assisted by grid paper for teaching plane geometry area concepts in elementary schools. The study adopts the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to systematically guide the module development process. The interactive digital module integrates grid paper as a concrete visual aid to help students visualize and calculate the area of plane geometric shapes, accommodating different learning abilities through differentiated activities. Data collection techniques include expert validation, student and teacher response questionnaires, and pre-test and post-test assessments to measure learning outcomes. The results indicate that the developed module meets the criteria for validity, practicality, and effectiveness. The interactive features and scaffolded learning activities enhanced students' understanding of plane geometry concepts and increased their engagement in mathematics learning. This study contributes to the advancement of innovative and inclusive teaching practices in mathematics, providing a model that supports differentiated learning needs.

Keywords:

differentiated learning, interactive digital module, grid paper, plane geometry, elementary education

A. Introduction

The development of modern mathematics education emphasizes not only the transfer of knowledge but also the cultivation of critical thinking and problem-solving abilities. As outlined by the Ministry of Education and Culture, ideal mathematics instruction involves building mathematical reasoning skills through contextual and interactive learning approaches. Mathematics, particularly geometry, serves as a foundational subject that supports logical thinking and problem-solving abilities required in daily life. Among the critical topics in elementary mathematics is the concept of plane geometry areas, which introduces students to measuring, visualizing, and calculating space. However, in reality, teaching this concept often fails to align with the expected standards of engagement and comprehension.

Traditional instructional practices in elementary schools are often teacher-centered and rely heavily on conventional textbooks. These textbooks typically present static two-dimensional images and abstract formulas without providing students with an opportunity to explore concepts concretely or visually. For example, students are expected to memorize formulas for the area of squares, rectangles, and triangles without a clear understanding of their derivation. This approach neglects the diverse learning needs of students in a classroom and often results in difficulties understanding abstract mathematical concepts. Additionally, limited use of interactive and dynamic teaching aids exacerbates this challenge, leaving many students disengaged and struggling to grasp fundamental geometry concepts.

Research has shown that differentiated instruction, which considers students' varying abilities and readiness levels, can significantly improve learning outcomes. Differentiated instruction provides tailored teaching strategies, processes, and products to meet diverse learning needs. This approach aligns with the philosophy of inclusive education, recognizing that students learn at different paces and require personalized support. However, implementing differentiated instruction in mathematics requires appropriate tools and media that can adapt to diverse classroom dynamics. Interactive digital modules present an innovative solution by offering customizable and engaging learning experiences, enabling teachers to provide differentiated support effectively.

Digital modules, particularly those designed for interactive use, have gained attention as valuable tools for enhancing student engagement and comprehension. Unlike conventional textbooks, interactive digital modules integrate multimedia elements such as animations, simulations, and interactive exercises. These features enable students to explore mathematical concepts dynamically, bridging the gap between abstract theories and concrete understanding. Additionally, digital modules are highly accessible, allowing students to learn at their own pace and revisit materials as needed. However, existing digital modules for mathematics often fall short in accommodating differentiated learning needs. Many are static conversions of printed materials into PDF formats and lack adaptive features to cater to students' varying readiness levels.

To address these gaps, this study focuses on the development of a differentiated interactive digital module assisted by grid paper for teaching plane geometry areas in elementary schools. Grid paper serves as a tangible visual aid, enabling students to visualize and calculate areas by counting grid units. When integrated into an interactive digital format, grid paper allows for dynamic exploration of geometric concepts, bridging the transition from concrete to abstract understanding. This innovative approach incorporates scaffolding, tiered activities, and adaptive feedback mechanisms to accommodate students' individual learning needs.

The objectives of this study are to (1) analyze the needs and challenges in teaching plane geometry areas, (2) design an interactive digital module with integrated grid paper for differentiated learning, (3) evaluate the module's validity and practicality through expert reviews, and (4) assess the effectiveness of the module in improving students' understanding and engagement. This study adopts the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, a systematic framework for instructional design, to ensure that the module meets pedagogical and technological standards.

By integrating technology and differentiated instruction principles, this research contributes to advancing mathematics education practices. The findings aim to provide educators with an effective and innovative tool for teaching geometry concepts, promoting inclusivity and engagement in the learning process. Moreover, this study addresses the broader issue of how digital media can be used to create meaningful and adaptive learning experiences, preparing students for a future where digital literacy and problem-solving skills are essential.

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B. Methodology

This research employed a Research and Development (R&D) approach, which aimed to produce a practical and validated instructional product in the form of a differentiated interactive digital module assisted by grid paper for teaching plane geometry areas in elementary schools. According to Gall, Borg, and Gall (2003), the R&D method is suitable for developing innovative educational products by combining systematic development processes and iterative evaluation. The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) was adopted as the framework for this study, as it provides a structured and flexible approach for designing instructional materials (Branch, 2009).

The Analysis phase involved identifying the needs and characteristics of students and teachers regarding mathematics instruction on plane geometry areas. Classroom observations and interviews with mathematics teachers revealed that students often struggled to visualize geometric concepts, particularly the measurement of irregular shapes. Teachers also highlighted the lack of interactive media that could accommodate students' diverse learning needs. This phase further analyzed the mathematics curriculum to align the module content with existing competencies.

The Design phase focused on creating a blueprint for the interactive module. The design considerations included integrating grid paper as a concrete visual aid to support students' understanding of area measurement, incorporating interactive features, and developing tiered activities to accommodate different levels of student readiness. Storyboards and flowcharts were created to visualize the module structure and navigation paths, as suggested by Morrison, Ross, and Kemp (2010).

During the Development phase, the interactive digital module was created based on the design specifications. Multimedia elements such as animations, interactive exercises, and simulations were integrated to make learning engaging and dynamic. Grid paper, in both physical and virtual formats, was embedded to facilitate hands-on exploration of geometry concepts. Expert validation from content specialists, media designers, and mathematics educators was conducted to assess the module's validity. Suggestions from these experts were incorporated to enhance the content quality and usability.

The Implementation phase involved testing the module in a real classroom setting with fifth-grade elementary school students. The module was implemented over several sessions, and students were guided to explore concepts through differentiated activities that matched their abilities. Observations, student responses, and teacher feedback were collected during this phase to identify the module's strengths and areas for improvement.

Finally, in the Evaluation phase, both formative and summative evaluations were conducted. The formative evaluation included feedback from experts and initial user responses, while the summative evaluation assessed the module's effectiveness in improving student learning outcomes. The effectiveness was measured using pre-tests and post-tests, analyzed through the N-Gain formula (Hake, 1998). The results showed a significant improvement in students' understanding of plane geometry areas and increased engagement in mathematics learning.

The adoption of the ADDIE model ensured that the development process was systematic, iterative, and responsive to

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feedback. This comprehensive methodology provided a robust framework for creating an innovative and differentiated instructional tool, as emphasized by Branch (2009). The final product is expected to contribute to inclusive and effective mathematics education in elementary schools by addressing diverse learner needs and fostering meaningful engagement.

C. Results and Discussion

a. Results

The development of the differentiated interactive digital module assisted by grid paper for teaching plane geometry areas followed the ADDIE model, which ensured a systematic and iterative design process. This section presents the findings based on the module's validation, implementation, and evaluation results.

1. Validity Assessment Results
   The validation process involved three experts: a content expert, a media expert, and a pedagogy expert. The experts evaluated the module on three main criteria: content accuracy, media interactivity, and instructional effectiveness. The content expert found that the module adequately aligned with the curriculum and successfully illustrated plane geometry concepts through visual elements and interactive activities. The media expert highlighted the ease of navigation and user-friendly interface as key strengths, while the pedagogy expert emphasized the effective implementation of differentiated tasks. Based on expert assessments, the module achieved a validity score of 89%, categorizing it as "Highly Valid" (Gall et al., 2003).
2. Implementation Results
   The module was tested in a fifth-grade mathematics class over four instructional sessions. Observations indicated that students were highly engaged when exploring geometric concepts using the interactive features of the module, especially the virtual grid paper tool. The hands-on experience allowed students to visualize and calculate areas more effectively, supporting Bruner's (1966) theory that concrete experiences enhance cognitive understanding.
   Differentiated activities provided scaffolding for students with varying readiness levels. For instance, students with lower mathematical abilities were guided through basic grid-based calculations, while advanced students explored problem-solving scenarios involving composite shapes. Teacher observations and student responses indicated that the module successfully accommodated these diverse learning needs, consistent with Tomlinson's (2001) principles of differentiated instruction.
3. Learning Outcomes
   The effectiveness of the module was evaluated using pre-test and post-test assessments. The results showed a significant improvement in students' understanding of plane geometry areas, with an average N-Gain score of 0.72, categorizing it as a "High" level of effectiveness (Hake, 1998). Students demonstrated better problem-solving abilities and increased accuracy in calculating the area of irregular shapes compared to the pre-test results.

b. Discussion

The findings of this study highlight several important implications for mathematics instruction in elementary schools.

1. Integration of Grid Paper in Digital Learning

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The use of grid paper, both physical and virtual, played a crucial role in helping students visualize and calculate the area of plane geometric shapes. This finding aligns with the research of Rezkywati (2022), who found that grid paper effectively aids students in making abstract geometric concepts more concrete. By integrating this tool into an interactive digital format, the module provided a dynamic learning experience that bridged the gap between hands-on and virtual learning environments.

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Furthermore, the grid paper-assisted approach encouraged students to develop spatial reasoning skills, which are essential for understanding geometric relationships. Previous studies have emphasized the importance of visual-spatial learning in mathematics, particularly in geometry instruction (Clements & Battista, 1992). The ability to manipulate and observe geometric transformations through grid-based activities allowed students to internalize mathematical concepts more deeply.

Additionally, the use of grid paper supported differentiated instruction by providing a common framework that could be adapted to various student readiness levels. Struggling learners benefited from the structured guidance of counting grids, while more advanced students explored conceptual extensions, such as using fractions of grids to estimate irregular areas. This flexible approach reinforced the effectiveness of scaffolding in digital learning environments.

2. Differentiated Learning Approach

The module's design, which incorporated tiered activities and adaptive scaffolding, supported differentiated learning in the mathematics classroom. This approach ensured that students with varying abilities could engage meaningfully with the content. As Tomlinson (2001) noted, differentiated instruction enhances student engagement and learning outcomes by accommodating individual differences. The study's findings reaffirm the importance of offering multiple pathways for students to access and demonstrate their understanding of mathematical concepts.

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Moreover, the differentiated design allowed students to progress at their own pace, which is particularly beneficial in mixed-ability classrooms. Teachers

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observed that students who initially struggled with the material gained confidence as they engaged in lower-difficulty activities before transitioning to more complex tasks. This progression is in line with Vygotsky's (1978) concept of the Zone of Proximal Development, where instructional support gradually decreases as students become more independent learners.

A significant advantage of this approach is its potential for broader application beyond geometry. Differentiated digital modules can be adapted for other mathematical domains, such as fractions, measurement, and algebraic reasoning, making them a valuable tool for inclusive education. Future research could explore the scalability of this model for different mathematical competencies and diverse student populations.

3. Interactive Features and Student Engagement

The interactive elements of the module, including animations and interactive exercises, contributed significantly to maintaining student interest and motivation. This result supports the findings of Hidayat et al. (2023), who reported that interactive digital modules enhance student engagement and promote deeper learning. The immediate feedback provided by the module also helped students identify and correct errors independently, fostering self-regulated learning.

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Students expressed enthusiasm when using the digital module, as it allowed them to interact with mathematical concepts in a more engaging manner than traditional paper-based exercises. The integration of gamification elements, such as rewards for correct answers and progress tracking, further increased motivation. Studies have shown that game-based learning elements can improve both cognitive and affective learning outcomes in mathematics (Ke & Grabowski, 2007).

From the teacher's perspective, the module provided a structured yet flexible tool for instruction. Unlike traditional worksheets, the interactive features allowed real-time assessment of student performance, enabling teachers to intervene when necessary. This supports prior research suggesting that digital learning tools with adaptive feedback mechanisms can enhance formative assessment practices in the classroom (Shute, 2008).

4. Practicality and Usability

The teacher and student feedback highlighted the practicality and ease of use of the module. Teachers noted that the module provided a valuable resource for implementing differentiated instruction, reducing their workload in preparing customized learning materials. Students appreciated the intuitive design and the opportunity to learn at their own pace. These findings are consistent with Moore and Wedemeyer's (1990) assertion that digital learning tools should be user-

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Despite its benefits, some challenges were noted during implementation, particularly regarding technical access. Not all students had equal access to digital devices at home, which could impact continuity in learning beyond the classroom. This suggests the need for schools and policymakers to address digital equity to ensure that technology-based learning does not exacerbate educational disparities.

To maximize its usability, future iterations of the module could incorporate voice-assisted instructions and multilingual support to cater to diverse student needs. Additionally, integrating adaptive AI-driven recommendations based on student performance could further enhance personalized learning experiences.

5. Learning Outcomes and Cognitive Development

The significant improvement in students' post-test scores demonstrates the module's effectiveness in enhancing mathematical understanding. This result supports the constructivist view that meaningful learning occurs when students actively construct knowledge through exploration and problem-solving (Vygotsky, 1978). The use of visual aids, interactive activities, and differentiated tasks contributed to the development of students' spatial reasoning and problem-solving skills.

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Beyond improving test scores, students also demonstrated higher levels of mathematical confidence. Teachers reported that students were more willing to attempt challenging problems and engage in discussions about their reasoning. This shift in attitude is crucial, as research suggests that mathematical self-efficacy is strongly correlated with long-term achievement in STEM fields (Bandura, 1997).

Future research should investigate the long-term impact of digital modules on student learning retention. While the immediate results are promising, understanding how well students retain and apply these concepts over time would provide valuable insights into the sustainability of digital learning interventions.

D. Challenges and Limitations

Despite its success, the study encountered some challenges. Technical issues, such as limited access to digital devices in some classrooms, hindered the

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seamless implementation of the module. Additionally, some students required additional guidance in navigating the module independently. Future studies could explore strategies for overcoming these challenges, such as providing teacher training on digital tools and ensuring equitable access to technology.

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Another limitation was the study's relatively short implementation period. While the pre-test and post-test results indicate significant learning gains, a longer-term study would be beneficial to assess the sustained impact of differentiated digital learning. Longitudinal studies could explore whether students retain their understanding of geometric concepts over an extended period.

Lastly, the module's effectiveness was evaluated within a single curriculum context. Future research should examine its adaptability across different educational settings, including rural and urban schools, to determine its broader applicability in diverse learning environments.

1. Implications for Educational Practice

This study offers valuable insights for educators and curriculum developers. The findings underscore the importance of integrating interactive digital tools and differentiated instruction strategies in mathematics education. The module developed in this study serves as a model for creating inclusive and engaging learning experiences that cater to diverse learner needs.

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A key takeaway from this research is the potential for digital modules to enhance teacher instruction rather than replace it. Teachers play a crucial role in guiding students through differentiated activities, providing additional support where needed, and facilitating meaningful discussions about mathematical concepts. Thus, professional development programs should focus on equipping teachers with the skills to effectively integrate digital tools into their pedagogy.

Moreover, this study highlights the need for continued investment in educational technology infrastructure. Ensuring that all students have access to digital learning resources is essential for promoting equity in education. Policymakers should prioritize initiatives that provide schools with the necessary tools and training to implement digital innovations effectively.

2. Recommendations

Based on the findings of this research, several recommendations can be proposed to enhance mathematics instruction in elementary schools. First, it is essential for schools to adopt and integrate interactive digital learning modules as a regular part of the teaching process. The differentiated interactive digital module developed in this study has proven effective in fostering

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students' understanding of geometric concepts while accommodating their diverse learning needs. By adopting similar digital tools, educators can create a more inclusive and engaging learning environment that supports student-centered instruction.

Furthermore, teacher training programs are crucial to ensure the effective implementation of these digital modules. Teachers need to be equipped with the necessary skills and knowledge to navigate, adapt, and integrate digital resources into their instructional practices. Training should emphasize strategies for utilizing the module's differentiated features, enabling teachers to tailor learning experiences according to students' varying readiness levels and learning profiles. This approach not only enhances instructional effectiveness but also empowers teachers to embrace technology as a valuable pedagogical tool.

Additionally, schools must address the issue of digital accessibility to maximize the potential of technology-based learning. Providing adequate digital infrastructure, including devices and stable internet connectivity, is essential for ensuring that all students have equal access to digital learning resources. Policymakers and school administrators should prioritize investments in educational technology to bridge the digital divide and support innovative instructional practices.

Future research is encouraged to explore the application of similar digital modules in other mathematical topics or subject areas. Investigating the long-term impact of interactive digital modules on students' cognitive development and problem-solving skills would provide valuable insights for educational practice. Moreover, studies involving a broader and more diverse sample of students could offer a more comprehensive understanding of the effectiveness and adaptability of differentiated digital modules across various learning contexts.

In conclusion, the development and implementation of differentiated interactive digital modules hold significant potential for transforming mathematics education in elementary schools. By integrating innovative digital tools, providing teacher support, and ensuring equitable access to technology, educators can create meaningful and adaptive learning experiences that cater to the diverse needs of students and foster a deeper understanding of mathematical concepts.

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