



Development of Microsite-Based Learning Media on the Schrödinger Equation to Improve Students' Critical Thinking Skills

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Abstract: *Critical thinking skills are essential for students' success in modern education. This study focuses on the development of microsite-based learning media to improve students' critical thinking skills, especially in understanding the Schrödinger equation. The focus of this study is the important role of critical thinking in modern education and the problems faced by Indonesian students when they learn with a rote approach from traditional learning. The research problem shows that innovative and creative learning methods are needed to improve critical thinking skills. The solution to this problem is to create a Schrödinger equation microsite. The methodology used is Research and Development (R&D) using the 4D development model consisting of Define, Design, Develop, and Disseminate. The results show that the microsite-based learning media is valid and practical, as evidenced by expert validation and positive student comments. Overall, the microsite learning media is considered feasible and useful for students to use in class, and shows the possibility of additional improvements depending on input for wider implementation. Implementation with a group of students shows that the Schrödinger equation microsite is effective.*

Keywords: *critical thinking, learning media, microsite, quantum physics, Schrödinger equation*

Pengembangan Media Pembelajaran Berbasis *Microsite* pada Persamaan *Schrödinger* untuk meningkatkan Keterampilan Berpikir Kritis Mahasiswa

Abstrak: Keterampilan berpikir kritis sangat penting untuk keberhasilan siswa dalam dunia Pendidikan modern. Penelitian ini berkonsentrasi pada pengembangan media pembelajaran berbasis *microsite* untuk meningkatkan kemampuan siswa dalam berpikir kritis, khususnya memahami persamaan *Schrödinger*. Fokus penelitian ini adalah peran berpikir kritis yang penting dalam pendidikan modern dan masalah yang dihadapi siswa Indonesia, ketika mereka belajar dengan pendekatan hafalan dari pembelajaran tradisional. Masalah penelitian menunjukkan bahwa metode pembelajaran inovatif dan kreatif diperlukan untuk meningkatkan keterampilan berpikir kritis. Untuk solusi dari permasalahan ini yang ditawarkan adalah membuat situs mikro persamaan *Schrödinger*. Metodologi yang digunakan adalah Research and Development (R&D) dengan menggunakan model pengembangan 4D terdiri dari *define, design, develop, dan disseminate*. Hasilnya menunjukkan bahwa media pembelajaran berbasis *microsite* valid dan praktis, dibuktikan dengan validasi ahli dan komentar positif siswa. Secara keseluruhan, media pembelajaran *microsite* dianggap layak dan bermanfaat bagi siswa untuk digunakan di kelas, serta menunjukkan kemungkinan penyempurnaan tambahan yang bergantung pada masukan untuk implementasi yang lebih luas. Implementasi dengan sekelompok siswa menunjukkan bahwa *microsite* persamaan *Schrödinger* efektif

Kata kunci: berpikir kritis; persamaan Schrödinger; fisika kuantum; media pembelajaran; *microsite*.

INTRODUCTION

The development of science and technology in the 21st century has undergone significant changes. To compete and adapt quickly Modern education demands skills that require students to be able to compete and adapt quickly. The skills in question are known as 4Cs skills, namely communication, collaboration, critical thinking and creativity (Kereluik et al., 2013).

One of the 4Cs skills that is very important is critical thinking skills. Critical thinking is one of the life skills that is very much needed by students in the 21st century. Critical thinking skills are useful in academics and in everyday life, this requires someone to be able to solve every problem with an effective solution (Ismail et al., 2018; Widana, 2018). Learning physics is very good for improving critical thinking skills because the concepts are complex and interconnected. However, the facts on the ground show that Indonesian students have a low level of critical thinking. This is caused by a less effective learning process. Many students are accustomed to memorizing concepts, without really how they can be applied in real life (Respatiningrum et al., 2017). This lack of understanding results in students having difficulty applying the concepts they have learned when faced with real problems.

To improve critical thinking skills, an approach is needed that connects learning materials with everyday life problems. In this way, students can more easily understand the material and its relevance in a broader context. One way to learn is by using effective learning media. This media not only conveys information, but also helps individuals interact with each other, which supports the learning process (Gan et al., 2015; Greenhow & Lewin, 2016).

The right learning media can improve students' critical thinking skills. The stimuli activated by the media can encourage better responses, feedback, and interactions, as well as encourage positive and negative responses (Ogink & Dong, 2019; Weitzl & Hutzinger, 2017). Web-based learning media or microsities have great potential in this regard. Microsites are free platforms that allow the integration of various needs and links into one website, making it easier to access information and learning resources (Divina et al., 2023).

The use of microsities in learning can train students in independent and group learning. This can motivate students and hone their critical thinking skills, because they have to explore, analyze, and synthesize information independently (Khairani et al., 2020). Microsites also provide flexibility in teaching, allowing educators to provide interactive and engaging content.

This study focuses on the development of microsite-based learning media for Schrödinger's equation material. Schrödinger's equation is one of the important concepts in quantum physics that is often considered difficult by many students. By using microsite, it is hoped that students can more easily understand this concept through a more interactive and practical approach.

The purpose of this study is to produce a microsite-based learning media product that is feasible to be used in improving students' critical thinking skills. This study uses the Research and Development (R&D) methodology with a 4D approach, namely define, design, develop, and disseminate. These steps ensure that the learning media developed is not only valid and practical (Gunawan et al., 2022), but also effective in supporting the learning process.

Microsite-based learning media allows for more dynamic and interesting presentation of materials, including the use of multimedia elements such as video, audio, graphics, and interactive animations. These elements can help reduce boredom and increase student engagement in the learning process.

By integrating various types of media and resources in one platform, microsites provide a more comprehensive and structured learning experience. This allows students to access information more easily and learn in a more varied and enjoyable way.

In the development process, this study involved validation by media experts and material experts to ensure that the content presented in the microsite met high quality standards. Feedback from students was also collected to evaluate the effectiveness and usefulness of this learning media in the context of real learning.

Thus, this study contributes to the development of innovation in education, especially in the use of technology to improve students' critical thinking skills. The results of this study are expected to be a reference for educators and other learning media developers in creating learning solutions that are more effective and relevant to the needs of students in the 21st century.

METHOD

The research and development method or Research and Development (R&D) used in this research. According to (Sugiyono, 2013), R&D is a research method used to create a particular product and test how effective it is. In this study, the product produced is a microsite-based learning media that is expected to improve students' critical thinking. The steps used in this development research are the 4D models steps. According to Thiagarajan & Melvyn (1974), The 4D development model consists of four stages: namely (1) Define, (2) Design, Develop, and (4) Disseminate. An overview of the research flow is shown below.

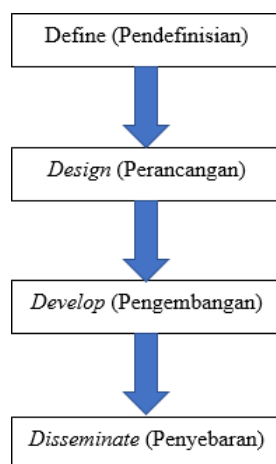


Figure 1. 4D Model Flow

At the define stage, two stages of analysis are carried out, namely the analysis of Schrödinger's equation material and the analysis of needs in the quantum physics learning process. First, the analysis of Schrödinger's equation material is carried out to see what materials are contained in the Schrödinger equation. Second, the analysis of needs is based on the results of discussions with fellow students and observations during the study of quantum physics by seeing what is needed and what kind of media is desired. The purpose of these two analyzes is to determine the content and media needed through the development of the Schrödinger equation microsite so that it is in accordance with the expected needs and can be used as independent learning.

The next stage is the design stage which begins with the creation of a storyboard based on the content and materials that have been previously determined. The next step is the preparation of the concept of learning media and the mechanism of the Schrödinger

equation microsite which will later be used, such as determining the design, animation, color, elements, types of writing, music, and other supporting applications such as canva, flipbook and others.

Next, at the develop stage, a product will be produced in the form of learning media based on the Schrödinger equation microsite. At this stage, a feasibility test will also be carried out by validating the material and media of the Schrödinger equation microsite carried out by expert validators. In addition, a practicality test was also carried out by several physics education students to see the effectiveness and efficiency and to see the suitability of the objectives, materials, and questions. After the Schrödinger equation microsite learning media developed was declared valid by experts and practical by students, revisions were made based on the suggestions of validators and students who conducted the practicality test. In the next stage, the media was tested on a limited basis to 9 students to see the increase in critical thinking on the Schrödinger equation material. The last is the disseminate stage, where the resulting media is applied to students with a large reach after research was conducted in quantum physics learning.

The data collection technique in this study used a questionnaire. The questionnaire was used to validate the Schrödinger equation microsite learning media to assess the feasibility of the media. The assessment of product feasibility is based on looking at aspects of language, media appearance, media content, and ease of use. Meanwhile, the questionnaire sheet used to assess the practicality of the Schrödinger equation microsite media is included in the student response questionnaire. The assessment of the practicality of the Schrödinger equation microsite media is based on aspects of media appearance, material presentation, practicality, and language.

Data analysis in this study was conducted in two stages. The first stage was conducted to analyze the feasibility of the product developed, namely the Schrödinger equation microsite media. The second stage was conducted to analyze the practicality of the product developed. Data obtained from validators and students have five assessment categories, namely strongly agree, agree, quite agree, disagree, and strongly disagree. To analyze the feasibility and practicality, the ideal Standard Deviation (S_{Bi}) analysis technique was used. The stages in the analysis are as follows:

- a. Change the assessment category into a score of 1 to 5.

Table 1. Assessment Scores

Category	Score
Strongly agree	5
Agree	4
Quite Agree	3
Don't agree	2
Strongly Disagree	1

(Sugiyono, 2013)

- b. Changing the average score of all aspects assessed.

$$Mean \bar{x} = \frac{\sum x}{N} \quad (1)$$

Information:

Mean \bar{x} : Average score

$\sum x$: Total score

N : Number of respondents

c. Convert the scores obtained into quantitative values.

Table 2. Average Score Conversion Formula

Value Interval	Category
$\bar{x} > (x_i + 1,80 SBi)$	Very Worth It
$(x_i + 0,60 SBi) < \bar{x} \leq (x_i + 1,80 SBi)$	Worthy
$(x_i - 0,60 SBi) < \bar{x} \leq (x_i + 0,60 SBi)$	Quite Decent
$(x_i - 1,80 SBi) < \bar{x} \leq (x_i - 0,60 SBi)$	Not feasible
$\bar{x} \leq (x_i - 1,80 SBi)$	Totally Unworthy

Source: (Widoyoko, 2009)

Information:

\bar{x} : Score obtained

\bar{x}_i : Ideal average score

x_i : $\frac{1}{2}$ (highest score + lowest score)

SBi : $\frac{1}{6}$ (highest score + lowest score)

Based on the average score conversion equation guidelines, it can be seen that the value interval for determining the category in determining the feasibility and practicality of the product being developed is as follows:

Table 3. Conversion of Average Score Sum

Value Interval	Category
$\bar{x} > 4,2$	Very good
$3,4 < \bar{x} \leq 4,2$	Good
$2,6 < \bar{x} \leq 3,4$	Pretty good
$1,8 < \bar{x} \leq 2,6$	Not good
$\bar{x} \leq 1,8$	Very Bad

After the trial was conducted, the media was then used to measure the increase in students' critical thinking on the Schrödinger equation material. The measurement of the increase in students' critical thinking was carried out using the N-gain analysis technique (Hake, 1999). The N-Gain can be calculated using the equation below and can be categorized as in Table 4.

$$N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Ideal\ Score - Pretest\ Score} \quad (2)$$

Table 4. N-Gain Score Categories

N-Gain Value	Category
$g > 0,7$	Tall
$0,3 \leq g \leq 0,7$	Currently
$0 < g < 0,3$	Low
$g \leq 0$	Fail

Source: (Sukarelawa et al., 2024)

RESULTS AND DISCUSSION

At the define stage, a series of activities were carried out to identify the needs and relevance of microsite media in learning. A literature study was conducted to find information on the use of microsites in implementing classroom learning. The results of the study showed that the use of microsites in learning is still very little and rarely applied (Adi et al., 2023). In addition, an analysis of material related to the Schrödinger equation was carried out. The results of the analysis covered various important topics such as the time-independent wave equation, the time-dependent wave equation, infinite well potential, ladder potential, and box potential. This material analysis is an important step in the define stage (Sulistyanto et al., 2022), ensuring that the content developed is in accordance with learning needs. An analysis of learning needs has also been carried out, showing that the learning media needed is one that can facilitate access to material and present material in an interesting and interactive way.

At the design stage, a storyboard was created for the Schrödinger equation microsite to facilitate design design and development. This learning media was developed using a website platform. To use the microsite, users can access the link via various devices, such as smartphones, tablets, or laptops, without limitations of space and time (De-Haan et al., 2018; Widyaningsih et al., 2025). When the link is accessed, the user will be directed to the main display consisting of 10 features containing Schrödinger equation material.

Each feature presents materials in the form of various media such as posters, mind maps, and short learning videos. Users can access the desired material by clicking on the available features, and after accessing the material, they can return to the initial display by clicking the back button. This design ensures ease of navigation and accessibility for all Schrödinger's equation materials contained in the microsite (Bradford et al., 2017).

At the development stage, the planned storyboard was realized into a Schrödinger's equation microsite display. The microsite that had been created was then validated by a validator who was a teacher with experience in the field of learning media. In addition to expert validation, the media was also tested and assessed by students who had taken quantum physics courses. A total of 6 students were involved in the assessment of this media. The results of expert validation and media assessment are shown in Table 5 and Table 6.

Table 5. Expert Validator Results

No.	Aspect	Results	Suggestion
1	Language	0,9	For the overall media it is good, but for the background and writing it is better to have a light color and the writing a dark color.
2	Media View	0,88	Overall good, just a little problem with the sound on the video. The second speaker's voice could be louder
3	Media Content	0,6	
4	Ease of Use	0,95	
	Total	0,82	

Table 5 presents the results of expert validation based on four aspects: language, media appearance, content, and ease of use. The highest score was on ease of use 0.95, followed by language 0.90 and media appearance 0.88 though suggestions were given to improve color contrast and audio quality. The lowest score was on content 0.60, indicating the need of content revision. Overall, the media received an average score of 0.82, categorized as very good, through some improvements are still needed.

After the expert validation process, the learning media was tested directly by students to determine its level of practicality (Sulistyanto et al., 2022). This practicality test aimed to assess students' responses to the media in terms of appearance, material presentation, practicality, and language use. Student feedback is essential to evaluate whether the developed media is truly effective and comfortable to use during the learning process. The results of the students practicality assessment are presented in Table 6 below.

Table 6. Results of The Student Practicality Test Assessment

No.	Aspect	Results	Suggestion
1	Display Aspect	3,58	<ul style="list-style-type: none"> • In the second learning video, the volume is slightly increased • Overall, the media can provide new knowledge about the Schrödinger equation and attractive media design
2	Material Presentation Aspects	3,69	The design is good
3	Practical Aspects	4	<ul style="list-style-type: none"> • Additional information can be prepared in the right corner for FYI • Only one media editing application is enough so that it is not difficult to open • The media is good and in the future it will be developed to be accessible without the internet so that it can be useful in areas that lack internet access
4	Language Aspects	3,64	-
	Total	3,73	

The results of the data analysis in Table 5 show that the feasibility test by media experts gave an average assessment of the Schrödinger's Equation microsite application of 0.82, which means it is included in the feasible category. The results of the data analysis in Table 6 for the practicality test carried out by students who have taken quantum physics courses show an average assessment of 3.73, which means that this media is very practical to use in learning the Schrödinger equation. Validation by media experts and practicality tests by students, along with the suggestions given, were followed up and revised on the Schrödinger Equation microsite media before being implemented on a large scale. The Schrödinger Equation microsite displays various features after the user clicks on the link <https://s.id/PersamaanSchrodinger>. On the home page, there are features that contain material presented in various forms of media such as posters, reading books, mind mapping, and learning videos. These features include an introduction to the Schrödinger equation, the conditions of the Schrödinger equation, TISE and TDSE, well potential material, ladder potential material, box potential, material summary, explanatory videos, questions, and discussion of questions. The initial appearance of the Schrödinger Equation microsite media can be seen in Figure 2.

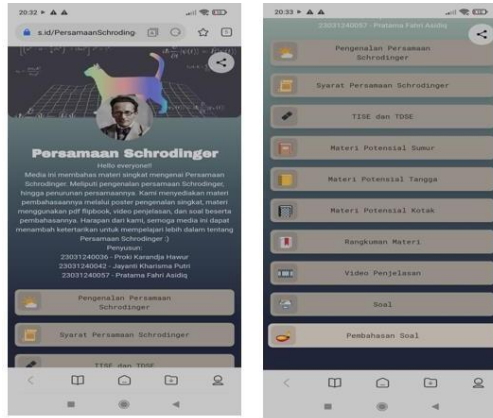


Figure 2. Initial Display on Smartphone

The first feature, an introduction to the Schrödinger equation, presents the material in an informative poster format. The second feature, the conditions for the Schrödinger equation, is also presented in an attractive poster format.

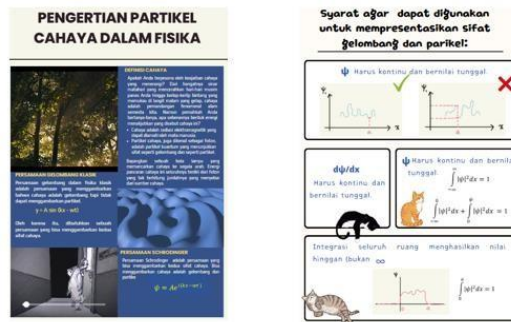


Figure 3. Display of Feature Material 1 and 2 in Poster Form

The third feature presents TISE and TDSE, where TISE is the time-independent wave equation and TDSE is the time-dependent wave equation. The materials for both equations are made in the form of posters designed with attractive visuals.

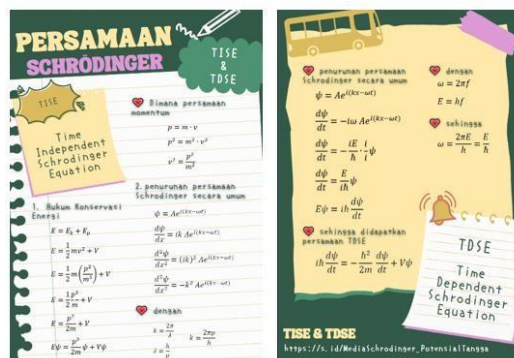


Figure 4. Display of TISE and TDSE Materials in Poster Form

The fourth to sixth features cover material on infinite well potential, ladder potential, and box potential. All materials in this feature are designed to resemble a diary with a handwritten appearance and are packaged in book form. Black pages are chosen to create a calm atmosphere with minimal distractions, thus increasing learning focus.

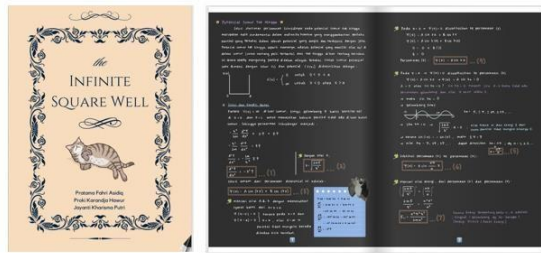


Figure 5. View of Potential Well Material

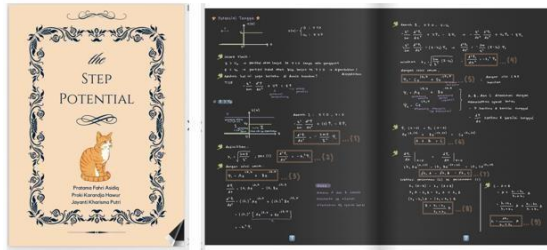


Figure 6. View of Ladder Potential Material

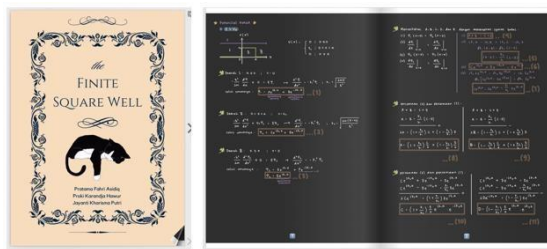


Figure 7. View of Potential Box Material

The seventh feature provides a summary of the Schrödinger equation material starting from the introduction of the properties of light to the derivation of the Schrödinger equation, summarized in the form of mind mapping to facilitate understanding.

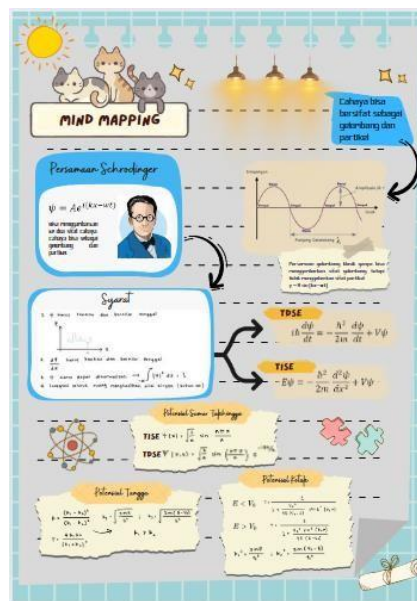


Figure 8. Summary View of Schrödinger's Equation Material

The eighth feature presents a short video that explains the Schrödinger equation material visually and interactively.



Figure 9. Video Display Explaining The Schrödinger Equation Material

The ninth feature is a video explaining the concept of the Schrödinger equation. In this feature, students are taught the introduction and conditions of the introduction and conditions of the Schrödinger equation, TISE and TDSE, and the potential well, ladder, and box materials.

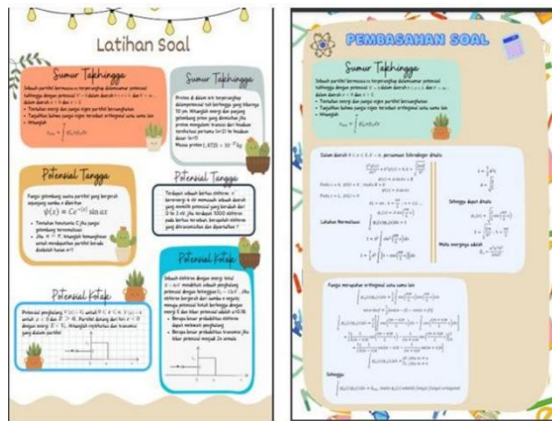


Figure 10. Display of Practice Questions and Discussion of Schrödinger's Equation Questions

The tenth feature consist of practice questions and discussions. After studying the material through the previous features, users can hone their skills by working on the practice questions provided, complete with answers and discussions to strengthen understanding in quantum physics.

Table 7. Summary of Pretest and Posttest Data on Students' Critical Thinking Skills

Test Average		Max Score	Improvement	n-Gain	Criteria
Pretest	Posttest				
44,44	83,33	100	38,89%	58,92	Sedang

Table 7 shows the results of the pretest and posttest measurements of students' critical thinking skills for the Schrödinger equation material. The average pretest result was 44.44 with the lowest score of 20 and the highest score of 70. After learning using microsite media, the posttest score showed a significant increase with an average of 83.33, the lowest score of 70, and the highest score of 100. Analysis using the N-Gain equation produced an average score of 58.92, which is included in the "Moderate" category.

Based on the research results, the trial of microsite-based learning media on the Schrödinger equation material shows that this media is effective for implementation in quantum physics learning in the classroom. (Tafonao, 2018) states that the benefits and advantages of a learning media in delivering material can stimulate the thoughts, attention, and interest of students. This is in line with the findings (Gan et al., 2015) dan (Wulandari et al., 2022) which states that learning media can improve students' critical thinking skills, which are very important in achieving 21st century learning goals. The use of media in physics learning can stimulate students to exchange ideas and express opinions, thereby improving their critical thinking skills. (Khairani et al., 2020; Wale & Bishaw, 2020) also stated that website-based learning media can train students to learn independently or in groups, which can motivate and hone students' thinking skills.

At the dissemination stage, microsite-based learning media for Schrödinger's equation material can be used both in quantum physics learning in class and for independent learning. This implementation is expected to significantly improve students' understanding and critical thinking skills.

CONCLUSION

This study successfully developed a microsite-based learning media for the Schrödinger equation material with the aim of improving students' critical thinking skills. The use of the Research and Development (R&D) method with the 4D approach (define, design, develop, disseminate) has produced valid and practical media based on expert validation and student trials.

The results of data analysis showed a significant increase in students' critical thinking skills after using this learning media. The average pretest score increased from 44.44 to 83.33 in the posttest, with an average N-Gain score of 58.92, which is in the moderate category. This shows that the use of microsites as a learning medium is effective in improving concept mastery and critical thinking skills.

This study also confirms previous findings regarding the benefits of interactive and interesting learning media in facilitating the learning process. Microsite-based learning media not only facilitates access to materials and increases interest in learning, but also encourages interaction and collaboration among students, in accordance with the goals of 21st-century education. Thus, microsite-based learning media for Schrödinger's equation material is feasible to be implemented in quantum physics learning, both in the classroom and for independent learning. This implementation is expected to improve the quality of learning and critical thinking skills of students, as well as provide a positive contribution to educational innovation.

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