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Improving Mathematical Problem-Solving Skills through the Development of Interactive Digital Modules

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Abstrak

Modul digital merupakan bahan pembelajaran dengan visualisasi konten berformat digital yang dapat diakses menggunakan perangkat elektronik. Penelitian ini bertujuan untuk mengembangkan media pembelajaran berupa modul digital interaktif serta efektivitasnya dalam pembelajaran. Modul digital interaktif dikembangkan mengadopsi tahapan model Alessi dan Trollip yaitu *planning, design,* dan *development.* Teknik pengumpulan data dengan kuesioner dan test hasil belajar terkiat kemampuan pemecahan matematis. Berdasarkan hasil uji alpha modul digital interaktif, penilaian ahli desain 83.3%, penilaian ahli materi 82%, dan penilaian ahli media 84.34%. Penilaian peserta didik terhadap modul digital interaktif 82.4% (sangat praktis). Penerapan modul digital interaktif dalam pembelajaran matematika dapat meningkatkan kemampuan pemecahan matematis dengan peningkatan 0.4 (sedang).
Kata Kunci: Modul Digital Interaktif; Kemampuan Pemecahan Matematis; penelitian dan pengembangan

Abstract

Digital modules are learning materials with visualisation of digital format content that can be accessed using electronic devices. This research aims to develop learning media in the form of interactive digital modules and their effectiveness in learning. The interactive digital module was developed adopting the stages of the Alessi and Trollip model, namely planning, design, and development. Data collection techniques with questionnaires and learning outcomes tests related to mathematical solving ability. Based on the results of the interactive digital module alpha test, the design expert assessment 83.3%, material expert assessment 82%, and media expert assessment 84.34%. Learners' assessment of interactive digital modules 82.4% (very practical). The application of interactive digital modules in learning mathematics can improve mathematical solution skills with an increase of 0.4 (medium).
Keywords: Interactive Digital Module; Mathematical Solving Ability; Research and Development

I. INTRODUCTION

Learning is understood as a systematic and structured effort designed to facilitate individuals in their educational pursuits, ultimately aimed at achieving specific, predetermined objectives (Sukmaningthias et al., 2023). The primary goal of learning is to transform student behavior, encompassing various dimensions such as knowledge, attitudes, and skills. In essence, learning constitutes a process of behavioral change resulting from an individual's experiences and interactions with their learning environment (Awalia, 2023; Pitriyani & Afriansyah, 2023; Ambrose, 2010; Surya, 2004).

The learning system comprises several key components, including teachers, students, learning objectives, educational materials and media, facilities and equipment, instructional strategies and methods, as well as assessment tools for evaluating learning outcomes (Sanjaya, 2010). Educators are tasked with the responsibility of integrating these components optimally to ensure that learning is conducted effectively and efficiently (Rahmawati & Afriansyah, 2023).

Learning media play a pivotal role in the educational process, serving as a conduit for transmitting information or messages from teachers to students (Ulfa & Roza, 2022). These media are utilized to stimulate student knowledge, interest, and attention, thus facilitating communication within the teaching and learning process (Resti, 2020; Smaldino, 2008). The contribution of learning media is significant, as it aids teachers in delivering instructional content and aligning student perceptions with the intended sources of information (Winola, 2021; Rachmadtullah, 2023).

With the advancement of information technology, numerous advantages have emerged that can be harnessed in educational settings. It is imperative for educational providers to integrate information technology into the learning process, as it has demonstrated notable and positive impacts in the realm of education (Machii, 2016; Darmawan, 2015; Kenedi, 2019; Arnseth & Hatlevik, 2010). The integration of Information and Communication Technology (ICT) within education is closely associated with the implementation of technology-based learning initiatives (Ghavifekr & Rosdy, 2015; Nadila et al., 2023).

Digital modules are instructional materials that necessitate the use of information technology devices, including smartphones and computers, for effective operation (Fitriyani, 2017; Ramadoni & Admulya, 2023). These modules serve as primary media to support independent student learning activities and enhance the overall quality of learning through systematic arrangement (Prastowo, 2012; Maulida, 2022; Winkel, 2009). Digital modules encompass learning materials presented in digital formats, incorporating elements such as video, animation, text, and images (Seruni, 2019; Marianti, 2023).

According to the Organization for Economic Cooperation and Development (OECD) through the PISA (Programme for International Student Assessment) program in 2022, only approximately 18% of students in Indonesia achieved Level 2 proficiency in mathematics, with a minimal number reaching Levels 5 or 6 in the PISA

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mathematics assessment (OECD, 2022). Mathematical problem-solving skills are a critical component of the numeracy skills that students are expected to develop as outlined in the independent curriculum (Fauziah et al., 2022; Lisnani & Inharjanto, 2023). Current observations indicate that the low proficiency in mathematical problem-solving among students is attributed to traditional teaching methods that emphasize rote memorization of concepts, thereby limiting the scope for deeper understanding (Sriwahyuni & Maryati, 2022). Chen (2019) highlighted that existing mathematics instruction often neglects substantive issues related to problem-solving, further contributing to students' difficulties in making constructive and reflective decisions (Masfufah & Afriansyah, 2021).

The development of digital modules is informed by interviews with educators, which revealed that the available printed teaching materials are limited in scope, predominantly comprising text and images that render the subject matter abstract. Kioni's (2019) study concluded that digital books can significantly enhance learning performance compared to traditional printed materials. This insight reinforces the rationale for developing digital learning resources in the form of interactive digital modules.

Moreover, the scarcity of printed textbooks restricts access to educational resources, confining their use to school settings and hindering students' opportunities for independent learning. The introduction of these digital modules is anticipated to facilitate access for students, enabling them to engage with learning materials at any time and from any location. The characteristics of the developed digital module include multimedia elements, such as text, images, sound, animations, and videos, complemented by interactive features that provide feedback to users.

II. METHOD

This research falls within the category of Research and Development (R&D). The primary objective of R&D is to create educational products and evaluate their effectiveness (Sugiyono, 2011). The development model for the interactive digital module is based on the framework established by Alessi and Trollip (2001), which encompasses three key stages: planning, design, and development. The selection of this development model is informed by the characteristics of the interactive digital module, which incorporates multimedia elements. The subsequent sections outline the stages involved in developing the interactive digital module (see Figure 1).

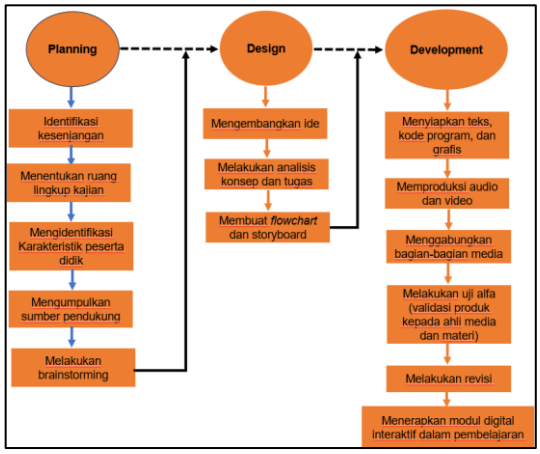

Figure 1. Stages of Interactive Digital Module Development

The development of the interactive digital modules involved the collaboration of six experts, comprising two media experts, two design experts, and two subject matter experts. The study participants consisted of seventh-grade students from junior high schools, selected through purposive sampling techniques. The research instruments utilized included questionnaires and assessments of learning outcomes. The questionnaires aimed to evaluate the quality of the developed product based on feedback from both experts and students. This assessment encompassed criteria such as the alignment of objectives, clarity of content, relevance of indicators, user interface appearance, and multimedia quality. Additionally, the learning outcome assessment consisted of mathematical problem-solving essay questions.

III. RESULT AND DISCUSSION

The development of interactive digital modules comprises three major stages: planning, design, and development.

1) Planning

The planning stage serves as the initial phase aimed at aligning the understanding of all team members involved in the project, assessing relevant constraints, and analyzing needs.

a. Identification of Gaps

The identification of gaps is conducted through interviews and questionnaires. Interviews with subject teachers are utilized to uncover challenges related to the learning process and the use of educational resources. Insights gained from these interviews revealed several issues, including a lack of accessible learning resources that facilitate independent learning activities without restrictions related to time and space,the delivery of lesson material primarily through verbal explanations accompanied by printed textbooks, which do not effectively visualize the content, a predominant focus on teacher-centered learning, which has led to a low level of student applicative skills.

Questionnaires were distributed to 40 randomly selected students to gather information regarding their responses to the learning process. The results indicated that the majority of students (88%) expressed a need for additional learning resources to support independent learning activities, and 100% agreed on the importance of developing interactive digital modules. Furthermore, all students reported having smartphones, which represent a valuable resource for supporting the functionality of these modules in learning.

b. Determining the Scope of the Study

The subject matter addressed in the development of interactive digital modules includes topics related to measurement, quantities, and units.

c. Identification of Student Characteristics

Identifying student characteristics involves assessing their learning experiences, learning styles, and

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existing knowledge and skills. Observations indicated that students typically assumed a passive role during lessons, primarily listening to the teacher's explanations.

Recognizing that students possess unique learning styles—categorized into audio, visual, and kinesthetic—there is a clear need for learning resources that accommodate all types of learners. Additionally, students have demonstrated proficiency in using smartphones and computers, which is a prerequisite for effectively utilizing the interactive digital modules that rely on these technological devices.

d. Collecting Supporting Sources

This step involves gathering relevant resources associated with the development process, subject matter, and learning methodologies. Supporting hardware must meet specific requirements, including a minimum of 4 GB RAM, at least 128 GB of hard disk space, and a Core i5 processor.

The supporting software includes Ms. Office (Word and PowerPoint), Audacity, Adobe InDesign, CorelDRAW, and Movie Maker for video editing. Subject matter and learning steps are guided by resources such as Kemdikbud textbooks, syllabi, and RPP (Lesson Plans).

e. Brainstorming

Brainstorming sessions engage the development team and subject teachers in discussions about the findings from the previous stages, product planning, and subject matter determination. This collaborative effort generates ideas by incorporating diverse perspectives from all participants.

2) Design

In this stage, the developer designs the product based on insights gained from the previous phase and the consensus of all parties involved.

a. Developing Ideas

This initial design phase involves conceptualizing the objects to be developed, which includes decisions regarding the use of text, font size, color schemes, images, animations, audio elements, hypertext, and videos.

All components are organized into a sequence of interconnected displays, establishing a benchmark for the basic layout of the interactive digital module.

b. Conducting Concept and Task Analysis

This stage entails analyzing the concepts and tasks that students will engage with, in alignment with the independent curriculum. The developer identifies the desired learning outcomes, compiles and sequences the learning materials to be covered, designs the learning steps (which encompass initial activities, core activities, and concluding activities), and creates assessment instruments to evaluate learning outcomes.

c. Creating Flowcharts and Storyboards

During this phase, the researcher develops flowcharts or flow diagrams that illustrate the menu structure and process steps required for navigating the interactive digital program or module (see Figure 2).

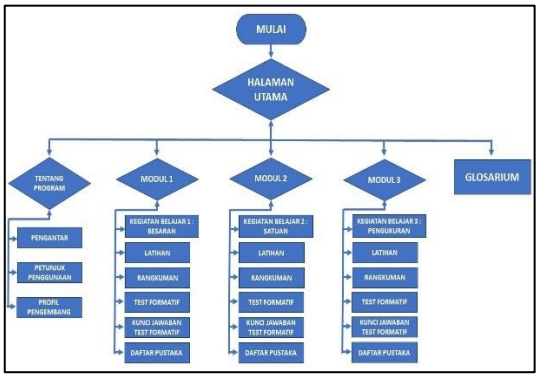

Figure 2. *Digital Interactive Module Flowchart*

The storyboard presents a sequential design of the images, covering all pages from the first to the last. It includes the following components: the initial page storyboard, the menu page storyboard, the program storyboard, the material menu storyboard, and the glossary storyboard.

3) *Development*

The development stage involves implementing the designs established in the previous stage.

a) Preparing Text

On the homepage, the text utilizes the Simhei font (body). For the menu and submenu pages, the Tekton Pro Cond font type is used, with a font size of 24. This choice of font type and size is made to ensure clear readability for users.

b) Producing Audio and Video

Audio production is accomplished using Audacity software, known for its ability to create stable and clear sound. To eliminate any unwanted noises, the Lexis audio editor application is also employed. For video production, Movie Maker software (Video Editor Pro) is used. The audio and video content is then incorporated into the interactive digital module to enhance the clarity of the subject matter, making the material more tangible and accommodating various student learning styles—visually, audio-visually, and auditorily.

c) Combining Media

At this stage, all produced media elements are integrated into the interactive digital module. This includes a combination of text, audio, images, video, animations, and hypertext (see Figure 3, 4, and 5).

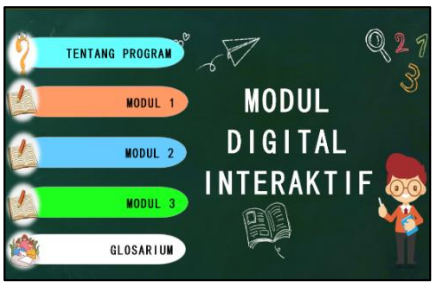

Figure 3. Home Page View

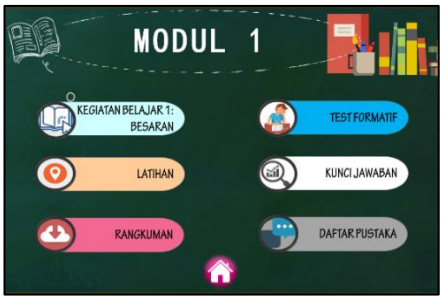

Figure 4. Module Menu Page View

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Figure 5. Learning Activity Page View

d) Conducting an Alpha Test

The alpha test is performed to gather information regarding the quality of the developed product. This involves assessments from various stakeholders, including media experts, subject matter experts, and design experts. Their feedback allows developers to evaluate the validity and effectiveness of the interactive digital module (see Table 1, 2, and 3).

Table 1.
Learning Design Expert Assessment Results

No	Aspects Assessed	Score (%)	Criteria
1	Suitability of learning objectives with learning strategies	78.8	Valid
2	Assessment indicators	91	Very Valid
3	Learning outcome assessment instruments	80	Valid
Total Score %		83.3	Very Valid

Table 2.
Learning Material Expert Assessment Results

No	Aspects Assessed	Score (%)	Criteria
1	Goal-oriented	84	Very Valid
2	Clarity of learning materials	82	Very Valid
3	Influence on students	80	Valid
Total Skor %		82	Very Valid

Table 3.
Learning Media Expert Assessment Results

No	Aspects Assessed	Score (%)	Criteria
1	Product Appearance	83	Very Valid
2	Multimedia Quality	82	Very Valid
3	Navigation	86	Very Valid
4	User Interface	82	Very Valid
5	Product Quality	88.7	Very Valid
Total Skor %		84.34	Very Valid

e) Performing Beta Test

Beta testing was conducted by selecting three students to evaluate the quality of the interactive digital module in terms of functionality and practicality. Sample selection was carried out using purposive sampling based on varying ability levels: high, medium, and low (see Table 4).

Table 4.
One-to-One Student Assessment Results

No	Aspects Assessed	Score (%)	Criteria
1	Clarity of Material	80.5	Practical
2	Media Suitability for Students	82.8	Very Praktis
3	Student Attitudes Towards Learning	85.5	Very Praktis
4	Evaluation Suitability	79.2	Practical
5	Suitability of Interactive Digital Modules for Students	84	Very Practical
Total Score %		82.4	Very Practical

1) Effectiveness of Interactive Digital Modules in Learning

Interactive digital modules are utilized in small groups to assess their effectiveness in teaching concepts of quantity, units, and measurement. These modules can be accessed on various electronic devices such as smartphones, tablets, and computers, enabling students to engage with the material independently without restrictions of space and time.

The evaluation of the effectiveness of these modules is based on and adapts indicators of mathematical problem-solving abilities as outlined by Polya (Winarti, 2017). A descriptive test is employed as the assessment instrument.

Prior to implementing the interactive digital module, a pretest is administered to gauge students' initial abilities. The application of the modules involves 30 research participants. Following the use of the interactive digital modules, a posttest is conducted to assess improvements in mathematical problem-solving abilities (see Table 5).

Table 5.
Results of Mathematical Solving Ability Assessment

Ability	Pretest	Postest
Identifying Problems	46	66
Formulating Problems	33	70
Planning Initial Steps to Solve Problems	46	73
Determining Problem Solving Methods	30	73
Applying Problem Solving Steps Systematically	30	76
Drawing Conclusions and Rechecking Results	36	76
Presenting Problem Solving Results	30	70

To evaluate the extent of improvement in mathematical problem-solving abilities post-implementation of the interactive digital module, a gain test is conducted. The results indicate an average gain of 0.4, which falls within the moderate increase category.

Data analysis reveals that the interactive digital modules effectively enhance mathematical problem-solving skills, evidenced by a 0.4 improvement categorized as moderate. The design of the interactive digital module was informed by an analysis of students' needs and characteristics. Teachers should conduct a needs analysis to ensure that the developed learning program aligns with both needs and objectives (Nasrulloh, 2017; Idris, 2024).

Recognizing that students have varying learning speeds and styles is crucial for teachers when designing instruction to meet individual learning needs (Wiedarti, 2018). This includes providing appropriate learning resources tailored to students' learning styles. The interactive digital modules incorporate multimedia elements such as images, text, sound, animation, and learning videos to accommodate diverse learning preferences, including auditory, visual, and audio-visual styles. Utilizing multimedia in learning significantly supports students with different learning styles (Tayo & Oluwakemi, 2015; Yulianci et al., 2021).

Selecting suitable media for interactive digital modules is essential to ensure that the information and materials presented are clear and easily understood. Key considerations in media selection include alignment with learning objectives, comprehensive lesson content (encompassing facts, principles, generalizations, and concepts), the skills of

both teachers and students in utilizing the media, technical quality, and target audience (Arsyad, 2009). According to Fadhilah (2016), media suitability in relation to learning objectives and subject matter is a critical determinant in the selection process.

IV. CONCLUSION

Based on the findings from the research and development conducted, the conclusions of this study highlight the successful development of interactive digital modules grounded in a thorough needs analysis, an understanding of student characteristics, and the availability of supporting resources. Careful media selection is crucial to ensure that the visualization of learning materials is clear and easily comprehensible.

The formative evaluation results indicated high validity across various assessments: media experts rated the modules at 84.34% (very valid), subject matter experts at 82% (very valid), and learning design experts at 83.3% (very valid). Additionally, student feedback on the practicality of the modules yielded a score of 82.4% (very practical). The implementation of the interactive digital modules demonstrated a positive impact on improving mathematical problem-solving skills, achieving a moderate increase of 0.4.

Selecting appropriate learning media significantly contributes to the achievement of educational objectives. The integration of digital technology through interactive digital modules is part of ongoing efforts to support the digital transformation of education, as mandated by government policies under the independent curriculum framework.

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