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Development and Implementation of Android-Based Interactive E-Modules to Improve Mathematical Problem-Solving Skills at Secondary Schools Hamid Khan Pulau Pinang Malaysia

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ABSTRACT

This study aims to develop and implement Android-based interactive e-modules to enhance mathematical problem-solving skills among students at Secondary Schools Hamid Khan, Pulau Pinang, Malaysia. The main issue in mathematics learning at the school lies in students' low engagement and the lack of interactive learning media aligned with technological developments. This research adopts a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The e-modules were developed with interactive features such as tutorial videos, adaptive exercises, and automated assessments. The study involved 60 upper secondary students divided into experimental and control groups. Data were collected through mathematical problem-solving tests, student response questionnaires, and classroom observation. The results indicated a significant improvement in the mathematical problem-solving abilities of students in the experimental group compared to the control group. Student responses toward the e-modules were highly positive, with the majority expressing that the modules helped them understand mathematical concepts more enjoyably and deeply. The study concludes that Android-based interactive e-modules are effective in enhancing the quality of mathematics learning and can serve as an innovative alternative in digital education at the secondary school level.

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INTRODUCTION

The development of mathematical problem-solving skills is central to preparing students for the challenges of the 21st century, where critical thinking, analytical reasoning, and logical decision-making are vital competencies. Mathematics, as a foundational discipline, offers an ideal context to cultivate these skills through structured problem-solving processes (Polya, 2004; Schoenfeld, 2013). However, numerous international studies report a consistent difficulty among secondary school students in applying mathematical concepts to real-world problems, indicating a gap between conceptual understanding and practical application (Baroody et al., 2018; Cai et al., 2020).

In recent years, educational paradigms have shifted toward student-centered approaches that prioritize engagement, autonomy, and contextualized learning. Digital technologies, particularly mobile learning (m-learning), have become powerful tools in promoting these approaches. Mobile devices, due to their portability and ubiquity, are increasingly integrated into classroom instruction, enabling access to resources anytime and anywhere (Traxler, 2009; Crompton & Burke, 2018). The implementation of Android-based interactive e-modules is one such innovation that aligns with current educational demands, especially in mathematics education.

Interactive e-modules are digital instructional materials designed to provide active learning experiences through interactive tasks, visual media, and adaptive content delivery. These modules support students' diverse learning styles by combining text, graphics, simulations, and assessments into a coherent, self-paced learning environment (Martin & Ertzberger, 2013; Choi & Johnson, 2005). Their relevance in mathematics instruction is particularly significant, as they allow for visualization of abstract concepts and exploration of problem-solving strategies in dynamic ways.

Research has shown that the integration of digital tools in mathematics instruction leads to improvements in motivation, understanding, and retention (Hilton, 2016; Ifenthaler & Yau, 2020). Interactive e-modules, especially those designed for mobile platforms like Android, provide accessible and engaging content that supports higher-order thinking. This is essential for mathematical problem-solving, which requires cognitive processes such as interpreting data, constructing strategies, and evaluating outcomes (Jonassen, 2011; Hwang & Chang, 2011).

Despite the availability of general e-learning tools, few are explicitly designed to enhance mathematical problem-solving. Many existing platforms focus on procedural fluency rather than deep conceptual engagement. Studies emphasize the need for instructional materials that scaffold the problem-solving process, offering guided steps, feedback loops, and opportunities for reflection (Tarmizi & Tarmizi, 2010; Gresalfi et al., 2012). The e-module proposed in this study seeks to address this gap through features grounded in pedagogical and cognitive learning theories.

The ADDIE model—comprising Analysis, Design, Development, Implementation, and Evaluation—has emerged as a robust framework for developing effective instructional materials. This model ensures that educational interventions are systematically designed based on learner needs, pedagogical goals, and technological affordances (Molenda, 2003; Branch, 2009). In this study, the ADDIE model guides the development of the Android-based e-module to ensure alignment with curriculum standards and the cognitive demands of mathematical problem-solving.

A critical aspect of e-module design is interactivity. According to Mayer's Cognitive Theory of Multimedia Learning, interactivity facilitates dual-channel processing and meaningful learning, especially when learners can manipulate content and receive instant feedback (Mayer, 2009). In mathematics learning, interactive features such as drag-and-drop tasks, animated examples, and gamified quizzes enhance students' engagement and reinforce understanding (Cheung & Slavin, 2013; Hsu et al., 2013).

The Malaysian education system, as represented by institutions like Secondary Schools Hamid Khan, faces increasing pressure to integrate digital literacy and problem-solving into the mathematics curriculum. With the growing availability of mobile technology among students, the Android platform offers a viable medium for delivering personalized, flexible, and scalable learning experiences (Tan et al., 2020; Ramalingam et al., 2021). This study aligns with Malaysia's national agenda to promote STEM education and digital innovation in schools.

Students in Malaysia, like their peers globally, are digital natives with high exposure to mobile apps and technology-based communication. Traditional lecture-based mathematics instruction often fails to meet their expectations or leverage their digital competencies (Yen et al., 2021). An Android-based e-module, developed with responsive design and real-time interactivity, can foster more effective learning environments that resonate with learners' preferences and improve performance.

Effective mathematical problem-solving involves not only understanding concepts but also the ability to formulate, plan, and monitor solutions. This multifaceted process requires scaffolding, which can be provided through adaptive e-modules that personalize learning paths based on student input and progress (Liu et al., 2014; Alemdag et al., 2018). By embedding these scaffolds into an interactive digital module, educators can provide richer support than is feasible in conventional classrooms.

Furthermore, international studies affirm that mobile-assisted learning environments improve student autonomy and motivation. Learners can control the pace and sequence of content, revisit materials, and engage in reflective practice, all of which are conducive to problem-solving development (Burden & Kearney, 2017; Park et al., 2019). The use of Android-based interactive e-modules thus aligns with constructivist theories of learning, empowering students to build knowledge actively.

Digital e-modules also enhance teacher facilitation. Teachers can track student progress, provide timely interventions, and tailor instruction based on analytics provided by the platform. This functionality is critical in problem-solving instruction, where timely feedback and strategic questioning play a vital role (Papadakis et al., 2018). Teachers in SMK Hamid Khan can thus be more effective in managing diverse learning needs using this tool.

Moreover, the integration of multimedia components such as videos, infographics, and simulations makes abstract mathematical concepts more concrete. These multimodal inputs cater to different learning modalities and increase content accessibility for students with varying abilities (Sung et al., 2016;

Riconscente, 2013). Such design features are essential in addressing performance gaps in mathematics and promoting equity in learning outcomes.

This research also considers the usability of the e-module, a key determinant of learning success in digital contexts. Usability factors such as intuitive navigation, aesthetic appeal, responsiveness, and system stability influence learner satisfaction and continued usage (Khalil & Ebner, 2017). The design and evaluation of the Android-based e-module in this study prioritize these aspects to ensure effectiveness and sustainability.

In conclusion, the integration of Android-based interactive e-modules in secondary mathematics education represents a strategic response to the demands of 21st-century learning. This study aims to develop and implement a digital module that is pedagogically sound, technologically robust, and contextually relevant to the Malaysian secondary education system. The research outcomes are expected to inform instructional design practices and contribute to the broader discourse on digital innovation in mathematics education.

RESEARCH METHOD

This research employed a Research and Development (R&D) design using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional development model as the guiding framework for creating and applying the Android-based interactive e-module. The ADDIE model was chosen due to its systematic approach, which emphasizes iterative evaluation at each development stage, ensuring that the final product is both pedagogically sound and technologically robust. This method is particularly suited to educational innovations that require comprehensive needs analysis, structured instructional design, and empirical testing to validate efficacy in improving learning outcomes—in this case, students' mathematical problem-solving skills. The research was conducted at Secondary Schools Hamid Khan, Pulau Pinang, with the target population being Form Four students enrolled in mathematics courses.

In the analysis phase, the researchers conducted a thorough needs assessment by distributing questionnaires to mathematics teachers and students to identify current problems in the teaching and learning process. These surveys focused on the challenges faced in problem-solving instruction, student learning preferences, and the availability of mobile learning tools. Additionally, interviews were conducted with curriculum experts to ensure that the content of the e-module would be aligned with the Malaysian secondary school mathematics syllabus. The data gathered were used to formulate design specifications for the e-module, including topic selection, interactivity level, and user interface requirements. The results from this phase indicated a clear need for innovative, technology-based learning materials to bridge the gap between conceptual understanding and problem-solving application.

The design and development phases focused on translating the analysis results into an Android-based interactive e-module. Using instructional design principles, the module was structured into several components: concept explanation, problem-solving examples, interactive quizzes, video animations, and feedback tools. The design emphasized learner control, immediate feedback, and visual representations to facilitate understanding of complex mathematical concepts. The development utilized Android Studio as the primary platform, supported by multimedia tools such as Adobe Illustrator and Camtasia to produce dynamic learning content. The prototype was validated by experts in educational technology and mathematics education through a content validity index (CVI), followed by revisions to improve usability and pedagogical alignment before classroom implementation.

The implementation phase involved a field trial with 60 students from SMK Hamid Khan, divided into experimental and control groups using a quasi-experimental nonequivalent control group design. The experimental group used the Android-based e-module, while the control group received traditional textbook-based instruction. Both groups were taught the same mathematical problem-solving topic over a period of four weeks. Pre-tests and post-tests were administered to both groups to assess changes in mathematical problem-solving performance. The tests included multiple-choice and essay items designed to measure problem identification, planning strategies, execution, and solution evaluation—key components of mathematical problem-solving. Classroom observations were also conducted to evaluate student engagement and interaction with the module.

In the evaluation phase, data from pre-tests and post-tests were analyzed using descriptive statistics and inferential analysis, specifically paired and independent samples t-tests, to determine the significance of the differences between the two groups. Additionally, qualitative data were collected through student feedback forms and semi-structured interviews with participating teachers to assess user satisfaction, perceived benefits, and areas for improvement. The results showed a statistically significant improvement in the mathematical problem-solving abilities of students who used the Android-based interactive e-module, supporting its effectiveness as an instructional tool. Students reported increased motivation and better understanding due to the interactive and visual nature of the module, while teachers noted improvements in student participation and concept retention.

Ethical considerations were strictly observed throughout the research process. Informed consent was obtained from school administrators, teachers, students, and parents prior to data collection. Participants were assured that their personal information would remain confidential and that their involvement was voluntary. All data were anonymized during analysis and securely stored. Furthermore, the research was approved by the institutional review board (IRB) of the affiliated university and adhered to ethical standards set by the Malaysian Ministry of Education. By ensuring ethical compliance and methodological rigor, this study contributes valuable insights into the integration of mobile learning tools to enhance mathematics education at the secondary level.

The mathematical problem-solving test instrument used in this study was developed based on indicators adapted from Polya's (2004) stages, including understanding the problem, planning strategies, executing the solution, and evaluating the results. Content validity was examined by three mathematics education experts and one educational media specialist using the Content Validity Index (CVI), yielding a score of 0.89, which indicates excellent validity. Reliability testing was conducted using the KR-20 method, resulting in a reliability coefficient of 0.87, indicating high internal consistency. The sample was selected using purposive sampling based on school willingness and class-level homogeneity. Additionally, a scoring rubric was developed for each problem-solving indicator with a scale of 0–4, allowing for objective and standardized assessment.

RESULTS AND DISCUSSION

The implementation of the Android-based interactive e-module yielded significant improvements in students' mathematical problem-solving abilities. The experimental group, which utilized the e-module, demonstrated a notable increase in post-test scores compared to the control group that received traditional instruction. Statistical analysis revealed a mean score increase of 25% in the experimental group, indicating the effectiveness of the e-module in enhancing problem-solving skills.

Students using the e-module exhibited a deeper understanding of mathematical concepts. The interactive features, such as animations and real-time feedback, facilitated better comprehension of abstract ideas. This aligns with findings by Mayer (2009), who emphasized the role of multimedia in improving learning outcomes.

The e-module encouraged students to adopt systematic approaches to problem-solving. Features like guided problem-solving steps and instant feedback allowed learners to refine their strategies, leading to more accurate and efficient solutions. This observation is consistent with Jonassen's (2011) assertion that structured learning environments enhance problem-solving skills.

The interactive nature of the e-module significantly boosted student engagement. Gamified elements and interactive quizzes maintained student interest and motivation throughout the learning process. This finding corroborates the study by Hsu et al. (2013), which highlighted the positive impact of interactive multimedia on student engagement.

Student feedback indicated high levels of satisfaction with the e-module. Learners appreciated the flexibility, interactivity, and clarity provided by the module. Many reported that the e-module made learning mathematics more enjoyable and less intimidating.

Teachers observed noticeable improvements in students' problem-solving abilities and overall participation. The e-module facilitated differentiated instruction, allowing teachers to cater to diverse learning needs effectively. This observation aligns with the findings of Papadakis et al. (2018), who emphasized the benefits of technology in supporting diverse learners.

The e-module was designed with user-friendly interfaces, ensuring ease of navigation for students. Its compatibility with various Android devices made it accessible to a broad student population, promoting inclusive education.

Content within the e-module was meticulously aligned with the Malaysian secondary school mathematics curriculum. This ensured that students received relevant and standardized instruction, reinforcing their classroom learning.

The e-module's emphasis on problem-solving fostered the development of higher-order thinking skills among students. Activities required learners to analyze, evaluate, and create solutions, aligning with Bloom's taxonomy's upper levels.

Students reported an increased sense of autonomy in their learning journey. The e-module allowed learners to progress at their own pace, revisit challenging concepts, and take ownership of their learning process.

The supportive and interactive environment provided by the e-module contributed to a reduction in math anxiety among students. The ability to practice without the fear of immediate judgment encouraged risk-taking and experimentation.

Given its digital nature, the e-module can be easily scaled and adapted for use in other educational institutions. Its design allows for modifications to suit different curricula and student needs, making it a versatile educational tool.

The e-module complemented traditional teaching methods effectively. Teachers integrated the module into their lesson plans, using it as a supplementary resource to reinforce concepts taught in class.

Features within the e-module promoted collaborative learning. Students engaged in discussions, shared problem-solving strategies, and learned from each other's perspectives, fostering a collaborative classroom environment.

The e-module provided continuous assessment opportunities, allowing students to monitor their progress. Instant feedback helped learners identify areas for improvement and adjust their learning strategies accordingly.

The implementation of the e-module necessitated professional development for teachers. Training sessions equipped educators with the skills to integrate technology into their teaching effectively, enhancing overall instructional quality.

Despite its successes, the implementation faced challenges, including technical issues and varying levels of digital literacy among students and teachers. Addressing these challenges is crucial for the sustained success of such technological interventions.

The positive outcomes of this study suggest that educational policymakers should consider integrating similar technological tools into the national curriculum. Such integration can enhance learning outcomes and better prepare students for the digital age.

Future studies should explore the long-term impacts of using interactive e-modules on student achievement and retention. Additionally, research could investigate the effectiveness of such tools across different subjects and educational levels.

The Android-based interactive e-module proved to be an effective tool in enhancing mathematical problem-solving skills among secondary school students. Its integration into the educational process not only improved academic performance but also fostered positive attitudes towards mathematics, indicating its potential as a valuable resource in modern education.

Limitations of the Study This study has several limitations that should be considered. First, the research sample was drawn from only one secondary school in Pulau Pinang, thus caution should be exercised when generalizing the findings to other educational contexts. Second, the limited availability of Android devices among students meant that some participants had to share devices, which could have influenced the level of interactivity and engagement. Third, variations in the digital literacy levels of students and teachers required different adaptation times, potentially affecting the overall effectiveness of the e-module during implementation.

Practical Implications

The results of this study provide practical implications for teachers, schools, and educational media developers. Teachers can integrate this Android-based e-module into lesson plans as part of technology-enhanced learning strategies. Schools may facilitate training for teachers in using interactive media and provide infrastructure support such as stable internet access. For developers, the findings offer guidance for designing adaptive interactive learning media aligned with curriculum requirements and accessible to students from diverse technological backgrounds.

CONCLUSION

The development and implementation of Android-based interactive e-modules at Secondary Schools Hamid Khan have shown substantial effectiveness in enhancing students' mathematical problem-solving abilities. The integration of multimedia, interactive simulations, real-time feedback, and structured learning pathways empowered students to better understand mathematical concepts and apply strategic methods when approaching complex problems. The significant increase in post-test scores of the experimental group compared to the control group provides strong empirical evidence of the module's impact. Moreover, students displayed improved confidence, engagement, and willingness to tackle mathematical tasks, indicating that the learning environment fostered by the e-module was both supportive and stimulating.

In addition to cognitive benefits, the e-module positively influenced students' attitudes toward mathematics. Many learners reported enjoying the flexibility of learning at their own pace and revisiting difficult topics as needed. The interactivity and gamified elements increased motivation and reduced math anxiety, creating a more inclusive and responsive learning environment. Teachers observed that students demonstrated more active participation and autonomy in class discussions. The ability of the e-module to accommodate diverse learning needs also made it a valuable complement to conventional teaching methods, encouraging blended learning approaches that are increasingly relevant in today's digital education era.

Despite certain challenges such as limited device availability and varying digital literacy levels, the e-module proved scalable and adaptable across different learning contexts. Its success supports the growing body of research advocating for the integration of mobile learning tools in formal education. Policymakers and educators are encouraged to invest in professional development and digital infrastructure to support such innovations. Overall, the study confirms that well-designed educational technology can significantly enhance learning outcomes, particularly in skill-based domains like mathematics. Future research should explore long-term impacts and possibilities for cross-curricular application, ensuring the continuous refinement and effectiveness of mobile-based learning modules.

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