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Interactive Learning Media Utilizing Google Sites on Quantum Mechanics Topic

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ABSTRAK

Pesatnya perkembangan teknologi telah memberikan kontribusi signifikan dalam transformasi pendidikan. Integrasi platform pembelajaran interaktif menjadi semakin krusial untuk meningkatkan keterlibatan dan pemahaman mahasiswa terhadap konsep-konsep yang kompleks seperti fungsi gelombang dalam mekanika kuantum. Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi sebuah media pembelajaran interaktif yang efektif untuk diaplikasikan dalam pembelajaran fisika kuantum di tingkat perguruan tinggi. Penelitian ini mengadopsi pendekatan penelitian dan pengembangan yang melibatkan ahli konten, ahli media, dan mahasiswa sebagai subjek penelitian. Sampel ahli dipilih secara purposive, sedangkan mahasiswa dipilih secara convenience*. Pengumpulan data dilakukan melalui kuesioner, dan analisis data menggunakan statistik deskriptif dengan acuan tabel kriteria kelayakan media. Berdasarkan hasil uji kelayakan dari ahli media, ahli konten, dan respon pengguna, media pembelajaran interaktif yang dikembangkan dinilai sangat valid dan layak untuk digunakan dalam pembelajaran fisika kuantum, terutama pada topik fungsi gelombang. Hasil penelitian ini mengindikasikan bahwa media pembelajaran interaktif berbasis* Google Sites *dapat menjadi alternatif yang menarik untuk meningkatkan pengalaman belajar dan pemahaman mahasiswa tentang mekanika kuantum.*

ABSTRACT

The rapid advancement of technology has significantly transformed the landscape of education. The integration of interactive learning platforms has become increasingly crucial in enhancing student engagement and comprehension of complex concepts such as wave functions in quantum mechanics. This research aims to develop and evaluate an effective interactive learning medium for teaching quantum physics at the university level. Employing a research and development approach, this study involved content experts, media experts, and students as research subjects. Experts were selected through purposive sampling, while students were selected through convenience sampling. Data was collected using questionnaires and analyzed descriptively using a media feasibility criteria table. The results of the feasibility assessment by media experts, content experts, and user responses indicate that the developed interactive learning medium is highly valid and feasible for teaching quantum physics, particularly the topic of wave functions. This research suggests that Google Sites-based interactive learning media can be an attractive alternative to enhance students' learning experiences and understanding of quantum mechanics.

1. INTRODUCTION

In the 21st century, technology is advancing at an accelerated pace. This technological progress has had a significant impact on various aspects of social life, including the field of education (Ernest et al., 2023; Luckin & Cukurova, 2019; Maritsa et al., 2021; Sabil et al., 2023; Sugiyanto et al., 2016). The rapid advancement of technology demands educators to be professional and keep up with the times, one of which is by employing technology for learning (Maulani et al., 2022; Viktor & Hakim, 2021). Educators must be able to adapt to flexible learning environments to meet the needs of students in the modern era (Deed et al., 2020; Yustitia et al., 2024). Integrating technology into the learning process is one way to develop

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educators' professionalism, enhance teaching effectiveness and efficiency (Suyuti et al., 2023; Zhang & Liu, 2022). Technology has proven to be invaluable in the realm of education (Kaden, 2020; Chen & Tsai, 2021). In today's digital age, educators serve as learning facilitators (Sugiyanto et al., 2021; Yuliani, 2022). This means that educators must foster learning environments that stimulate creativity. This involves leveraging digital tools to develop innovative learning activities that enhance student engagement, motivation, and cognitive abilities, thereby facilitating the attainment of desired learning outcomes.

The utilization of technology, such as learning management systems and interactive online platforms, is paramount in enhancing the quality of education, especially at the higher education level.. Educational progress can be measured by how technology is utilized to support the learning process (Ernest et al., 2023; Hamid et al., 2021; Jang et al., 2021). Easy access to information and the ability to succeed academically through technology are key factors (Ernest et al., 2023; Huang et al., 2021). Technological integration in education can significantly improve the effectiveness and efficiency of teaching and learning (Mas'ud & Maemunah, 2022; Popham, 2020). Moreover, technology can make learning more engaging for students. Therefore, not only teachers but also students should be actively involved in utilizing technology as an independent learning resource (Chin & Wang, 2021; Ernest et al., 2023). Through technology, students can access information swiftly, pursue self-directed learning, build a robust knowledge base to prevent misinformation, and efficiently share knowledge (Ernest et al., 2023; Khasanah et al., 2021). In the educational context, student engagement with digital technology-based media can enhance students' knowledge, skills, understanding, and involvement (Chen & Tsai, 2021; Clark & Mayer, 2016; Sakti, 2023).

The development of digital learning materials enables easy access for students anytime and anywhere (Jufriansah et al., 2022; Septianti & Firdaus, 2024). One form of digital learning material is interactive media. Interactive learning media can effectively facilitate the achievement of learning competencies. It can be filled with systematically organized digital content, including images, illustrations, videos, audio, and animations, presented in a more engaging manner to enhance student understanding. Interactive learning media enables self-directed study (Kusumawati et al., 2021; Manurung, 2020; Munawir et al., 2024; Ulfa Mukhtar et al., 2022). Web-based interactive learning media can serve as supplementary learning materials, providing various content and video sites to reinforce learning. Therefore, it is crucial for educators to develop learning media as an effective tool for teaching complex concepts to students, such as those found in quantum mechanics.

Quantum mechanics, as a branch of modern physics, presents abstract concepts that often pose challenges for students to grasp (Bouchée et al., 2022; Ubben, 2020). The concept of wave function, a fundamental cornerstone of quantum mechanics, is particularly difficult for students to master. Students frequently struggle with understanding basic concepts and equations in quantum mechanics, including the wave function. A study highlights that the abstract nature of quantum physics and the demand for a high level of professionalization in comprehending these concepts contribute to the challenges faced by students. The study found that a deep understanding of quantum models, such as the wave function, requires mastery of theoretical aspects and their application in practical scenarios, which many students find difficult. The rapid advancement of information technology has opened up opportunities to develop more interactive and engaging learning media to address these challenges (Krijtenburg-Lewerissa et al., 2017; Pereira & Solbes, 2022; Ubben, 2020).

Google Sites, as a user-friendly website development platform, holds significant potential for creating innovative learning materials. Teachers can utilize Google Sites to provide learning materials and assignments in interactive formats (Alam Syah & Hidayatullah, 2024; Kamilah et al., 2023; Tambunan & Siagian, 2022). Moreover, with the use of internet-connected devices, Google Sites is highly accessible to students (Adzkiya & Suryaman, 2021; Ernest et al., 2023; Thomas et al., 2022). Google Sites-based websites offer several advantages, such as ease of creation, free of charge, collaborative features, free online storage, user-friendliness, and accessibility from anywhere and anytime, without spatial or temporal limitations (Abdjul, 2023; Fitriani et al., 2022; Septianti & Firdaus, 2024). Google Sites can integrate various types of information into a single platform, including videos, materials, presentations, images, attachments, text, quizzes, assessments integrated with Quizizz and Google Forms, and simulations that can enhance students' understanding of the subject matter (Mas'ud & Maemunah, 2022; Mukti et al., 2020; Ramadannisa & Hartina, 2021; Septianti & Firdaus, 2024). Using Google Sites to develop learning materials can help students access content more flexibly and support independent learning. In quantum physics learning, this facilitates exploration of widely accessible digital information regarding scientific advancements (Ariastika, 2022; Tarjiah et al., 2020). However, study on the development of interactive media utilizing Google Sites for quantum mechanics topic is still very limited

Ideally, learning quantum mechanics, especially the concept of wave functions, can be effectively achieved if students can visualize these abstract concepts interactively. However, in practice, there are still many obstacles (Dachraoui et al., 2022; Ubben & Bitzenbauer, 2023). Some of these include limited

laboratory facilities, a lack of engaging learning media, and difficulties for educators in conveying abstract concepts. The gap between the ideal conditions and the reality in the field highlights the urgency of developing innovative and effective learning media. Interactive learning media based on Google Sites is expected to overcome some of these obstacles, such as: (1) visualizing abstract concepts: interactive simulations can help students visualize the behavior of particles at the quantum level, (2) increasing learning motivation: attractive and interactive designs can enhance students' motivation to learn, and (3) providing instant feedback: students can immediately receive feedback on their answers, allowing them to correct misunderstandings.

Studies have demonstrated that utilizing Google Sites as a learning medium can significantly enhance students' understanding of physics concepts. Research conducted at SMK Negeri 4 Palangka Raya revealed that utilizing Google Sites as a learning tool positively influenced student achievement. This research indicated that using Google Sites can improve student achievement by 20.8%. Additionally, Google Sites-based learning can enhance students' problem-solving skills, digital literacy, critical thinking, and motivation to learn, as well as increase student understanding and engagement in the learning process (Ernest et al., 2023; M. Maryani et al., 2022; Mas'ud & Maemunah, 2022; Ramadannisa & Hartina, 2021; Thomas et al., 2022; Wulandari, 2022). Using Google Sites can make learning more engaging, interactive, and effective (Ramadannisa & Hartina, 2021; Abdjul, 2023; Pertiwi & Purnawarman, 2023). However, despite these numerous studies, research focusing on the development of interactive learning media using Google Sites for quantum mechanics, particularly the concept of wave functions, remains very limited.

Observations of quantum physics courses at Yogyakarta State University indicate an underutilization of interactive learning media by lecturers, resulting in students experiencing difficulties in understanding the taught wave function topic. Classroom learning tends to be one-way, where all information related to the learning material comes from the lecturer, and students have not been facilitated to learn independently with interactive and innovative learning media. Therefore, a development study is needed that utilizes Google Sites as an interactive learning media for the quantum mechanics topic, especially on the wave function topic in higher education. This research offers novelty, namely: (1) a focus on the wave function concept, which is often considered difficult by students, (2) the innovative application of Google Sites as a platform for interactive quantum physics learning, and (3) the development of learning media that integrates various interactive features, such as videos, animations, and quizzes. This research aims to develop interactive learning media using Google Sites to support students' understanding of the wave function concept in quantum mechanics, and determine the feasibility of development products by conducting validity and feasibility tests. This research is expected to have a significant impact on education, especially in physics, by improving learning quality, enhancing student learning experiences, and deepening their understanding of quantum mechanics.

2. METHOD

The objective of this study is to develop an interactive learning media s for Quantum Mechanics courses at the university level utilizing Google Site. This is a research and development study. Employing the 4D development model, this research will encompass several stages: (1) initial analysis of problems, subject needs, and literature review, (2) design of a suitable media as a solution to the identified problems or to meet subject needs, (3) development of a prototype validated by experts and users, and (4) dissemination of the innovative learning media. This study involved 3 media experts, 2 topic content experts, and 50 students as users. The media experts included one Technology Ambassador from the Ministry of Education and Culture, one Guru Penggerak from Sukamara Regency, and one Chemistry teacher from SMAN 1 Balai Riam. The content experts consisted of one Indonesian language teacher and one Mathematics teacher from SMAN 1 Balai Riam. Additionally, 50 students majoring in physics and physics education from various universities in Indonesia served as users. The selection of research subjects was carried out using two different sampling techniques. Media and content experts were chosen purposively to gain in-depth assessments, while the students were selected through convenience sampling to represent general users. Data for this research was collected using questionnaires. Two types of questionnaires were employed: product feasibility questionnaires and response questionnaires. The product feasibility questionnaires were used to obtain data on the feasibility of the developed product, while the response questionnaires were used to gather feedback from users regarding the suitability of the developed media. The product feasibility questionnaires were further divided into media expert feasibility questionnaires and content expert feasibility questionnaires. A 5-point Likert scale was used for all questionnaires. The data collected in this study was analyzed using descriptive statistics. The questionnaire items for all experts are presented in Table 1, Table 2, and Table 3.

Table 1. Media Experts Questionnaire Item

No.	Assessment Aspects
1	Feasibility of Material Content
2	Language Feasibility
3	Presentation of Material

Table 2. Content Experts Questionnaire Item

No.	Assessment Aspects
1	Media Design
2	Text
3	Color Combinations
4	Picture
5	Animation
6	Audio
7	Navigation Buttons
8	Practicality

Table 3. Response Questionnaire Item

No.	Assessment Aspects
1	Learning Media
2	Material
3	Benefit

3. RESULT AND DISCUSSION

Result

The results of this study show the feasibility of developing products based on Google Sites-based interactive learning media on wave function material. This development consists of four main steps: *Define*, *Design*, *Develop*, and *Disseminate*. The *Define* stage is the stage of determining and defining the conditions needed in learning development. Determining the required conditions is carried out by paying attention to and adjusting the learning needs of students. The fundamental problem in the learning process is that because there are still some students educators must teach, there are still students who are less active in the learning process using conventional methods. Students need learning media that allows them to learn independently. Based on this problem, the researcher developed learning media to support independent learning. By utilizing technology today, it is hoped that learning media developed online can help students in independent learning. A student analysis is conducted to identify the characteristics of the students and the challenges they encounter during the learning process. The lack of interest and motivation during classroom learning due to the use of less interactive media is a key consideration for researchers in developing new learning media. Therefore, it is hoped that the developed media will simplify the material for students to understand. The concept analysis is carried out before creating learning media and conducting research. This makes the content presented in learning seem complete and systematic, making it easier for students to construct knowledge and understand concepts. The activity conducted at this stage is the analysis of the curriculum of learning subjects to produce an overview of the teaching materials provided in the learning media to be developed. Setting learning goals is a stage that must be done to achieve the expected behavior change in students after implementing the learning process. The expected behavior change is in line with the learning objectives developed based on the achievement indicators that have been set. Analysis of students shows that students tend to be passive in the learning process. Therefore, learning media development is expected to increase student activities throughout the learning process.

At the design stage, the researcher began to design a Google Sites-based interactive learning media on wave function material. The activities conducted at this design stage are: (1) *Constructing criterion-referenced test*. Preparing the criterion test is an activity that compiles Google Sites-based interactive learning media on wave function topics to achieve learning objectives as planned. The learning objectives in question are expected to explain the statistical interpretation of wave functions, use the wave function to determine probability, calculate the expected value of position, momentum, and kinetic energy, and explain the physical meaning of Heisenberg's uncertainty principle. (2) *Media selection*. The selection of media in developing Google Sites-based interactive learning media on wave function material is very important to ensure the content is delivered and presented effectively and excitingly. Some types of media integrated into

this Google Sites-based interactive learning media are infographics designed using the Canva application, animated video-based materials, examples of questions that are equipped with discussions, and online-based quizzes using Google Forms. (3) *Format selection*. The selection of format in the Google Sites-based interactive learning media on the wave function material adjusts the CPMK (Learning Objectives of the Course) we want to achieve. The material format used is infographics (posters), videos, sample questions equipped with discussions, and quizzes adjusted to the wave function material. (4) *Initial design*. The initial design developed on the Google Sites-based interactive learning media on the wave function material includes clear pages, proper media selection, and easy-to-use navigation.

In the development stage, the researcher develops learning media based on the concept from the design stage. There are several steps taken at the development stage, namely: (1) creation of learning media, (2) product feasibility validation, and (3) development testing. The development of this interactive learning media focuses on creating learning media based on Google Sites. All items prepared during the design stage are realized in tangible form. In this study, wave function material in the form of infographics, videos, sample questions, and quizzes will be implemented into a website. Here's what Google Sites looks like in the development. The google sites work screen is shown in Figure 1

Figure 1. Google Sites *Work Screen*

The developed Google Sites-based interactive learning media includes various navigation menus, such as (1) home, (2) main menu, (3) topic menu, (4) sample question menu, and (5) quiz. Home is the main page that contains several navigation menus to start programming *Google Sites*. This page also contains Capaian Pembelajaran Mata Kuliah (CPMK), which is to be achieved after studying the wave function material in this interactive learning media. The home page display is shown in Figure 2.

Figure 2. The Display of Home Page

The main menu has several navigation items: home, poster material, video material, sample questions, quizzes, and developer profiles. Figure 3 shows the display of the main menu.

Figure 3. The Display of the Main Menu Page

On the topic menu page, there are several material selection items that can be selected, namely wave function, normalization, expectation value, and home. The home item serves to make it easier for users to return to the previous page. Figure 4 shows the display of the material menu page.

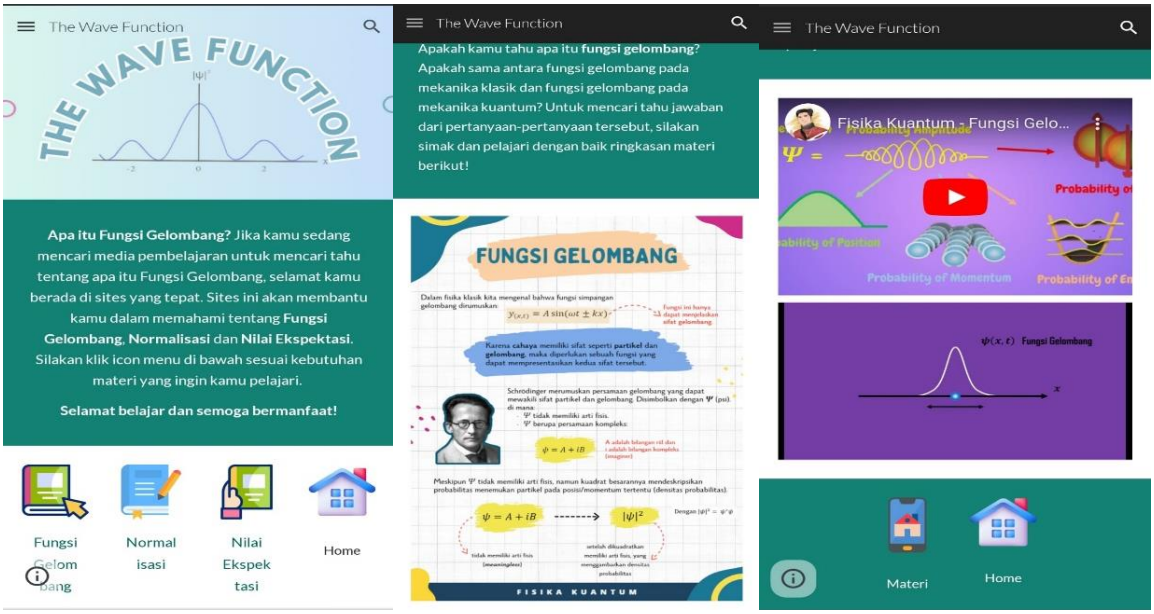

Figure 4. The Display of Material Menu

The sample question menu page has several items, namely sample questions 1 and 2, challenge questions, and home. The sample questions presented are equipped with a very detailed, clear, and easy-to-understand discussion for users. Example questions have question levels from the easy, medium, and difficult question categories (challenge questions). The home item returns to the main page. Figure 5 shows the display of the sample question menu.

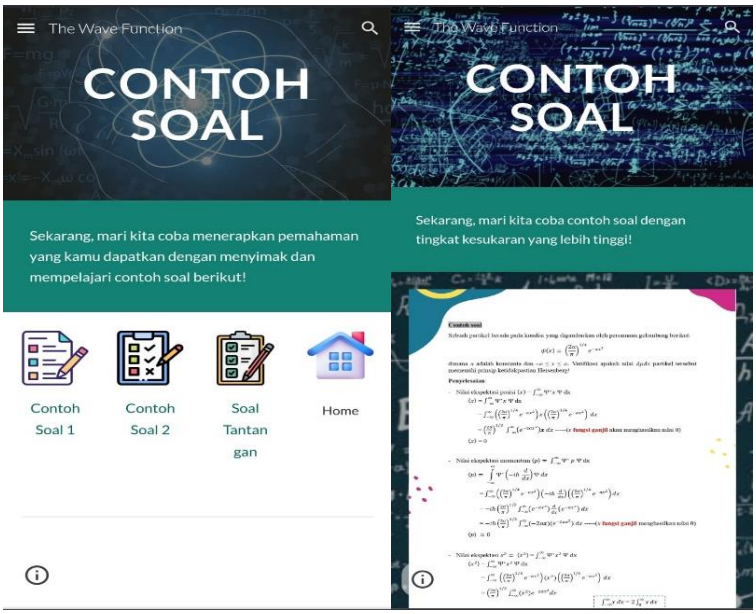

Figure 5. The Display of Sample Question Menu

On the quiz page, two items will be displayed: sample questions and home. Sample question items will allow students to access previously studied questions, and home will return them to the main menu page. To complete this quiz, students can press the Quiz icon, as shown in Figure 6.

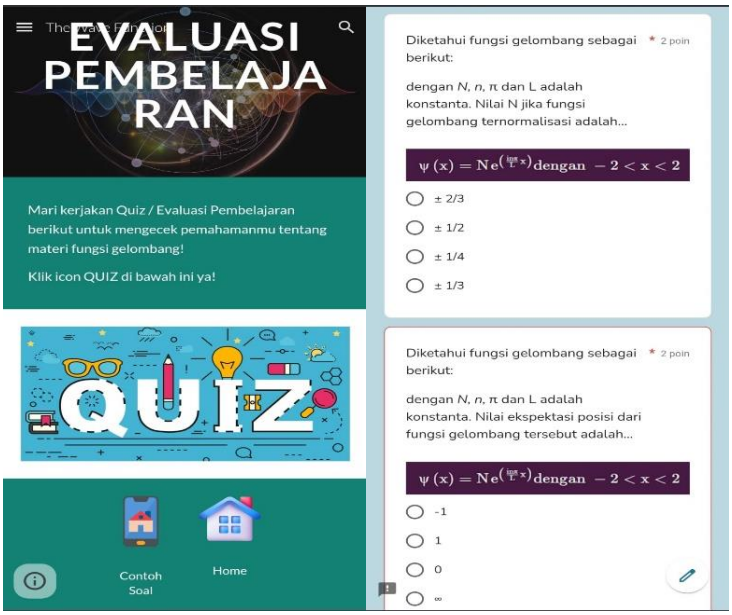

Figure 6. The Display of Quiz

Following the development of the learning media, the next stage is validating the product's feasibility. The feasibility validation of this product is carried out to assess the learning media developed by providing assessment instruments in the form of questionnaires to content and media experts. As a consideration in choosing content and media experts, this is adjusted to the criteria or the field of expertise they have. The content and media experts used in the validation of the feasibility of this product are teachers from SMAN 1 Balai Riam, namely one teacher from the Ministry of Education and Culture's Technology Ambassador, one Guru Penggerak Kabupaten Sukamara, and one Chemistry teacher as a media expert, as well as one Indonesian teacher and one Mathematics teacher as a content expert. The validation sheets use a Likert scale with five alternative answers: Very Good (VG), Good (G), Good Enough (GE), Not Good (NG), and Very Not Good (VNG). The results of the validation data analysis by media experts and content experts are presented in Table 4, and Table 5.

Table 4. The Validation Percentage by Topic's Content Experts

No.	Assessment Aspects	Total Score		Average Score	Category
		Validator 1	Validator 2		
1	Feasibility of Material Content	90	95	92.5	Very Good
2	Language Feasibility	90	85	87.5	Very Good
3	Presentation of Material	93.33	96.67	95	Very Good
Average Total Score				**91.67**	**Very Valid**

Table 5. The Validation Percentage by Media Experts

No.	Assessment Aspects	Total Score			Average Score	Category
		Validator 1	Validator 2	Validator 3		
1	Media Design	80	90	80	83.33	Very Good
2	Text	90	90	80	86.67	Very Good
3	Color Combinations	80	80	80	80.00	Good
4	Picture	86.67	93.33	86.67	88.89	Very Good
5	Animation	100	100	90	96.67	Very Good
6	Audio	80	80	80	80.00	Good
7	Navigation Buttons	100	90	90	93.33	Very Good
8	Practicality	90	90	80	86.67	Very Good
Total Score					**86.94**	**Very Valid**

At the development trial stage, the learning media that content experts and media experts have validated has been validated by 50 students majoring in physics and physics education from several universities in Indonesia as users, including Yogyakarta State University, Semarang State University, Palangka Raya University, IAIN Palangka Raya, Padjajaran University, Makassar State University, Mataram State University, UIN Mataram, Jenderal Soedirman University, Surabaya State University, and UIN Alauddin Makassar. The validation was conducted by distributing the questionnaire online via Google Forms through the WhatsApp application on June 6, 2024; then, students conducted a trial of the developed learning media and conducted an assessment by completing the provided questionnaire. The questionnaire given is an assessment questionnaire for learning media. The validation of the learning media was conducted by completing a questionnaire using a Likert scale with five alternative answers: Very Good, Good, Good Enough, Not Good, Very Bad. The analysis of the results of student validation as a user can be seen in the following in Table 6.

Table 6. The Validation Percentage by User

No.	Assessment Aspects	Average Score	Percentage	Category
		50 Students		
1	Learning Media	4.72	94.40	Very Good
2	Material	4.64	92.80	Very Good
3	Benefit	4.55	91.00	Very Good
Average Total Score			**92.73**	**Very Valid**

Based on the validation tests conducted by content experts, media experts, and users, the overall results of the validity and feasibility test for the development of Google Sites-based interactive learning media on the wave function material are presented in Table 7.

Table 7. Total Results of the Google Sites-Based Interactive Learning Media Validation Test

No.	Assessment Aspects	Average Total Score	Category
1	Content	91.67	Very Valid
2	Media	86.94	Very Valid
3	User	92.73	Very Valid
Average Total Score		**90.45**	**Very Valid**

Table 7 indicates that the overall validation results for the Google Sites-based interactive learning media on wave function material, as assessed by several expert validators, achieved a score of 90.45%, which

falls into the Very Valid category. Consequently, it is deemed suitable as a physics learning medium for wave function material.

The dissemination stage is the final stage of this development research. This stage functions so that the learning media products developed can be used by all students majoring in physics education at Yogyakarta State University, both at the undergraduate and graduate (Master) levels. The trial of Google Sites-based interactive learning media on this wave function material was previously only conducted to content experts, media experts, and 50 samples of students majoring in physics and physics education from several universities in Indonesia. Therefore, in order for this media to be used more widely and reach many students majoring in physics education, especially students majoring in physics education at Yogyakarta State University, this media will be disseminated through researcher social media and social media Keluarga Mahasiswa Magister dan Doktor (KMMD) FMIPA UNY. The learning media that will be shared is online-based, so students from anywhere and anytime can access it.

Discussion

The use of technology in the learning process can enhance student engagement and understanding of the subject matter. Implementing technology in education, such as interactive learning media, facilitates educators in explaining abstract and complex concepts more effectively. Interactive learning media can effectively facilitate students in improving their learning outcomes (Kustyarini et al., 2020; Sahronih et al., 2019). It can be filled with systematically organized digital content, including images, illustrations, videos, audio, and animations, presented in a more engaging manner to enhance student understanding. The use of media such as videos, animations, and images provides students with a concrete representation of the concepts discussed in text form, and stimulates learners to engage in critical and analytical thinking (Kurniawan & Haniva, 2022; Munjiatun et al., 2023). Interactive learning media enables self-directed study (Kusumawati et al., 2021; Manurung, 2020; Munawir et al., 2024; Sahronih et al., 2019; Ulfa Mukhtar et al., 2022). Therefore, educators can develop interactive learning media, such as using Google Sites, to enhance the quality of instruction and provide students with meaningful learning experiences.

This study has developed Google Sites-based interactive learning media for the subtopic of wave functions in quantum mechanics, which has been deemed very valid and very feasible by media experts, content experts, and users. The interactive learning media developed in this study is designed with an attractive interface and includes several navigation menus, such as home, main menu, topic menu, sample questions menu, and quiz, making it highly practical to use. The educational material presented in this interactive media is organized in simple and easily understandable language, consisting of content in the form of posters, animations, and videos, which enhances student interest and motivation. This aligns with previous research that indicates that media in the form of videos and animations can boost student interest and motivation (Irmawati et al., 2022; Isnaini et al., 2023; Sya'bania et al., 2020; Wirnawa & Sukma Dewi, 2022; Wiryajati et al., 2022; Yus & Saragih, 2023). The sample questions menu features example questions with detailed solution steps, facilitating users' understanding of the material. The sample questions are categorized into easy, medium, and challenging levels, allowing users to study the material progressively.

The research results show that the media content, structure, and interactive elements have been well-designed and meet educational standards. User responses reflect a high level of satisfaction, confirming the media's effectiveness in enhancing the learning experience. These findings are consistent with several previous studies that showed the effectiveness of interactive learning media based on the web. Integrating technology in the learning process, such as implementing learning using web-based interactive media, has been proven to increase students' motivation and learning outcomes (Hadidi & Setiawan, 2021; Ramadannisa & Hartina, 2021). A study showed that interactive learning media based on the web using Articulate Storyline is valid, practical, and effective in increasing middle school student's interest in mathematics (Rahmania et al., 2023). The developed interactive learning media can enhance students' conceptual understanding and engagement in physics learning (Bunga Wulandari et al., 2022; Rahman & Fuad, 2023; Santhalia & Sampebatu, 2020).

Using Google Sites as an interactive learning medium for wave function topics has elicited a positive response from users. This is shown by a user validation with the Very Valid category. This result is also supported by previous studies that have also received positive responses from users (I. Maryani et al., 2021; Pertiwi & Purnawarman, 2023; Prihatiningtyas et al., 2022; Saputri et al., 2022). This positive response is inseparable from the practicality of Google Sites as a learning media. Google Sites can combine various information in a single platform, such as video, images, text, audio, attachments, materials, and various simulations (Mas'ud & Maemunah, 2022; Mukti et al., 2020; Ramadannisa & Hartina, 2021; Septianti & Firdaus, 2024). Google Sites is very easy to integrate with various other platforms, such as Google Drive, YouTube, quizizz, Google Forms, Virtual Lab, and others. Using Google Sites as a learning media will make it easier for students to learn the material being discussed. Google Sites can improve student activity, improve

learning outcomes, improve problem-solving skills, mastery of concepts and digital literacy. However, Google Sites has limitations related to internet connection. Accessing Google Sites requires a stable internet connection, which may pose a challenge in areas with inadequate ICT infrastructure. This learning media is suitable for use in urban areas or regions with sufficient internet connectivity. Therefore, the researchers recommend further studies to develop interactive learning media that can be accessed without an internet connection, incorporating more advanced and comprehensive interactive features for the entire quantum mechanics material (Abdjul, 2023; Adzkiya & Suryaman, 2021; Devya et al., 2022; Ernest et al., 2023; Hadidi & Setiawan, 2021; Hernita et al., 2024; Kesumawati et al., 2022; Kusmaharti & Yustitia, 2022; M. Maryani et al., 2022; Nifa Nailul Rahmah, 2022; Pertiwi & Purnawarman, 2023; Ramadannisa & Hartina, 2021; Rosiyana, 2021).

Based on several studies that also underlie the findings of this research, this study makes a significant contribution to the development of learning media in the field of quantum mechanics. The Google Sites-based interactive media offers a new approach to learning, where students can engage more actively in the educational process through direct interaction with the content (A. N. Harahap et al., 2024; Permatasari et al., 2022). This aligns with the constructivist paradigm, which encourages learners to build their own knowledge, thus learning should be student-centered (Arifah & Marzuki, 2021; N. Harahap et al., 2023; Saleem et al., 2021). Consequently, this media can enhance the learning experience and improve students' understanding of complex concepts in quantum mechanics. Using Google Sites as an interactive learning media can be a solution for educators to provide cost-effective, practical, and easily accessible learning media for students anytime and anywhere (N. Harahap et al., 2023; Kamilah et al., 2023; Rosiyana, 2021; Tambunan & Siagian, 2022). The success of using the 4D model in this research shows that this model is effective for developing educational media. Positive feedback from users indicates strong potential for integrating similar media in blended learning environments, which can result in more personalized and engaging learning experiences. Future research can be conducted by exploring Google Sites in various subjects and educational levels to validate its generalization and effectiveness further. Additionally, there is a need for in-depth research on the long-term effectiveness of using this interactive learning media on student academic performance, as well as a comparative study between this Google Sites-based interactive learning media and conventional teaching methods to identify significant differences.

4. CONCLUSION

The research findings show that the Google Sites-based interactive learning media developed for the subtopic of wave functions in quantum mechanics was validated and considered appropriate by media experts, content experts, and users. Consequently, the developed interactive learning media can be utilized as an educational resource for wave function topics at the university level.

5. REFERENCES

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