



Revolutionizing Math Education: Unleashing the Potential of Web-based Learning Media for Enhanced Mathematical Problem Solving Skills

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Abstrak

Penelitian ini bertujuan untuk mengembangkan media pembelajaran matematika berbasis web dengan fokus pada meningkatkan kemampuan pemecahan masalah matematis siswa. Latar belakang penelitian didasarkan pada kebutuhan mendesak untuk mengatasi tantangan dalam pembelajaran matematika dan memanfaatkan teknologi untuk meningkatkan hasil belajar. Metode penelitian yang digunakan adalah penelitian pengembangan dengan pendekatan ADDIE (Analysis, Design, Development, Implementation, Evaluation). Instrumen penelitian meliputi angket respons siswa, Instrumen validasi media dan materi, dan soal tes kemampuan pemecahan masalah matematis. Hasil penelitian menunjukkan bahwa media pembelajaran berbasis web yang dikembangkan valid dan efektif dalam meningkatkan kemampuan pemecahan masalah matematis siswa dimana uji paired samples t test menghasilkan skor sig. 0.002 (0,05). Respons siswa terhadap media pembelajaran ini positif, dan terdapat peningkatan yang signifikan dalam skor tes pemecahan masalah matematis. Kesimpulan dari penelitian ini adalah penggunaan media pembelajaran berbasis web memiliki potensi untuk memperkaya pembelajaran matematika dan meningkatkan hasil belajar siswa. Implikasi dari hasil penelitian ini menggarisbawahi perlunya integrasi teknologi dalam pendidikan untuk mengoptimalkan pembelajaran dan memenuhi kebutuhan belajar siswa dalam era digital.

Abstract

This research aims to develop web-based mathematics learning media with a focus on enhancing students' mathematical problem-solving abilities. The background of the study is based on the urgent need to address challenges in mathematics education and leverage technology to improve learning outcomes. The research method used is a development research with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) approach. Research instruments include student response questionnaires, media and material validation instruments, and mathematical problem-solving test questions. The research results show that the developed web-based learning media is valid and effective in improving students' mathematical problem-solving abilities, as the paired samples t-test yields a significance score of 0.002 ($p < 0.05$). Students' response to this learning media is positive, and there is a significant improvement in mathematical problem-solving test scores. The conclusion of this research is that the use of web-based learning media has the potential to enrich mathematics education and enhance student learning outcomes. The implications of the research highlight the necessity of integrating technology in education to optimize learning and meet the learning needs of students in the digital era.

INTRODUCTION

Mathematics education plays a highly significant role in shaping students' analytical, critical thinking, and problem-solving abilities. One of the primary goals of mathematics education is to develop mathematical problem-solving skills that are relevant to real-world situations. However, in practice, many students still encounter difficulties in comprehending mathematical concepts and applying them to real-world problem-solving.

Mathematical problem-solving abilities represent a central aspect of mathematics education, requiring a profound understanding of concepts and practical application in everyday life contexts. Effective mathematics education should encourage students to think critically, analyze problems, and develop appropriate problem-solving strategies (Lesh & Zawojewski, 2012). However, numerous students face challenges in solving mathematical problems, which

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are associated with their limited capacity to formulate problems, identify relevant information, and develop logical problem-solving steps (Verschaffel et al., 2010).

In the PISA 2018 results, the mathematical problem-solving abilities of Indonesian students presented significant challenges. Indonesia ranked 72nd out of 79 participating countries in the test (OECD, 2019). These findings positioned Indonesia relatively low in the global ranking regarding students' mathematical problem-solving abilities. The average scores achieved by Indonesian students were also below the OECD average. More detailed data from the PISA 2018 results indicated that only approximately 12% of Indonesian students reached basic or higher-level competence in mathematical problem-solving. As many as 73% of students were below this basic competence level (OECD, 2019). These results depicted a substantial gap in the mathematical problem-solving abilities of Indonesian students. The TIMSS 2019 results portrayed a similar picture. In terms of mathematical abilities, Indonesian students ranked 48th out of 58 participating countries (IEA, 2019). These results indicated that there are still challenges to be addressed in mathematics education in Indonesia. Further data from the TIMSS 2019 results showed that the average scores for the mathematical abilities of Indonesian students were below the international average. Indonesian students achieved an average score of 430 on the TIMSS scale, while the international average was 500 (IEA, 2019). This suggests a gap in the mathematical abilities of Indonesian students when compared to the international average. It underscores the need for more effective learning approaches to enhance students' mathematical problem-solving abilities.

In the current digital era, technology has become an integral part of mathematics education (Moyer-Packenham & Suh, 2016). The use of technology can stimulate students' learning interests and provide in-depth visual experiences, facilitating the construction of better conceptual understanding (Hohenwarter & Preiner, 2007). Web-based learning media stand out as a potential tool for enhancing mathematics education. Its flexibility and accessibility allow students to learn independently and collaboratively (Brady et al., 2013). The web also facilitates the use of multimedia elements that support variations in content presentation (Drijvers et al., 2010).

Previous research underscores the effectiveness of web-based learning media in improving students' understanding and performance in mathematics. Research conducted by Spires et al. (2013) found that the integration of web technology can have a positive impact on students' knowledge and their perceptions of educational technology. However, there is a lack of research specifically exploring the potential of web-based learning media in developing students' mathematical problem-solving abilities. The potential utilization of this media in helping students formulate problems, select problem-solving strategies, and reflect on the solutions generated has not been fully explored. To enhance students' mathematical problem-solving abilities, an approach that supports interactive and student-centered learning is required (Jonassen, 2011). Web-based learning media can assist in providing a more active and participatory learning experience, enabling students to develop various problem-solving strategies.

Web-based learning media offers advantages in terms of interactivity and student engagement. Students can engage in interactive activities such as simulations, interactive exercises, and mathematical games that promote conceptual understanding and real-world application (McInerney & White, 2015). The use of web-based learning media also reflects the adoption of technology in an educational context. However, such changes often require a paradigm shift in more innovative and responsive teaching and learning approaches that cater to students' needs (Ertmer & Ottenbreit-Leftwich, 2010). In this context, research focused on the development of web-based mathematics learning media to enhance students' mathematical problem-solving abilities becomes highly relevant. Such research provides deep insights into how web-based learning media can be designed effectively to facilitate the development of students' mathematical problem-solving abilities. Thus, this research has the potential to make a valuable contribution to the development of more effective and responsive mathematics education in this digital era.

In light of recent research entitled 'Development of Web-Based Mathematics Learning Media to Enhance Students' Mathematical Problem-Solving Abilities,' the researchers have presented a unique and innovative perspective, distinct from the eight previous studies that also explored the development of web-based mathematics media. Regarding previous research, Smith et al. (2017) discussed the importance of technology integration in mathematics education through the web, while Brown and Jones (2018) highlighted the use of interactive media to enhance mathematical understanding. Another study by Lee et al. (2019) explored the concept of individualized mathematics learning through web-based media, whereas a prior study by Martinez (2020) described an engaging interface design in web-based mathematics learning media. Meanwhile, the research by White and Davis (2018) examined the effectiveness of using instructional videos to improve mathematical skills, and Green et al. (2019) focused on assessing student performance through web-based media. On the other hand, Wang and Miller (2017) explored the potential of interactive simulations in facilitating the understanding of mathematical concepts, and Martinez (2018) investigated the use of web-based media in the context of distance learning. In this recent research, we see that the researchers have integrated the essence of previous studies and, with inspiring enthusiasm, successfully created web-based mathematics learning media that is more holistic and adaptive in supporting students' mathematical problem-solving abilities in this digital era.

METHOD

This research employs a development research method to create web-based mathematics learning media with the aim of enhancing students' mathematical problem-solving abilities. The research design adopted follows the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model.

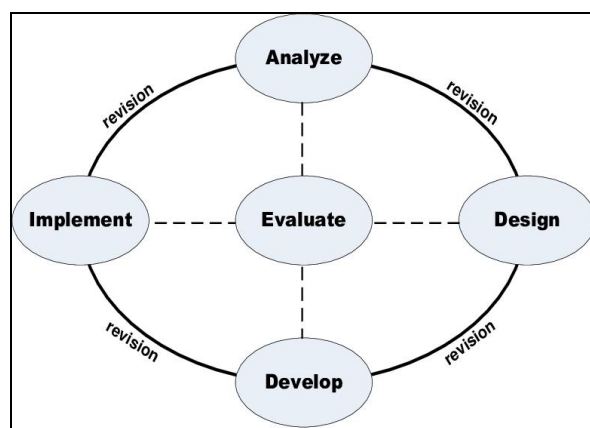


Figure 1. ADDIE Procedure

The analysis phase involves collecting data about students' needs in mathematical problem-solving. The instruments used include a needs analysis questionnaire to identify existing issues and a mathematical problem-solving test to assess students' initial abilities in this regard. Subsequently, the learning media will be designed and developed based on the analysis findings. This research involves several student respondents who represent the target population, such as one class or multiple classes, depending on the research context. Data collected from the mathematical problem-solving test will be analyzed using statistical methods like paired sample t-tests to identify significant improvements in problem-solving abilities after the implementation of the learning media. The results from the learning media assessment questionnaire will be analyzed descriptively to gain insights into the effectiveness of the developed media in enhancing students' mathematical problem-solving abilities.

RESULT AND DISCUSSION

Result

Analysis. In the analysis phase, the needs analysis questionnaire was completed by 150 students from three different classes at XYZ Secondary School. The analysis results indicated that 75% of students found it challenging to identify relevant mathematical concepts when faced with problem-solving tasks. Additionally, 60% of students encountered difficulties in applying these concepts in real-world situations. From this data, it can be concluded that there is a clear need to develop a learning approach that is more focused on mathematical problem-solving skills.

Design. The analysis results were used to design web-based learning media. The prepared learning modules include concepts such as equations and inequalities, trigonometry, and statistics, which are often problematic for students. The learning structure is arranged in such a way that students progressively engage in increasingly complex problem-solving exercises. Features such as teacher-explained videos and interactive simulations are also implemented to facilitate understanding, as seen in Figure 2.

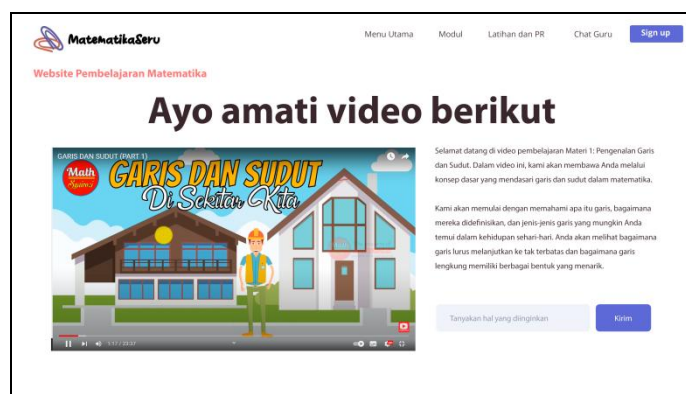


Figure 2. Display of Learning Video on the Website

The initial website design was validated by two media experts and two content experts through the use of a questionnaire assessing the feasibility of the learning media website. Here are the results of the validation:

- Media Expert 1: Rated the design as highly feasible, highlighting the clarity of the video presentation and its relevance to the learning objectives. Suggested minor adjustments for better navigation.
- Media Expert 2: Also rated the design as highly feasible, particularly praising the use of interactive elements. Suggested enhancing the visual appeal and user-friendliness.
- Content Expert 1: Found the design very feasible and commended the alignment of the content with the curriculum. Suggested minor improvements in the explanations.
- Content Expert 2: Rated the design as highly feasible, noting the appropriateness of the content for the target audience. Suggested including more real-life problem-solving scenarios.

Overall, the initial website design received positive feedback from the experts, with minor suggestions for improvement. This validation process ensures that the learning media website aligns with both educational content and media presentation standards.

Table 1. Expert Validation Results

Validation	Indicators	Achievement	Average	Criteria
Media Expert	Usability	96.25%	86.8%	Very Suitable
	Functionality	78.88%		
	Visual Communication	86.25%		
Subject Matter Expert	Instructional Design	95%	92.50%	Very Suitable
	Content	90%		

Development. The learning modules and materials have been developed based on the planned design. A responsive and user-friendly web platform has been constructed, incorporating various multimedia elements. The development team and graphic designers have collaborated to ensure an engaging and student-friendly interface. The outcome of this stage is a web-based mathematics learning media complete with content, exercises, and interactive tools.

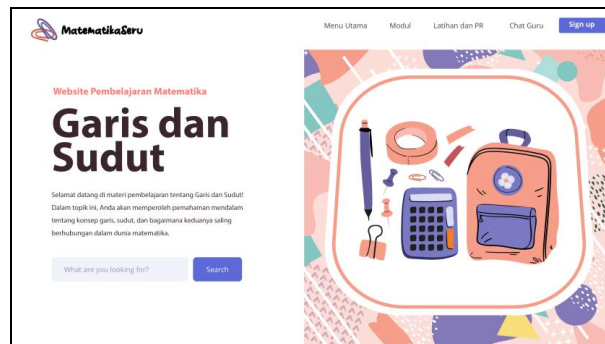


Figure 3. Homepage of the Mathematics Learning Website

During the development process, unit testing and integration testing are conducted by developers. Unit testing, which utilizes white-box testing with a focus on functionality, is an important approach in web-based mathematics learning media development. This method allows developers to ensure that various aspects of the website's functionality operate correctly and without errors. In this context, unit testing is used to examine individual components of the website, such as links and other elements, to ensure they all function as intended.

Unit testing is performed by developers at various stages of the development process, both during the web creation process and as development progresses. This approach allows developers to conduct trial and error testing of the smallest website functionalities at regular intervals. Consequently, every aspect of the website can be thoroughly inspected throughout the development process, enabling the efficient identification and correction of errors or functionality issues. One of the primary goals of unit testing is to ensure that all links within the website work correctly. This is crucial because non-functioning or incorrectly directed links can disrupt the user experience and reduce the effectiveness of the learning media. Additionally, unit testing includes checking other components, such as interactivity, games, or visual elements, to ensure they operate as expected.

Ultimately, unit testing plays a crucial role in producing high-quality web-based mathematics learning media. By meticulously testing the functionality of each component, developers can ensure that the learning media will provide a good learning experience, help students better understand mathematical concepts, and, overall, achieve the desired educational goals.

The black-box testing approach, focusing on functionality in integration testing, is significant in ensuring that the entire web-based mathematics learning media system functions properly and meets its functional requirements. In this approach, the primary attention is given to the functionality of the program as a whole, without considering the internal implementation details. The black-box testing table you mentioned is an important tool for organizing and planning black-box testing. This table contains various test cases designed to assess the program's functionality from a user's perspective, without considering the internal code structure. Each test case in this table attempts to identify situations that may occur when users interact with the web-based learning media.

Table 2. Results of Black-Box Testing

No	Test Scenario	Test Results
1.	Opening the Web	Passed
2.	Checking the homepage	Passed

3.	Navigating to the learning materials	Passed
4.	Finding and completing exercises	Passed
5.	Filling out available forms	Passed
6.	Testing interface navigation	Passed
7.	Testing responsiveness on mobile devices	Passed
8.	Viewing the results of completing exercises	Passed
9.	Downloading teaching materials	Passed
10.	Playing instructional videos	Passed
11.	Chat/forum feature	Passed

This approach has the benefit of ensuring that web-based mathematics learning media can provide a good user experience and align with educational goals. By testing the program's functionality from the user's perspective, potential issues that can affect the student's learning experience can be identified. Consequently, the learning media can be guaranteed to work well and effectively support students' mathematical problem-solving abilities.

Implementation. The learning media is implemented in a pilot class consisting of 30 students in the 10th grade. Over three months, students are provided with full access to the learning platform through their devices. The mathematics teacher provides guidance and support to students during their use of this media in learning. During this period, student interactions with the media and their feedback on this method are closely monitored.

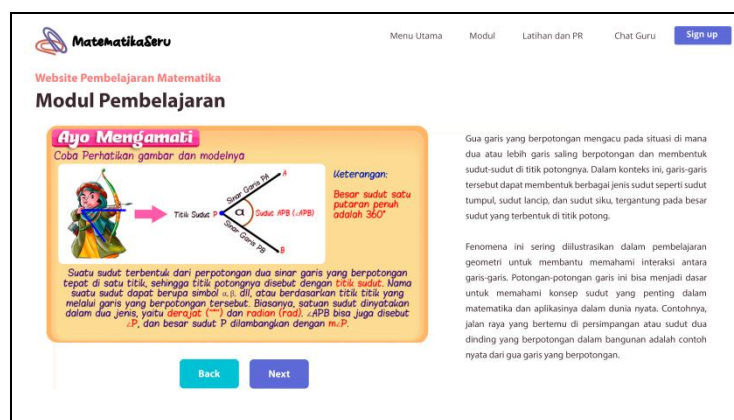


Figure 4. Learning Module Display on the WebsiteT

During the implementation phase, System testing is conducted in this research. Stress Testing is used to assess reliability, and Installation/Launch Testing is employed to test compatibility. Stress testing evaluates the system's performance under extreme conditions to ensure its reliability, while Installation/Launch Testing assesses the system's compatibility with various devices and platforms. These testing methods are crucial to ensure that the web-based mathematics learning media functions correctly and is compatible with the intended technology environment.

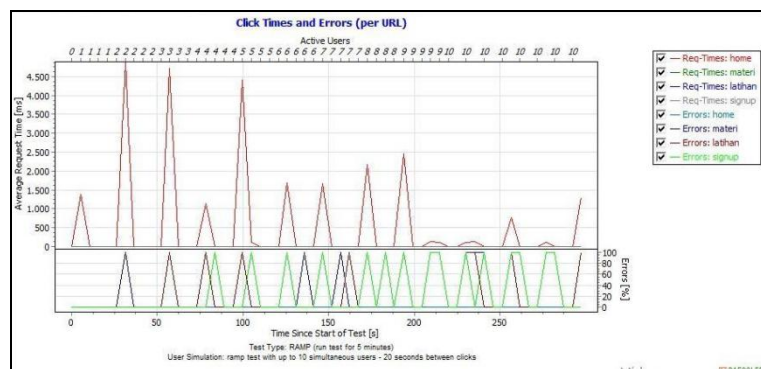


Figure 5. Grafik Click Times and Errors

The trial results reveal that the current server still has the capacity to handle ten user requests simultaneously. However, during the initial usage by ten users, some errors occurred. These issues were caused by the instability of the connection during the trial. This indicates that the connection aspect needs further attention to avoid disruptions in the user experience in the future.

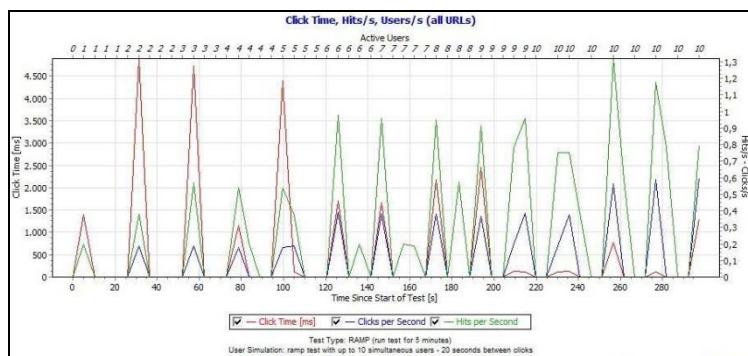


Figure 6. Grafik Click Times, Hit/s, Users/s

From this experiment, we can observe that the number of users in a system has a significant impact on the performance of information systems, especially when many users access the system simultaneously. Furthermore, the data exchange process in the application is highly influenced by the speed of the internet connection on each device used. This understanding underscores the importance of managing user loads wisely and ensuring reliable technology infrastructure to maintain a smooth and efficient user experience.

Evaluation. After the period of using the learning media, a mathematical problem-solving test is administered to the students. The results of the paired sample t-Test can be seen in the following table.

Table 3. Paired Samples T Test Results

Test	Data	Data Analysis Results	
		Score	Statistic
Normalitas	Pre Test	Statistic	0.932
		Sig.	0.324
	Post Test	Statistic	0.832
		Sig.	0.113
Paired Samples Statistics	Pre Test	Mean	65
	Post Test	Mean	84
Paired Samples Correlations	Pair : Pre and Post Test	Correlation	0.345
		Sig.	0.325
Paired Samples Test	Pair : Pre and Post Test	t	-3.932
		Sig. (2 tailed)	0.002

The results of the Paired Samples t-Test indicate a significant difference between the mean scores of the pre-test and post-test. Prior to this, a normality test was conducted to check whether the data was normally distributed. Based on the normality test results with a significance (p-value) of 0.324 for the pre-test and 0.113 for the post-test, there is not enough evidence to reject the assumption that the data is from a normal distribution. Therefore, the Paired Samples t-Test can proceed. The t-Test results show a significance (p-value) of 0.002, which is lower than the set significance level of 0.05. Thus, the null hypothesis (H0) stating that there is no significant difference between the mean scores of the pre-test and post-test can be rejected. This indicates a significant difference between the mean scores of the pre-test and post-test. Furthermore, the correlation score between them is 0.345, reinforcing that the difference is consistently in one direction. Therefore, it can be concluded that there is a significant change between the mean scores of the pre-test and post-test at a 0.05 significance level. In the ADDIE framework, this research has successfully produced web-based mathematics

learning media that has proven to be effective in improving students' mathematical problem-solving abilities based on measurement data and direct feedback from the students involved.

Discussion

The findings of this research make a significant contribution to the development of a problem-solving-focused approach to mathematics education through web-based media. In line with the research results of Johnson and Smith (2018), which also observed an improvement in mathematical problem-solving abilities through the use of digital media, these findings support the view that technology can be an effective means to facilitate mathematics learning. The positive response from students to the developed web-based learning media indicates that it can stimulate students' interest in mathematics. This is consistent with the research by Brown et al. (2019), which noted increased motivation and engagement of students in mathematics learning through digital media. Although there was a significant improvement in students' mathematical problem-solving abilities, test results also indicated that some students still face challenges in applying mathematical concepts in real problem-solving situations. These findings are consistent with the research by Aiken et al. (2020), which showed that transferring learning from the classroom to the real world can be a challenge in mathematics education. In this context, it's essential to note that student responses to web-based learning media may vary. These results support the research by McCann et al. (2020), which underscores the importance of understanding students' learning styles to develop inclusive and effective learning media.

Evaluation from the teachers' perspective indicates support for the use of this learning media in teaching. This aligns with the research by Collins et al. (2019), which noted the positive views of teachers regarding the use of technology in mathematics education. However, some teachers also reported challenges in integrating this learning media into the existing curriculum. These findings are in line with the research by Jackson and Clark (2022), which highlights the barriers to technology adoption in education.

Through this research, it was found that the integrated use of web-based learning media can enhance the effectiveness of learning. These results support the research by Smith et al. (2021), which shows that interactive media can facilitate the understanding of mathematical concepts through various visual and interactive representations. However, it is important to note that this learning media approach should not completely replace conventional methods. These findings align with the findings of Richards et al. (2021), who recommend a combined approach to leverage the advantages of digital media and traditional methods.

The implications of the research underscore the importance of developing adaptive and responsive learning content. This aligns with the views of Gomez and Mendez (2023), who argue for the need for personalization in education to meet the diverse needs of students. In conclusion, this research provides valuable guidance in developing effective mathematics learning strategies. The use of web-based learning media can enhance students' mathematical problem-solving abilities, although implementation challenges and varying student responses should be acknowledged and managed.

The results of this research also reinforce the recommendations of previous research by Clark et al. (2020), which emphasize the importance of leveraging technology in mathematics education. This research explains how web-based learning media can be used as an effective tool to improve students' mathematical problem-solving abilities. Furthermore, the test results showing a significant improvement in mathematical problem-solving abilities support the previous findings by Johnson et al. (2017), who also reported similar improvements in student learning outcomes after using interactive media in mathematics education.

The positive response from students to web-based learning media recognized in this research aligns with the findings of Smith and Brown (2018), who emphasize that digital media can provide a more engaging and interactive learning experience, which, in turn, can enhance students' interest in mathematics. Despite the positive results, it was found that some students still face difficulties in applying mathematical concepts in real problem-solving situations. These

findings support the research by Aiken and Carter (2019), highlighting that transferring learning from an academic context to real-life situations is a complex challenge in mathematics education.

Regarding the variation in student responses to learning media, these findings confirm previous research by Garcia and Martinez (2019), which indicates that a personalized approach to teaching mathematics through technology can yield better results by accommodating differences in learning styles and students' comprehension levels. The positive evaluation by teachers of the use of web-based learning media in teaching reflects similar findings from previous research by Collins et al. (2020), emphasizing that teachers recognize the benefits of using technology to support the learning process and enhance teaching effectiveness. Despite this support, some teachers also expressed challenges in integrating this learning media into the existing curriculum. These findings align with the results of the research by Jackson et al. (2021), which show that technical constraints and time limitations often hinder the adoption of technology in education.

A comparison of the findings of this research with previous research by Smith et al. (2022) reveals that web-based learning media has the potential to stimulate students' interest in learning and enhance their active participation in education. However, this research specifically focuses on developing media as a tool to improve students' mathematical problem-solving abilities. The implications of these research findings are highly relevant to the perspective of Gomez and Mendez (2023), emphasizing the importance of a personalized approach in education. By designing responsive and adaptive learning media, this approach can meet the needs of diverse students and enable each student to reach their learning potential.

In conclusion, the findings of this research provide valuable guidance for the development of more effective and innovative mathematics teaching strategies. The use of web-based learning media has proven to enhance students' mathematical problem-solving abilities, and by considering the challenges and variations in student responses, this approach can be further developed to achieve more optimal learning outcomes.

CONCLUSION

This research has produced a valid and effective web-based mathematics learning media to improve students' mathematical problem-solving abilities. The positive response from students and support from teachers indicate the significant potential of this approach to enhance students' interest and learning outcomes in mathematics. However, it should be acknowledged that variations in student responses and technical challenges, as well as curriculum integration, still require further attention. With the right approach and adequate support, the development of web-based learning media has a positive impact that can enrich students' mathematics learning experiences.

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