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Development of a STEM-PJBL-Based Digital Book With Geogebra™ Using the Assure Model to Enhance Students' Mathematical Literacy in Geometry

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ABSTRACT

Mathematical literacy among junior high school students in Indonesia remains low due to limited educational resources that support its development. Many materials emphasize procedural mathematics rather than critical thinking and problem-solving, hindering real-world application. The STEM-Project-Based Learning (STEM-PjBL) approach addresses this by connecting mathematics to everyday life and integrating technology like GeoGebra™ for interactive learning. This study aims to develop a digital book incorporating STEM-PjBL and GeoGebra™ to enhance students' mathematical literacy in Geometry. Using the ASSURE model, the research follows stages of analysis, objective setting, resource selection, learner participation, and evaluation. Expert validation confirms the digital book's feasibility and effectiveness, with construct validity supporting its reliability in classrooms. This study is significant as it introduces an innovative learning resource that integrates STEM-PjBL with technology, fostering problem-solving and critical thinking. The findings suggest that interactive, project-based digital books can bridge the gap between theoretical knowledge and practical application, helping educators create engaging learning experiences and better prepare students for future academic and career challenges.

Keywords: Digital Book, Mathematical Literacy, STEM- PjBL, Geogebra™, Technology-Enhanced Learning,

INTRODUCTION

Indonesian students struggle with mathematical literacy, as reflected in their performance on international assessments. According to the Kementerian Pendidikan dan Kebudayaan (2019), Indonesian students scored 379 out of 487 on the OECD's 2017 PISA assessment, significantly below the global average of 487. Between 2000 and 2012, no student in Indonesia reached level 6 in mathematical literacy (Muzaki & Masjudin, 2019). Only 0.3% of Indonesian students in the PISA assessment achieved levels 5 or 6, while 76% scored below level 2, the benchmark for moving beyond the low-achiever category (Basedan, 2014). These findings indicate that Indonesian students' mathematical literacy remains low. The highest recorded performance level is level 3, where even high-ability students can only solve level 3 problems, while those with lower abilities are limited to level 1 (Kurniati, 2017; Asmara, Waluya, & Rochmad, 2017). Several studies confirm that Indonesian students still face significant challenges in developing mathematical literacy (Sari, Sugiyanti, & Pramasdyahsari, 2021; Nur'Aisyah, Sutrisno, &

Pramasdyahsari, 2021; Lutfiyana, Dwijayanti, & Pramasdyahsari, 2021). Given its crucial role in academic success and real-world problem-solving, the persistent lack of mathematical literacy among Indonesian students remains a major concern that requires urgent educational intervention (Muzaki & Masjudin, 2019).

Several factors contribute to students' low levels of mathematical literacy, one of which is the quality of teaching resources. Traditional textbooks may not be sufficient to support students in developing mathematical literacy, highlighting the need for innovative learning materials (Harmini et al., 2020). According to Yusta et al. (2016), inadequate teaching materials hinder students' ability to grasp mathematical concepts effectively. Additionally, the improper use of teaching resources and learning media can lead to low self-awareness of mathematical skills among students (Siniguian, 2017). Ummah et al. (2018) argue that Indonesia's educational resources do not promote a balanced understanding of science, which further impacts mathematical literacy. The use of inadequate teaching resources not only affects students' comprehension of mathematics but also limits their ability to apply mathematical concepts in real-life contexts (Yusta et al., 2016). Moreover, the learning media is important in helping teachers present and solve mathematical problems engagingly while enhancing students' mathematical skills (Buchori, Pramasdyahsari& Kholifah, 2022; Nusuki, et. al., 2023). These findings highlight the urgent need for innovative teaching resources to improve students' mathematical literacy and overall learning experience.

Various approaches can be implemented to enhance students' mathematical literacy, one of which is the use of digital books. Digital books serve as modern educational materials that evolve alongside technological advancements, making them a valuable tool for improving mathematical literacy (Mardiana, 2018; Febrianti, 2021; Pramasdyahsari, Aini & Setyawati, 2024). Digital books can increase student engagement in the learning process by providing accessible and interactive content (Pambudi et al., 2018). Their flexibility allows students to read anytime and anywhere, simply by using a digital device.

In remote learning settings, digital books facilitate better communication between teachers and students, enhancing the overall learning experience (Rachmah et al., 2018). Students also find digital books beneficial for STEM learning, as they are more cost-effective and help optimize storage space (Nurmala R & Maharani Izzatin, 2019; Pramasdyahsari, 2023). Additionally, the STEM-PjBL digital book plays a crucial role in fostering critical thinking and positively impacting other essential 21st-century skills (Pramasdyahsari et al., 2023; Pramasdyahsari, et.al., 2024b). These advantages highlight the potential of digital books as an effective educational tool for strengthening students' mathematical literacy and supporting modern learning environments.

Geometry plays a crucial role in developing mathematical literacy. Therefore, the primary objective of this study was to design and develop a digital book aimed at enhancing students' mathematical literacy, with a specific focus on geometry. To achieve this goal, GeoGebra was selected as the primary software tool for creating interactive activities within the digital book, providing students with a dynamic and engaging learning experience. Additionally, the instructional philosophy guiding the development of the digital book was based on Project-Based Learning (PjBL) combined with the STEM approach. This integration was intended to foster active learning, critical thinking, and real-world problem-solving skills.

LITERATURE REVIEW

In the following sections, we provide a detailed justification for the selection of each of these key components, highlighting their significance in enhancing students' conceptual understanding and engagement with geometry.

GeoGebra™ is a versatile tool that can be integrated into geometry instruction to enhance students' understanding of mathematical concepts. Developed by Markus Hohenwarter in 2001,

GeoGebra™ is a computer program designed to solve algebraic, computational, and geometric problems (Hohenwarter & Fuchs, 2005). Over the years, it has evolved into an interactive platform that supports dynamic mathematical exploration. Asngari (2015) highlights that one of its primary functions is to illustrate mathematical concepts, making abstract ideas more accessible to students.

In geometry learning, GeoGebra™ serves as a digital representation of physical spatial construction materials commonly used in classrooms. Concepts such as constructing three-dimensional shapes including cubes, blocks, and pyramids are fundamental in mathematics education. By transforming these geometric structures into digital models and integrating them with the STEM-PjBL approach, GeoGebra™ can enhance mathematical literacy. Its interactive features allow students to visualize, manipulate, and explore geometric figures dynamically, fostering deeper understanding and engagement in learning.

For the instructional philosophy underlying the development of the digital book, we adopted Project-Based Learning (PjBL) in combination with the STEM (Science, Technology, Engineering, and Mathematics) approach. PjBL is a student-centered instructional method that enhances learning by emphasizing hands-on experiences and real-world problem-solving. According to Afriana et al. (2016), PjBL enables students to actively engage in meaningful learning, positioning them as the focal point of the educational process. Through project-based activities, students can explore new ideas, cultivate creativity, and apply their knowledge in innovative ways (Juwanti et al., 2020).

To further enrich student learning, PjBL can be integrated with the STEM approach, which connects science, technology, engineering, and mathematics in an interdisciplinary manner. This integration strengthens students' understanding of complex concepts while fostering critical thinking, problem-solving, and collaboration skills, preparing them for real-world challenges. Given the importance of geometry and STEM in shaping digital learning resources, their incorporation significantly influences the design, layout, interactivity, and technological integration of the digital book. Di Paola et al. (2013) highlight the effectiveness of interactive software and technology in teaching descriptive and projective geometry, demonstrating how these tools enhance both student interest and comprehension. Additionally, Jones et al. (2009) emphasize the need to consider geometric principles and learner needs when designing digital educational resources, while Galitskaya & Drigas (2020) underscore the role of technology in improving accessibility, particularly for students in special education, by enhancing visualization and conceptual understanding.

Based on these insights, this study aims to develop a STEM-PjBL-based digital book utilizing GeoGebra™ to enhance students' mathematical literacy. By integrating PjBL, STEM, and GeoGebra™, this digital book seeks to bridge the gap between theoretical knowledge and practical application, offering students an interactive, inquiry-driven learning experience that enhances their mathematical literacy in geometry.

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METHODOLOGY

This research utilized the ASSURE model, a development-based Research and Development (R&D) framework, following these six steps: (1) Analyze Learners—identify student needs; (2) State Standards and Objectives—set learning goals and standards; (3) Choose Strategies and Resources—select instructional methods and media; (4) Utilize Resources—integrate technology into learning; (5) Require Learner Participation—actively engage students; and (6) Evaluate and Revise—assess and refine the learning materials. A needs analysis was conducted based on student trials, followed by validation from a mathematics education lecturer

at Universitas PGRI Semarang and a mathematics teacher from SMP Negeri 40 Semarang. The digital book learning media was structured into five key categories: general aspects, material aspects, literacy aspects, PjBL-STEM aspects, and media technology aspects. The study incorporated digital book-based learning and included four assessment questions. A total of 28 eighth-grade students from SMP Negeri 40 Semarang (class VIII C) participated as respondents. Additionally, this study adopted the e (2011), which consists of five structured learning stages, as outlined in Table 1. The pre-test and post-test were administered to define the effectiveness of using this digital book towards students' mathematical literacy.

Table 1. Five Stages of Learning STEM-PjBL syntax by Laboy-Rush

No	Phase	Teacher Activities	Students Activities
.	Reflection	In the first stage, the teacher provides the context of the problem and gives students the opportunity to determine the output to start investigations and investigations.	In the first stage, students will be brought into the context of the problem and provided output to students to start investigations and investigations.
.	Research	In the second stage, the teacher accompanies students to take part in the form of research based on relevant sources.	In this second stage, students take part in the form of research to examine scientific concepts, determine readings, and gather information based on relevant sources.
.	Discovery	In the third stage, the teacher accompanies and focuses on himself as a facilitator if there are students who ask questions about something that is not yet known.	In the third stage, students begin action by finding processes in learning, and they also determine what students do not know and also determine project procedures to solve existing problems in the research to be carried out.
.	Application	The teacher becomes a companion in the application of the model by students who have been found in the third stage.	In this fourth stage students will design a form of problem solving, provide a trial of the designed model, and students will determine the results of the test.
.	Communication	In the last stage, the teacher gives time to students to present the results of the activities that have been carried out and provide feedback that has a constructive purpose.	In the last stage, students will try to present stills from the models and solutions obtained in order to develop communication and collaboration skills to receive and apply constructive feedback.

As part of the stages in the ASSURE model, in the Evaluate and Revise (review and improve products), the product was validated by the expert, based on several aspects such as general material, mathematical literacy, STEM-PjBL, and technology media. The developed learning product validation guidelines contain the assessment aspects shown in Table 2:

Table 2. Validation Guidelines

Assessment Aspect	No	Rated Aspect
General	1	PjBL-STEM-based Digital Book learning media to improve mathematical literacy skills is an interesting development.
	2	There are differences compared to conventional learning media that show advantages
	3	This learning media can increase the attractiveness of students in learning.
	4	The use of media is easy and not confusing.

Material	5	Clarity of learning objectives.
	6	The relevance of learning objectives to the curriculum/SK/KD.
	7	Scope and depth of learning objectives.
	8	Interactivity.
	9	Contextuality.
	10	Completeness and quality of study aid materials.
	11	Ease to understand.
	12	Clear descriptions, giving explanations, examples, exercises, and simulations.
Mathematical Literacy	13	Literacy indicators in accordance with the material
	14	Literacy indicators that match the questions
STEM-PjBL	15	Compatibility with PjBL-STEM syntax.
	16	Load Engineering Design Process.
Technology Media	17	Media can be used easily by students.
	18	Interactive aspects of the media.
	19	Aspect of ease when used on the media.
	20	Media that has an interesting design.

The developed product is considered valid if it meets the specified indicators for each aspect. Validity was assessed using a Likert scale, with expert validation playing a crucial role before broader implementation. Evaluations from media professionals were used to determine the effectiveness and feasibility of the product. According to Sugiyono (2015), the validation results are categorized as follows: a score between 81%–100% indicates "very good" validity, 61%–80% signifies "good," and 41%–60% is classified as "sufficient." If the product falls within these ranges, it is deemed viable and ready for further implementation.

RESULT AND DISCUSSION

Needs Analysis

A needs analysis was conducted to identify the challenges in mathematics learning at SMP Negeri 40 Semarang. This involved discussions with mathematics teachers to assess instructional strategies and students' experiences through questionnaires. The findings revealed that teaching and learning activities have remained largely traditional, with minimal adjustments or improvements over the years. Technology integration is limited to the use of LCDs and projectors as mere teaching aids, and practical activities to support student learning have not been incorporated into mathematics lessons. Additionally, there is a lack of hands-on practicum experiences, which further hinders students' understanding of mathematical concepts.

Student feedback from class VIII C on the topic of Flat-Sided Building Materials also highlighted several issues. Many students still perceive mathematics as a difficult subject due to teaching models and methods that do not align with their learning needs. Teachers provide limited real-world examples, making it challenging for students to relate mathematical concepts to everyday life. Moreover, mathematical literacy explanations are not sufficiently engaging. While 12 students agreed that they understood how to calculate the surface area of a cube, 9 students expressed uncertainty, and 2 students disagreed, indicating difficulty in grasping the concept.

Based on the input from teachers and students, there is a clear need for innovative learning media that enhance mathematical literacy by actively involving students in the learning process.

Shifting from a teacher-centred approach to a more interactive, student-centred model can foster better engagement and deeper conceptual understanding, ultimately improving students' mathematical literacy skills.

Product Design Stage

The developed product is a digital book designed as a learning medium incorporating the Project-Based Learning (PjBL) STEM approach, supported by GeoGebra™, to enhance students' mathematical literacy. This digital book serves as an interactive aid in classroom teaching and learning activities. The technology utilized includes mobile phones, the GeoGebra™ application, and Heyzine software, which together create an engaging and accessible learning experience.

The integration of GeoGebra™ within the STEM-PjBL-based digital book effectively promotes mathematical literacy through interactive modules, dynamic visualizations, problem-solving exercises, real-world applications, adaptive learning paths, and collaborative learning opportunities. These features provide students with a deeper understanding of mathematical concepts by allowing them to explore and apply their knowledge in meaningful ways. By leveraging technology, this digital book fosters a more interactive and effective learning environment, helping students develop essential STEM skills in a modern educational setting.

Development and Evaluation Stage

Product validity

The validity of the product was assessed by two media experts, a mathematics education lecturer, and a mathematics teacher using a validation sheet designed according to predefined validity criteria. The validation results were utilized to refine and improve the product based on the feedback and suggestions provided by them.

The validation process involved media professionals who assessed the effectiveness of the digital book as a learning medium. Based on the evaluators' feedback, the general assessment aspect of the digital book was highly rated, receiving a score of 84.375%. This indicates that the digital book offers significant advantages over traditional learning methods, enhances student engagement, and is user-friendly. The material aspect was also rated at 84.375%, placing it in the "Very Good" category (81%–100%). This confirms that the digital book content for Building a Flat-Sided Space is well-structured and suitable for classroom instruction.

For the literacy aspect, the validation results showed a score of 75%, which falls under the "Good" category. The PjBL-STEM component received an 81.75% rating, meeting the "Very Good" standard, while the Media Technology aspect scored 87.5%, also classified as "Very Good." Despite slight variations in the validation scores across different aspects, the overall assessment confirms that the digital book meets the validity criteria. These results indicate that the developed digital book is a valuable and effective educational resource for enhancing mathematical literacy through the PjBL-STEM approach.

Since the product was implemented within a limited group of students, their responses were collected using qualitative instrument. Eighth-grade students from SMP Negeri 40 Semarang participated in user testing to assess the effectiveness of the digital book. Many students provided insightful feedback and contributed to refining the imagery and design of the digital book during the evaluation process. Regarding media quality, the digital learning materials for Building Flat-Sided Spaces were found to be suitable for use as instructional tools, supporting both students and teachers in the teaching and learning process.

Based on the questionnaire, students actively engaged with the interactive learning modules integrated into the Digital Book, interacting with geometric concepts, manipulating shapes, and utilizing GeoGebra™ tools as intended. The software's combination of modelling, visualization, and programming features further enhances its effectiveness in teaching STEM subjects, including advanced mathematics (Ziatdinov & Valles, 2022). This active participation fostered a deeper understanding of mathematical concepts and increased student engagement.

Additionally, students effectively utilized the dynamic visualizations provided by GeoGebra™, improving their visualization skills, conceptual understanding, and overall mathematical literacy. This aligns with Lainufar et al. (2021), who found that integrating GeoGebra™'s augmented reality capabilities into project-based learning enhances visual-spatial skills and elicits positive student responses.

Furthermore, students demonstrated improved problem-solving skills using the Digital Book, enhancing their critical thinking and mathematical literacy based on the pretest and posttest results. The mathematical literacy test included word problems related to geometry, as outlined in Table 3. Post-test results revealed a significant improvement in mathematical literacy after utilizing the Digital Book. The experimental class, which implemented the Digital Book, achieved an average post-test score of 80.64, whereas the control class, which did not use the Digital Book, had an average score of 36.90. This indicates that students were able to apply mathematical concepts to real-world scenarios presented in the Digital Book, effectively bridging theoretical knowledge with practical applications. Additionally, the collaborative learning experiences facilitated through GeoGebra™ within the Digital Book contributed positively to students' comprehension and engagement.

Table 3. Mathematical Literacy Test

No	Questions
1	Pak Budi wants to send the package from the Hidayah shop, which is located in Semarang. The package which will be sent by the Hidayah shop is reasonably big, after being measured the length of all the sides is the same that is 100 cm. Hidayah Shop gives a warning that the goods in the package are prone to breaking, so they must be coated with a wooden board. Meanwhile, the shipping board stock in the expedition has many sizes available, including lengths: 50cm, 60cm, 75cm, 90cm, 100 cm, and 105 cm, and has a width equal length, namely 20 cm. a. Will the package be delivered to Sir Budi's cube? Explain your answer! b. Which board should be used by Mr. Budi for coating the package to be sent? c. How do you determine the minimum possibility that the package can enter the delivery truck?
2	Ratna asked to help his mother carry several goods which would be for sale in a store. Items to be sold are electronic, such as TVs and Sound Systems. These items are still wrapped neatly in cardboard packaging which is still coated by board delivery from a courier. Ratna helped bring a television with a coated board on each side showing 20 cm as width and 80 cm as height. a. What kind of information do you obtain from activities Ratna does? b. If Ratna wants to know the surface area, help Ratna to determine it. c. Why do you help Ratna with that method? Explain it.

Additionally, the Wilcoxon test was employed to assess the improvement in students' abilities after the intervention, as the data did not follow a normal distribution. The results indicated that the significance value for the control class was 0.028 (Table 5), which is lower than 0.05, confirming that the hypothesis was accepted. Similarly, the experimental class demonstrated a significance value of 0.000 (Table 4), further supporting the hypothesis that the use of digital book media incorporating the PjBL-STEM approach, assisted by GeoGebra™, effectively enhances students' mathematical literacy skills.

Table 4. Wilcoxon Test Experiment Class

		N	Mean Rank	Sum of Ranks
Eksperimen	Negative Ranks	0a	,00	,00
	Positive Ranks	31b	16,00	496,00
	Ties	0c		
	Total	31		

Test Statistics

Z	-4,861b
Asymp. Sig. (2-tailed)	,000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Table 5. Wilcoxon Test Control Class

		N	Mean Rank	Sum of Ranks
Kontrol	Negative Ranks	9a	12,89	116,00
	Positive Ranks	20b	15,95	319,00
	Ties	2c		
	Total	31		

Test Statistics[a]

Z	-2,197b
Asymp. Sig. (2-tailed)	,028

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Based on a few of the findings from the aforementioned research, it is possible to conclude that this digital book learning media through many development stages produces learning media that is appropriate for use in student teaching and learning activities.

Product Revision

The validation conducted by two experts confirmed that the digital book was suitable for classroom use. However, they recommended several revisions to enhance its effectiveness. These improvements included refining the visuals to capture students' attention, adding practice questions to reinforce learning (Figure 1), and enhancing the overall design to make the digital book more visually engaging. Additionally, feedback from students played a crucial role in guiding these refinements, ensuring that the final product better met their learning needs and preferences.

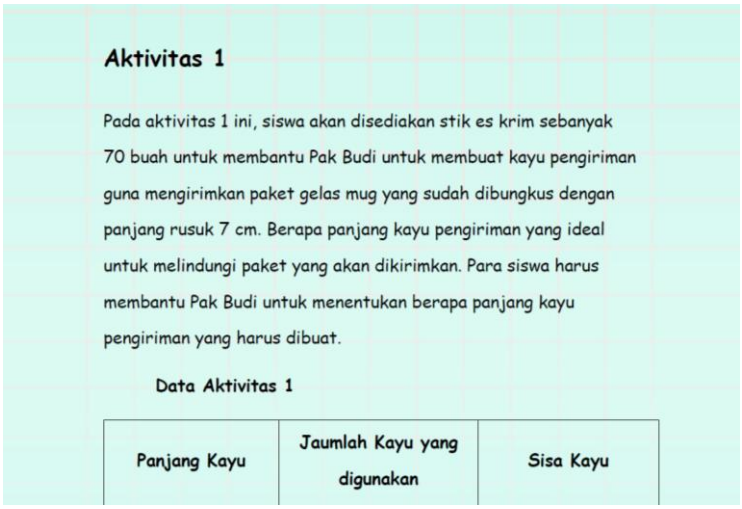

Figure 1. Word Problems

Final Product Results

The digital book was developed and refined based on validation feedback from two experts and trial results involving 28 students from class VIII C at SMP Negeri 40 Semarang, as illustrated in Figure 2.

Figure 2. Refinement Digital Book

The images above illustrate how the development of digital book-learning was revised as the validator suggested. Student feedback on the digital book was positive. The students found the digital book easy to understand, engaging, visually appealing, functional, and enjoyable. The digital book allows students to create simple visual representations of geometric concepts, making it easier for them to express, explore, and construct mathematical representations of their ideas (Nopiyani et al., 2018). Additionally, the GeoGebra™ application also received positive feedback, particularly for geometry transformation materials (Dewi et al., 2020). The integration of GeoGebra™ within STEM education supports the development of both conceptual and procedural knowledge in students (Bekene Bedada & Machaba, 2022).

In this study, the use of GeoGebra™ was specifically applied to geometric materials, particularly flat-sided shapes, aligning well with its geometry features, such as creating cube nets. GeoGebra™ was accessed online, ensuring students could use it anytime and anywhere. Figure 3 illustrates the cube nets generated through GeoGebra™.

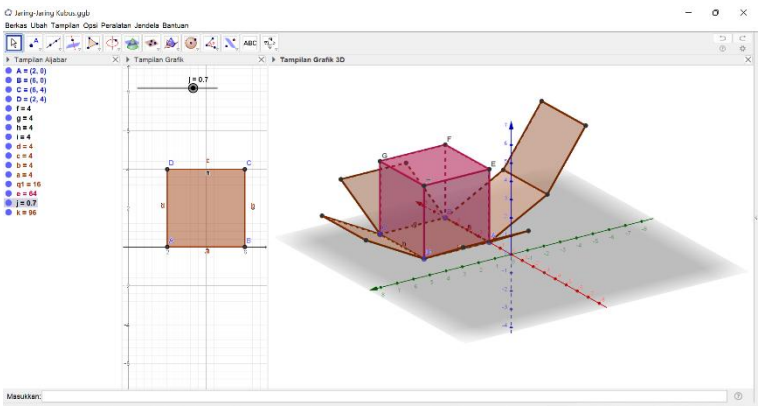

Figure 3. Cube Nets from Geogebra

The development of learning media aims to enhance students' mathematical literacy skills. Mathematical literacy refers to an individual's ability to understand and apply mathematical concepts in everyday life (Ojose, 2011). It encompasses mathematical reasoning, along with the use of mathematical concepts, procedures, facts, and tools to describe, explain, and predict real-world phenomena. In the PISA 2021 framework, mathematical literacy is defined as an individual's ability to define, interpret, and apply mathematics across various contexts (Khoirudin et al., 2017). Similarly, the OECD (2017) describes mathematical literacy as the capacity to reason mathematically and use mathematical knowledge to predict, explain, or describe events. The integration of GeoGebra™ into classroom learning has been shown to enhance mathematical literacy (Fahmy et al., 2018). A well-structured digital book, combined with creative and appropriately adjusted materials, can further support students in developing their mathematical literacy skills (Harmini et al., 2020).

CONCLUSION

This study systematically developed a digital book learning medium using the ASSURE model, guided by a needs analysis to enhance students' mathematical literacy. While the findings are specific to this context and cannot be generalized to broader settings, they provide valuable insights for future research in similar fields. The resulting digital book, incorporating the PjBL STEM approach and GeoGebra™ support, has been validated as an effective tool for improving mathematical literacy. The Development of Digital Media Book Materials for Flat-Sided Spaces has been deemed suitable for student use. Based on the findings, several recommendations are proposed. First, increasing the literacy component is essential to further support students in developing mathematical proficiency. Additionally, expanding the development of digital learning media to other scientific domains can provide more comprehensive and interdisciplinary learning experiences. Future research should explore ways to refine and adapt digital books for wider educational applications, ensuring their effectiveness across diverse learning environments.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this study. This research was conducted independently, and no financial, institutional, or personal relationships influenced the findings or interpretations presented in this paper.

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