Jurnal Ilmiah Pendidikan Fisika
https://ppjp.ulm.ac.id/journals/index.php/jipf/index
e-ISSN: 2549-9963 p-ISSN: 2549-9955
Vol 9 No 1 2025
DOI: https://doi.org/10.20527/jipf.v9i1.14717

Development of Integrated Physics Teaching Materials Virtual Laboratory PhET Simulation on Student's Critical Thinking Skills

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Article Info

Article history:
Received: January 28, 2025
Accepted: March 4, 2025
Published: March 13, 2025

Keywords:
Critical thinking skills
4D instructional model
Integrated learning virtual Laboratory PhET simulation

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Abstract

The world of education plays an important role in improving the quality of human resources through quality learning activities, namely through the development of adequate teaching materials to provide clear direction related to the competencies to be achieved. This research is development research that aims to produce integrated physics teaching materials, such as Virtual Laboratory PhET Simulation, that are valid, practical, and able to improve students' critical thinking skills. The development model for integrated physics teaching materials, the Virtual Laboratory PhET Simulation, is a 4D learning model (Define, Design, Develop, and Disseminate). Based on the results of data analysis, the following conclusions were obtained: 1) integrated physics teaching materials Virtual Laboratory PhET Simulation are declared valid and suitable for use with an expert agreement index value of 0.72 for the aspect of content suitability, 0.67 for the aspect of the presentation, 0.73 for the aspect of language, and 0.68 for the aspect of graphics; 2) integrated physics teaching materials Virtual Laboratory PhET Simulation reviewed from the response of practitioners, namely physics subject teachers, are in the very good category; 3) The effectiveness of the integrated physics teaching material PhET Virtual Laboratory Simulation reviewed from students' critical thinking skills obtained an average N-Gain value of 0.44 and is in the moderate category. Students experience increased critical thinking skills in interpretation, analysis, inference, evaluation, and explanation. It can be interpreted that the integrated physics teaching materials that the Virtual Laboratory PhET Simulation developed effectively improve students' critical thinking skills.

To cite this article: Herlina, H., Arsyad, M., & Palloan, P. (2025). Development of integrated physics teaching materials virtual laboratory phet simulation on student's critical thinking skills. *Jurnal Ilmiah Pendidikan Fisika, 9*(1), 91-112.

INTRODUCTION

The world of education plays an important role in improving quality human resources. Improving the quality of human resources can be done through quality learning activities. One learning support that needs to be developed to complement existing facilities/infrastructure is the availability of adequate teaching materials. With adequate teaching materials, students can learn and discuss teaching materials before learning begins. In addition, teaching materials are also able to provide clear guidance regarding the competencies to be achieved (Hakim, 2015; Kivunja, 2015; Satriawan & Rosmiati, 2016). In order to prepare quality and highly competitive Human Resources (HR), the world of education is required to improve the quality of education in Indonesia. Currently, it has received considerable attention. This can be seen in the improvement in educational

facilities and infrastructure, the professionalism of educators, and the improvement in the quality of students (Ariyanti et al., 2020).

In line with the opinion of Asrizal et al., (2018), teaching materials are one of the means used in learning activities to help to facilitate learning activities for teachers and students. The role of teaching materials in learning activities is very important. Teaching materials are the most important learning resources in supporting the learning process, and they can help students become more active and independent (Asrizal, 2017). Teaching materials play an important role in the implementation of learning activities. Its role is to help implement effective learning activities and serve as a learning evaluation tool (Misbah et al., 2021; Nadia et al., 2021; Putri & Yohandri, 2021).

Achievement of competency in learning is influenced by the rapid development of information technology this century. This has significantly impacted the world of education, as seen from the emergence of the 21st-century education era. The characteristics of the 21st century are learning models that include aspects of information, computing, automation, and communication. The four components conveyed by the Ministry of Education and Culture are characteristics of 21st-century education that cause a paradigm shift in learning. Information literacy transfer, computer skills, utilization of information and communication technology in the communication process, and communication skills must be mastered. In relation to 21st-century skills, various organizations have tried to formulate various competencies and skills needed to face the 21st-century (Zubaidah, 2016). The 21st-century skills summarized in the seven skills must be mastered and possessed by every student to face the challenges of the 21st century, one part of which is critical thinking, which has become a necessity for every student or young person today. Critical thinking skills affect a person's ability to solve everyday life problems. Therefore, critical thinking skills can develop the ability to investigate problems, ask questions, propose new answers that challenge the status quo, and find new information (Simanjuntak, 2019).

Critical thinking skills are the key to solving a problem in education (Misbah et al., 2022; Sujanem et al., 2022; Yani et al., 2021). Meanwhile, critical thinking skills have become part of thinking skills with life skills that need to be developed through education. Thinking skills are related to what will be done. Learning experiences are in the form of provisions for using scientific methods in obtaining new knowledge or developing existing knowledge through practical activities because, through practical activities, students will be involved in using tools and materials, measurements, and preparation or assembly of tools. This is illustrated in activities in the laboratory (Rabiah & Jasruddin, 2018).

Handling this problem can be done through a virtual laboratory. Virtual laboratories are designed to allow students to conduct experiments by interacting with real devices, real instruments, and visualization mechanisms through the right simulation platform, namely PhET (Physics Education and Technology). As an initial step, it is necessary to develop interactive multimedia-based learning teaching materials immediately. So, appropriate and good interactive multimedia learning media can be created to create interactive, inspiring, fun, creative, challenging, and motivating learning for students (Utomo et al., 2016).

PhET simulation media is one of the tools educators use in the learning process, and it has certain advantages when applied. These advantages include presenting information about fairly complex physics processes or concepts; being independent because it provides convenience and completeness of content so that users can use it without guidance from others; attracting students' attention so that it can increase learning motivation in the classroom; and being used offline, both in class and outside the home. The disadvantages of PhET simulation media include the success of a learning process depending on the independence of students; the applications run are very limited to files with the "jar" format;

and depending on the number of computer facilities provided by the school (Budi et al., 2021; Khoiriyah et al., 2015).

The learning process in schools often encounters obstacles. Students tend to be passive in learning. There is almost no interaction between teachers and students. This situation makes students feel bored with the learning process, which is dominated by teachers. Students are less able to receive or understand learning materials. As a first step, it is necessary to immediately develop interactive multimedia learning-based teaching materials to create appropriate and good interactive multimedia learning media to create interactive, inspiring, fun, creative, challenging, and motivating learning for students (Utomo et al., 2016).

In addition, every teacher in any subject certainly will not be able to teach directly just like that. All teachers must have or prepare their teaching materials and learning media to assist in teaching and learning. Teachers consciously plan teaching activities systematically by utilizing everything for teaching purposes. One of the important problems teachers often face in learning activities is choosing or determining the right teaching materials or learning materials to help students achieve competence (Magdalena et al., 2020).

Therefore, to help overcome the shortcomings of the PhET simulation platform and school constraints, the computer software teachers can use to create integrated physics teaching materials is the Virtual Laboratory PhET Simulation, one of which is iSpring Suite. Without learning media, students will have difficulty paying attention to the material and being directly involved in learning (Djamas et al., 2018). The use of learning media can improve the quality of education and increase the level of student understanding of the material being taught. Without the help of learning media, the learning process cannot be carried out optimally. However, using learning media can create a new learning atmosphere to make students happy during the learning process (Gunawardhana & Palaniappan, 2016).

Learning media is a channel of information or learning messages from the communicator (teacher) to the communicator (student) (Mahadi, 2021). Learning media is able to provide a stimulus for learning and activate students effectively. In addition, learning media is used to create an effective and efficient teaching and learning process. Learning media comes in many forms. The rapid advancement of technology has a positive impact on the development of learning media by utilizing current technology. Using technology in learning can overcome the limitations of space and time so that learning messages or information can be learned at any time (Afidah & Wulandari, 2021). One of the uses of technology that can be applied as a learning aid is iSpring Suite (Agustomi et al., 2022).

iSpring Suite is high-quality software, among other devices often used in education. The presentation is in the form of material presentation through PowerPoint slides by inserting additional explanatory videos or animations, self-competency tests for students through quizzes, and virtual laboratory practices through the Virtual Laboratory PhET Simulation, which can be used in HTML format for the benefit of the Android system (cellphone) of students (Juraev, 2019). This study uses the iSpring Suite application type iSpring Free 11 because of its easy access. The quality of the integrated physics teaching materials Virtual Laboratory PhET Simulation developed by researchers through the assistance of the iSpring Suite application type iSpring Free 11 must meet the validity, practicality, and effectiveness level in improving critical thinking skills. Validity is a condition where an instrument can measure a condition that must be measured accurately (Rahayu & Festiyed, 2018). In this regard, it is in line with the research conducted by Wicaksono (2016) measuring the level of validity, practicality, and effectiveness of the PhET learning device. The results of the validity of the learning device are categorized as good (Wicaksono, 2016).

Another related study by Noviana (2022) conducted in class XI MIPA Makassar Raya with 20 students as research subjects. The results of the study indicate that virtual laboratory-based learning media are declared valid (V value> 0.4 based on the Aiken's V expert analysis test), practical (through the results of teacher and student responses, which are in the very good category or the responses given are positive), and effective (the percentage of results of practical activities and physics learning test results 60% are above the KKM value) (Noviana, 2022). In addition, there is also a by Larasati et al. (2022) conducted in class X TITL 1 at SMKN 3 Surabaya with 38 students as research subjects. The study results showed that the media received 82.29%, valid or good. Meanwhile, the results of the student responses obtained were 83.40%, meaning that using Android-based media helps students understand the material independently (Larasati et al., 2022).

Based on the series of problem identifications from the previous explanation and the results of previous studies presented by the researcher above, the researcher is interested in developing innovations at SMAN 5 Jeneponto for class XI MIPA 5. The development is in the form of physics teaching materials, specifically integrated mechanics material Virtual Laboratory PhET Simulation assisted by iSpring Suite type iSpring Free 11 by conducting Research and Development (R&D).

METHOD

This research is research and development (R&D). The development model uses the 4D instructional development model (Four-D Model), which is carried out by developing and producing products in the form of integrated physics teaching materials in the Virtual Laboratory PhET Simulation. Thiagarajan, Semmel, and Sennek developed the 4D model, which consists of four stages: define, design, develop, and disseminate. Therefore, researchers use the 4D model because it is a procedural, descriptive model, showing clear and careful steps to produce physics teaching material products (Thiagarajan et al., 1974).

The trial of integrating physics teaching materials with a virtual laboratory PhET simulation was conducted at SMAN 5 Jeneponto. The research implementation time is the Even Semester of the 2023/2024 Academic Year. The trial design used in developing integrated physics teaching materials, such as the Virtual Laboratory PhET Simulation, to improve students' critical thinking skills is a one-group pretest-posttest design. In this study, the trial was conducted to determine the improvement of students' critical thinking skills by providing a critical thinking skills test before and after implementing integrated physics teaching materials Virtual Laboratory PhET Simulation.

The research subjects in the trial of integrated physics teaching materials Virtual Laboratory PhET Simulation in the form of assessments carried out by: 1). Lecturers of the Postgraduate Program in Physics Education, Makassar State University to meet the validity of integrated physics teaching materials Virtual Laboratory PhET Simulation; 2). High School Physics Teachers in Jeneponto Regency need to meet the practicality of integrated physics teaching materials in the Virtual Laboratory (PhET Simulation; 3). Students of Class XI MIPA 5 SMAN 5 Jeneponto in the 2023/2024 Academic Year to meet the effectiveness of the design of integrated physics teaching materials Virtual Laboratory PhET Simulation in improving students' critical thinking skills as seen from the test results. The development stages of the integrated physics teaching materials Virtual Laboratory PhET Simulation are carried out through four stages, namely the definition, design, development, and dissemination stages. This research procedure was carried out in several stages of development using the 4D model (Sugiyono, 2019), as in Figure 1.

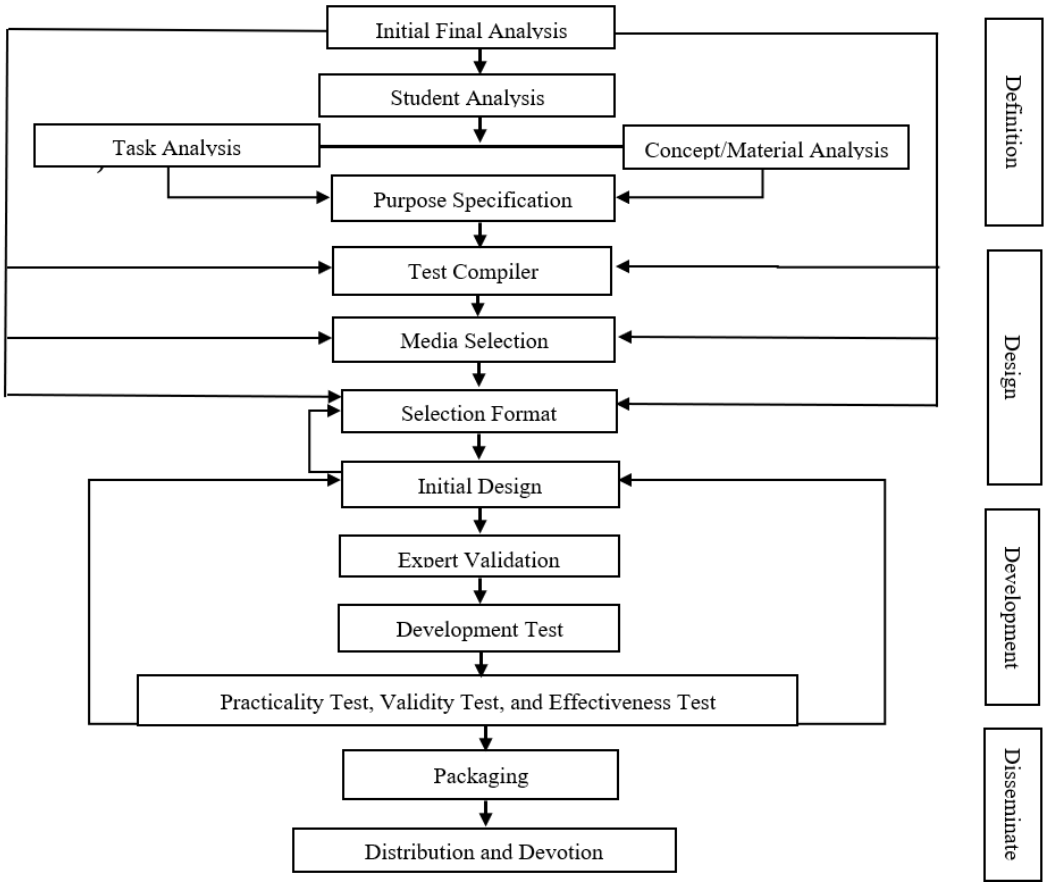

Figure 1. 4D Model Development Procedure

At the definition stage, the researcher conducted a front-end analysis to identify basic problems faced in learning and problems understanding physics material at SMAN 5 Jeneponto. This stage brings up facts and alternative solutions in understanding physics material, making it easier to determine the initial steps in developing physics teaching materials. This stage is very important in determining the next stages of research because all needs related to physics learning can be known through actual conditions (facts) and then compared with the expected conditions until an alternative solution is finally sought. Then, at this stage, student analysis is also carried out to analyze the needs related to physics teaching materials and practicums that cannot be implemented in real laboratories. The results of this analysis are used to design and develop physics teaching materials to improve students' critical thinking skills. To determine the level of students' critical thinking skills, a pretest was conducted on the scope of mechanics material for classes X E, XI MIPA, and XII MIPA. The scope of mechanics material is the scope of physics material developed in physics teaching materials. Student pretest data was analyzed as an initial reference before developing physics teaching materials. Analysis of learning experiences, learning styles, and needs related to physics material was obtained through a questionnaire test for students at the beginning of the meeting. Then, student needs analysis was carried out using a learning style questionnaire test to understand student characteristics in learning better. The analysis was carried out by analyzing student learning styles, including visual, auditory, and kinesthetic.

Next, task analysis, concept/material analysis, and learning objective specifications are carried out. Task analysis aims to analyze the main tasks that must be mastered by students in order to achieve minimum learning outcomes consisting of analysis of learning outcomes and learning objective flow related to the material to be developed, namely the mechanics material contained in phase F of class XI MIPA Merdeka Curriculum. Concept/material analysis contains a mechanics flow diagram. The learning objective specifications contain the scope of mechanics material, which is difficult to achieve because it requires virtual practicums in vectors and parabolic motion.

After determining the problems from the analysis stage, the next step is the design stage of the physics teaching materials. At this stage, the researcher compiles the media format in physics teaching materials, physics teaching material design, and physics teaching material assessment instruments integrated with the Virtual Laboratory PhET Simulation, which experts validate. The physics teaching material design stage consists of compiling materials, selecting media in physics teaching materials, selecting formats, and initial design of physics teaching materials.

The development stage is carried out by collecting the design of the content of physics teaching materials, selecting materials, and making physics teaching materials that are arranged based on Virtual Laboratory PhET Simulation learning by taking mechanics material (vectors and parabolic motion). Then, experts validate the Virtual Laboratory PhET Simulation physics teaching materials to be tested. This development stage aims to produce revised integrated Virtual Laboratory PhET Simulation physics teaching materials. The development stage consists of expert validation and product testing.

At this stage, the distribution of integrated physics teaching materials, Virtual Laboratory PhET Simulation, and limited trials of products that have been developed are carried out. This stage involves students and teachers analyzing responses to physics teaching materials to see product development quality before finally being applied and utilized widely. The instruments used to collect research data in this development research are an expert validation sheet, a practitioner assessment questionnaire sheet, and a critical thinking skills test. The expert validation sheet consists of a virtual laboratory PhET simulation integrated physics teaching material validation sheet, a practitioner assessment questionnaire validation sheet, and a critical thinking skills test validation sheet.

The data collection stage is the part that is carried out after the research planning stage is carried out. This stage contains the process of collecting data to support the research, namely data collection techniques through expert assessment, practitioner assessment, and critical thinking skills tests. Data collection techniques through expert assessment, namely by providing validation sheets and integrated physics teaching materials Virtual Laboratory PhET Simulation to three experts who are Postgraduate Lecturers in Physics Education at Makassar State University. Data collection techniques through practitioner assessment, namely by distributing integrated physics teaching materials Virtual Laboratory PhET Simulation and practitioner assessment questionnaire sheets to physics subject teachers at the high school/vocational high school level in Jeneponto Regency, totaling 21 people in each school. Data collection techniques through critical thinking skills tests of class XI MIPA 5 students of SMAN 5 Jeneponto were obtained by collecting 30 class XI MIPA 5 students of SMAN 5 Jeneponto in the same class. Then, the test will be given twice: pretest and post-test. Each test consists of 10 of the same questions. The critical thinking skills test instrument was used to measure the effectiveness of the integrated physics teaching materials of Virtual Laboratory PhET Simulation on improving students' critical thinking skills after using the integrated physics teaching materials of Virtual Laboratory PhET Simulation that had been developed. The data obtained were then analyzed to determine the validity, practicality, and effectiveness of the integrated physics teaching materials

PhET Virtual Laboratory Simulation developed. Data analysis techniques include expert validation data analysis, practitioner assessment questionnaire data analysis, and critical thinking skills data analysis.

The criteria for deciding whether physics teaching materials and research instruments have an adequate degree of validity is that the average validity value for all aspects is at least in the valid category. If not, then a revision process is needed based on expert advice or reviewing aspects considered lacking. The analysis was used to determine the level of relevance of the validation data of physics teaching materials by three experts, practitioner assessment questionnaire sheets, and critical thinking skills tests using the content validity coefficient equation (Aiken's V). The Aiken's V formula is used to calculate the content validity coefficient based on each expert's assessment of an item in the research instrument.

$$V = \frac{\sum s}{n\,(c-1)} \quad \ldots (1)$$

V = Expert agreement index regarding item validation
s = Difference in score set by each expert with the lowest score in the category used (s = r - Io)
r = Rater's set score
Io = Lowest assessment number
n = Number of experts
c = Highest validity assessment number
Aiken test requirement: After calculation, if V ≥ 0.4, then the expert agreement index is said to be valid (Azwar, 2012).

Analysis of practitioner responses to the integrated physics teaching materials Virtual Laboratory PhET Simulation was conducted after learning the integrated physics teaching materials Virtual Laboratory PhET Simulation that had been developed so that all data related to the practitioner assessment questionnaire had been fully collected and then analyzed. The practitioner response questionnaire was conducted by giving scores based on the provisions of Table 1.

Table 1 Practitioner response coding category

Category	The score for Each Positive Statement	The score for Each Negative Statement
Very Relevant	4	1
Relevant	3	2
Not Relevant	2	3
Very Irrelevant	1	4

(Sugiyono, 2019)

The analysis steps are as follows: a) Calculating the ideal score (maximum score) for each item/question; b) Calculating the total score obtained for each item; and c) Calculating the percentage of total score obtained per item. Practitioner assessment analysis is managed using the formula:

$$PRS = \frac{\sum A}{\sum B} \times 100\% \quad \ldots (2)$$

Description:
PRS = Percentage of the number of practitioners who responded to the category stated in the instrument
ΣA = Total score obtained by each category stated in the instrument
ΣB = Maximum score (ideal score) of each category that responded to the instrument (Trianto, 2011).

Criteria for the percentage of the assessment score of the assessed practitioners are presented in Table 2.

Table 2 Criteria percentage of practitioner assessment score

Percentage (%)	Classification
81 - 100	Very Good
61 - 80	Good
41 - 60	Moderate
21 - 40	Poor
0 - 20	Very Poor

(Riduwan, 2011)

The effectiveness of the integrated physics teaching materials Virtual Laboratory PhET Simulation can be seen through the improvement of critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto. The improvement of students' critical thinking skills was obtained from the critical thinking skills test before (pretest) and after (post-test) the application of integrated physics teaching materials Virtual Laboratory PhET Simulation using multiple choice questions (Riduwan, 2011).

The following are the criteria for students' critical thinking skills scores presented in Table 3.

Table 3 Criteria for students' critical thinking skills scores

Range	Category
$8 <$ test score ≤ 10	Very Good
$6 <$ test score ≤ 8	Good
$4 <$ test score ≤ 6	Moderate
$2 <$ test score ≤ 4	Poor
test score ≤ 2	Very Poor

Analysis of the increase in students' critical thinking skills using N-Gain (Normalized Gain). The N-Gain formula is used to measure the increase in critical thinking skills of students before and after learning using the integrated physics teaching materials of the Virtual Laboratory PhET Simulation that were developed. The interpretation of the N-Gain group can be seen in Table 4 below.

Table 4 Interpretation of N-Gain Values

Normalized Gain Value	Interpretation
$0.70 < g \leq 1.00$	High
$0.30 < g \leq 0.70$	Medium
$0.00 < g \leq 0.30$	Low
$g = 0.00$	No Increase
$-1.00 \leq g < 0.00$	Decrease

(Sundayana, 2014)

The creation of physics teaching materials is said to be effective if the purpose of creating them can be achieved through their use (Nieveen, 1999). The interpretation of the categorization of the effectiveness of the gain score in the form of (%) is as in Table 5.

Table 5 Interpretation category of N-Gain effectiveness

Percentage	Category
>76.00%	Very Effective
56% – 75%	Effective
40% – 55%	Quite Effective
< 40%	Ineffective

Source: (Riffalah et al., 2022)

Based on the interpretation categorization above, physics teaching materials with an average gain score percentage range of 40% to 100% are declared suitable for use with varying levels of effectiveness.

RESULTS AND DISCUSSION

The research procedure for developing integrated physics teaching materials Virtual Laboratory PhET Simulation refers to the 4D instructional design model. The study's results, in the form of the feasibility of physics teaching materials, practitioner assessments, and improvements in students' critical thinking skills, were measured at the development and implementation stages. At the development stage, the integrated physics teaching materials Virtual Laboratory PhET Simulation were validated by three experts to determine the feasibility of the physics teaching materials. While at the implementation stage, the physics teaching materials that had reached expert agreement were used to obtain research results in the form of practitioner assessments and analysis of improvements in students' critical thinking skills.

Results of Validity Analysis of Integrated Physics Teaching Materials Virtual Laboratory PhET Simulation

The result of the development of this research is the integrated physics teaching material Virtual Laboratory PhET Simulation for class XI MIPA 5 SMA/MA level on the material Mechanics (Vectors and Parabolic Motion). Before obtaining the final product of this research, the first design of the integrated physics teaching material Virtual Laboratory PhET Simulation (prototype I) was validated by three experts to determine the feasibility of the physics teaching material before the trial. The results of the validation of the integrated physics teaching material Virtual Laboratory PhET Simulation, as well as the practitioner assessment instrument and the critical thinking skills test of students, are explained as follows.

Validity Results of Integrated Physics Teaching Materials Virtual Laboratory PhET Simulation

The three experts assessed the content validation aspects of content feasibility, presentation, language, and graphics. Table 6 presents the score obtained from the expert agreement index's content validity coefficient analysis test with Aiken's V index analysis.

Table 6 Analysis of expert agreement index regarding validation of integrated physics teaching material items virtual laboratory PhET simulation

Aspect	V	Category
Content Feasibility	0.72	Valid
Presentation	0.67	Valid
Language	0.73	Valid
Graphics	0.68	Valid

The results of the expert agreement index analysis on the validation of the integrated physics teaching material items of Virtual Laboratory PhET Simulation in Table 6 are in the valid and feasible category with the respective expert agreement index scores, namely 0.72 for the aspect of content feasibility, 0.67 for the element of presentation, 0.73 for the element of language, and 0.68 for the aspect of graphics. The percentage of the feasibility of the integrated physics teaching material Virtual Laboratory PhET Simulation that has been validated is presented in Table 7.

Table 7 Percentage of eligibility of integrated physics teaching materials virtual laboratory PhET simulation

Aspect	V	Percentage
Content Feasibility	0.72	72.00%
Presentation	0.67	67.00%
Language	0.73	73.00%
Graphics	0.68	68.00%

Based on Table 7, the three experts agreed that 72.00% of the content feasibility aspect, 67.00% of the presentation aspect, 73.00% of the language aspect, and 68% of the graphic aspect of the integrated physics teaching material Virtual Laboratory PhET Simulation are suitable for use with minor revisions. The revision of the integrated physics teaching material Virtual Laboratory PhET Simulation was obtained from corrections and suggestions from the three experts, so the integrated physics teaching material Virtual Laboratory PhET Simulation was declared suitable for use at the implementation stage.

Results of the Validity of the Content of the Practitioner Assessment Questionnaire on the Integrated Physics Teaching Materials Virtual Laboratory PhET Simulation

The results of the validity analysis of the content of the statement items for each aspect of the practitioner assessment questionnaire instrument are presented in Table 8.

Table 8 Analysis of expert agreement index regarding the validity of practitioner assessment questionnaire items

Aspect	V	Category
Content Feasibility	0.67	Valid
Presentation	0.70	Valid
Language	0.67	Valid
Graphics	0.67	Valid

The results of the validation analysis of the statement items on the four aspects of practitioner assessment, based on Table 8, show that the elements of the feasibility of the content, language, and graphics of the practitioner assessment statement items are declared valid with an expert agreement index score of 0.67. Meanwhile, the presentation aspect is declared valid with an expert agreement index score of 0.70. The percentage of the feasibility of the practitioner assessment questionnaire instrument for each element can be seen in Table 9.

Table 9 Percentage of the eligibility of the practitioner assessment questionnaire for integrated physics teaching materials virtual laboratory PhET simulation

Aspect	Total Score Obtained	Percentage
Content Feasibility	0.67	67.00%
Presentation	0.70	70.00%
Language	0.67	67.00%
Graphics	0.67	67.00%

The percentage of the suitability of the practitioner assessment questionnaire that experts in Table 9 have validated shows that 67.00% of the statement items on content, language, and graphic suitability are suitable. Meanwhile, 0.70 of the statement items on the graphic aspect of the practitioner assessment questionnaire are suitable for use. Based on the expert agreement index analysis results on the validation of the practitioner assessment questionnaire items, it can be seen that the practitioner assessment

questionnaire instrument for the integrated physics teaching material Virtual Laboratory PhET Simulation is feasible to use with minor revisions. The revision of the practitioner assessment questionnaire was obtained from the corrections and suggestions of experts when conducting validation. After revisions were made based on the corrections and suggestions of the three experts, the practitioner assessment questionnaire for the integrated physics teaching material Virtual Laboratory PhET Simulation was declared feasible to use at the implementation stage.

Results of the Validity of the Content of the Critical Thinking Skills Test

Three experts validated the critical thinking skills test instrument to determine the feasibility of each test item. The test instrument that was declared feasible was then used to measure the improvement of critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto. The number of questions validated by the three experts was 10 multiple-choice questions on mechanics material, namely vectors and parabolic motion. The validation scores of the three experts were then analyzed using Aiken's V index equation. Based on the results of the analysis, Aiken's V index of the critical thinking skills test items was 0.60 and was in the valid category.

Results of Practitioner Assessment of Integrated Physics Teaching Materials Virtual Laboratory PhET Simulation

The practitioner assessment instrument aims to analyze physics teachers' responses to the developed physics teaching materials and is related to the usefulness and suitability of practitioner needs in physics learning. The criteria for physics teachers as practitioners in this study are high school/vocational high school physics teachers in Jeneponto Regency, totaling 21 people. The results of the practitioner assessment analysis of the integrated physics teaching materials Virtual Laboratory PhET Simulation can be seen in Table 10.

Table 10 Percentage of practitioner assessment scores for integrated physics teaching materials virtual laboratory PhET simulation

No.	Percentage of Practitioner Assessment Scores for Each Aspect			
	Content Eligibility(%)	Presentation (%)	Language (%)	Graphics (%)
1.	97.62	95.24	98.81	91.67
2.	96.43	94.05	90.48	92.86
3.	96.43	97.62	97.62	85.71
4.	70.24	96.43	75.00	85.71
5.	97.62	75.00	70.24	70.24
6.	98.81	70.24	98.81	75.00
7.	71.43	96.43	75.00	86.90
8.	97.62	75.00	96.43	91.67
9.	98.81	97.62	97.62	85.71
10.	71.43	71.43	71.43	70.24
Average	**89.64%**	**86.90%**	**87.02%**	**83.57%**
Assessment criteria	**Very Good**	**Very Good**	**Very Good**	**Very Good**

Based on the analysis of practitioner assessments in Table 10, practitioners gave very good assessments for the four aspects of the assessment of the integrated physics teaching materials of the Virtual Laboratory PhET Simulation that was developed. Regarding content feasibility, practitioners gave a very good response, with a percentage of 89.64%.

Regarding the presentation of physics teaching materials, practitioners gave a very good assessment with a percentage of 86.90%. The language aspect received a very good response, with a percentage of 87.02%, and the graphic aspect received a percentage of 83.57%.

In Table 10, practitioners gave a very good assessment for all aspects, with the highest percentage being content feasibility, 89.64%, while the lowest percentage was in the graphic aspect, 83.57%. Based on this analysis, it can be stated that practitioners gave a very good assessment or a positive response to the integrated physics teaching materials of the Virtual Laboratory PhET Simulation that was developed.

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Critical Thinking Skills Test Results

The critical thinking skills test instrument aims to measure the effectiveness of the integrated physics teaching materials. The Virtual Laboratory PhET Simulation was developed by improving the critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto. The application of the integrated physics teaching materials Virtual Laboratory PhET Simulation was carried out for eight meetings, which began with the implementation of a pretest of critical thinking skills, and at the last meeting, a post-test of critical thinking skills was carried out. The trial materials of the physics teaching materials were vector materials and class parabolic motion. The results of the descriptive statistical analysis of the critical thinking skills test are presented in Table 11.

Table 11 Descriptive statistics of students' critical thinking skills scores

Parameter	Pretest	Post-test
Number of Respondents	30	30
Maximum Ideal Score	10	10
Minimum Ideal Score	0	0
Maximum Empirical Score	9	9
Minimum Empirical Score	2	4
Average Score	4.23	7.10
Number of Classes	5	5
Class Interval	2	2
Standard Ideal Standard Deviation	1.67	1.67

Table 11 shows an increase in the average score of students' critical thinking skills before and after applying the integrated physics teaching materials in the Virtual Laboratory PhET Simulation. The average pretest score of students was 4.23, with a maximum empirical score of 30 students of 9 and a minimum empirical score of 2. The average score obtained by students in the post-test was 7.10, with a maximum empirical score of 9 and a minimum empirical score of 4. The results of the analysis of the critical thinking skills test of class XI MIPA 5 students of SMAN 5 Jeneponto. Before applying the integrated physics teaching materials Virtual Laboratory PhET Simulation are completely shown in Table 12.

Table 12 Percentage of critical thinking skills pretest scores of students

Interval Criteria	Category	Frequency	Percentage Score (%)
8 < test score ≤ 10	Very Good	1	3.33%
6 < test score ≤ 8	Good	5	16.67%
4 < test score ≤ 6	Average	5	16.67%
2 < test score ≤ 4	Poor	11	36.67%
test score ≤ 2	Very Poor	8	26.66%
Total		**30**	**100.00%**

The analysis of the pretest scores of critical thinking skills displayed in the frequency distribution table above explains that one student obtained a very good category test result with a percentage of 3.33% and a score of 9 during the pretest. In addition, five students obtained good category test results with a percentage of 16.67%. They obtained a score of 8, 5 students obtained moderate category test results with a percentage of 16.67% and obtained a score of 5 or 6, and 11 students obtained less category test results with a percentage of 36.67% and obtained a score of 3 or 4. Meanwhile, students who obtained a very poor category score amounted to 8 people with a percentage of 26.66% and a score of 2. The percentage analysis of students' critical thinking skills after applying the integrated physics teaching material Virtual Laboratory PhET Simulation is shown in Figure 1.

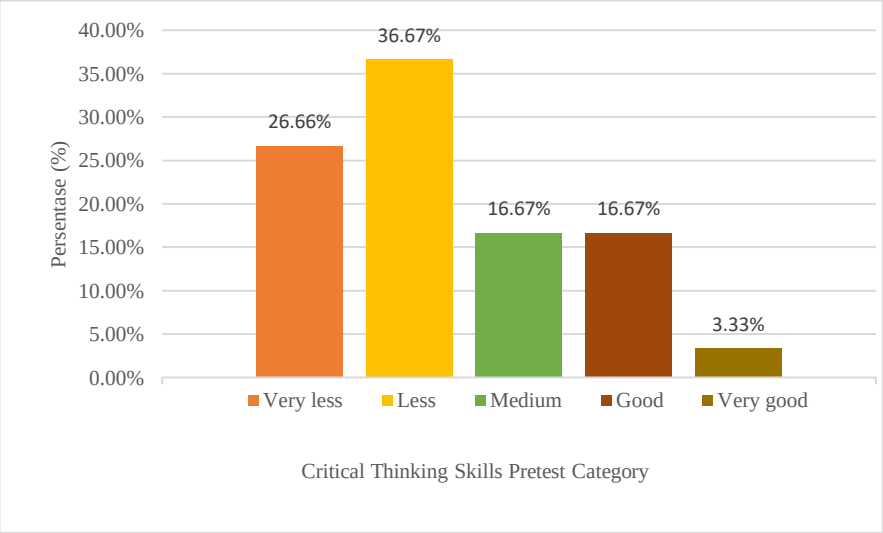

Figure 2 Percentage of students' critical thinking skills pretest

The percentage of students' critical thinking skills test results before implementing integrated physics teaching materials Virtual Laboratory PhET Simulation illustrates that students' critical thinking skills are still classified as moderate. This is evidenced by 11 out of 30 test subjects, or 36.67% of students who obtained test results in the poor category. Participants could only answer 3 to 4 questions correctly out of 10. However, one student, or 3.33% of test subjects, obtained a very good category score, which means they could answer nine questions correctly out of 10.

After implementing the integrated physics teaching materials, the Virtual Laboratory PhET Simulation was used for eight meetings, and critical thinking skills were further measured on the same subjects. The results of the critical thinking skills test analysis after implementing the integrated physics teaching materials Virtual Laboratory PhET Simulation are shown in Table 12.

Table 12 Percentage of post-test scores of critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto

Interval Criteria	Category	Frequency	Percentage Score (%)
8 < test score ≤ 10	Very Good	7	23.33%
6 < test score ≤ 8	Good	11	36.67%
4 < test score ≤ 6	Average	11	36.67%
2 < test score ≤ 4	Poor	1	3.33%
test score ≤ 2	Very Poor	0	0.00%
Total		**30**	**100.00%**

The results of the post-test analysis of critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto shown in Table 4.9 show that 7 students, or 23.33% of the trial subjects, get very good category test results with a score of 9. In addition, 11 students, or 36.67% of the trial subjects, got critical thinking skills test scores in the good category, namely 7 or 8. Students who get moderate category scores are 11 or 36.67% of the trial subjects with a score of 5 or 6. Meanwhile, students who get fewer category scores are one student or 3.33% of the trial subjects with a score of 4. The percentage analysis of students' critical thinking skills after the application of integrated physics teaching materials Virtual Laboratory PhET Simulation is shown in Figure 2.

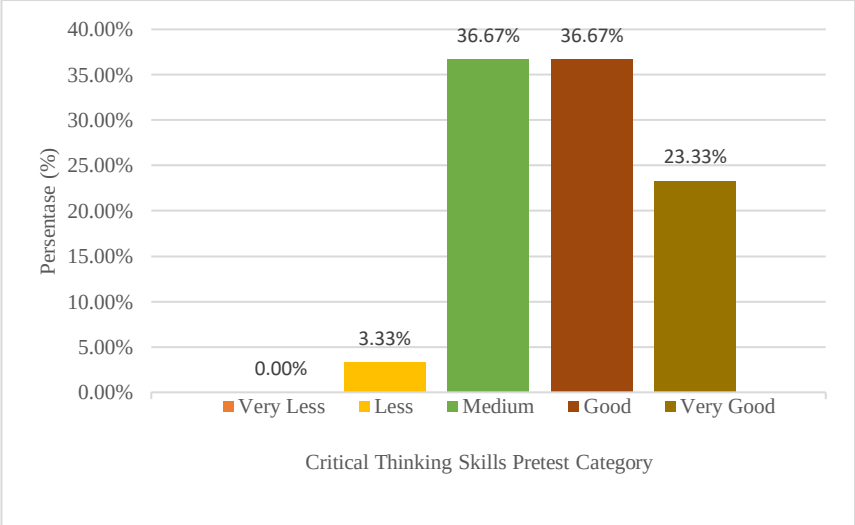

Figure 3 Percentage of post-test of students' critical thinking skills

The percentage of critical thinking skills test results of students after the application of integrated physics teaching materials Virtual Laboratory PhET Simulation in Figure 2 shows the highest graph in the good and moderate categories, namely 36.67% of test subjects who answered 5 to 8 questions correctly after learning using integrated physics teaching materials Virtual Laboratory PhET Simulation. Students who obtained the very good category were 23.33%, or the number of students who obtained a score above 8 increased to 7. Furthermore, the increase in students' critical thinking skills was analyzed using pretest and post-test data in the form of N-Gain to measure the increase in students' critical thinking skills. The results of the N-Gain analysis can be seen in Table 13.

Table 13 N-Gain score of critical thinking skills of class XI MIPA 5 SMAN 5 Jeneponto

Interval Criteria	**Category**	**Frequency**	**Percentage Score**
$0.70 < g \leq 1.00$	High	5	16.67%
$0.30 < g \leq 0.70$	Medium	18	60.00%
$0.00 < g \leq 0.30$	Low	2	6.66%
$g = 0{,}00$	No Increase	5	16.67%
$-1.00 \leq \ < 0.00$	Decrease	0	0.00%
Total		**30**	**100.00%**

Based on the N-Gain score in Table 13, 18 students, or 60.00% of the test subjects, experienced an increase in critical thinking skills in the medium category, and in the low category, there were two people, or 6.66% of the test subjects. While in the high category and did not experience an increase in critical thinking skills, there were the same number,

namely five people or 16.67%. The increase in students' critical thinking skills is more clearly shown in Figure 4.

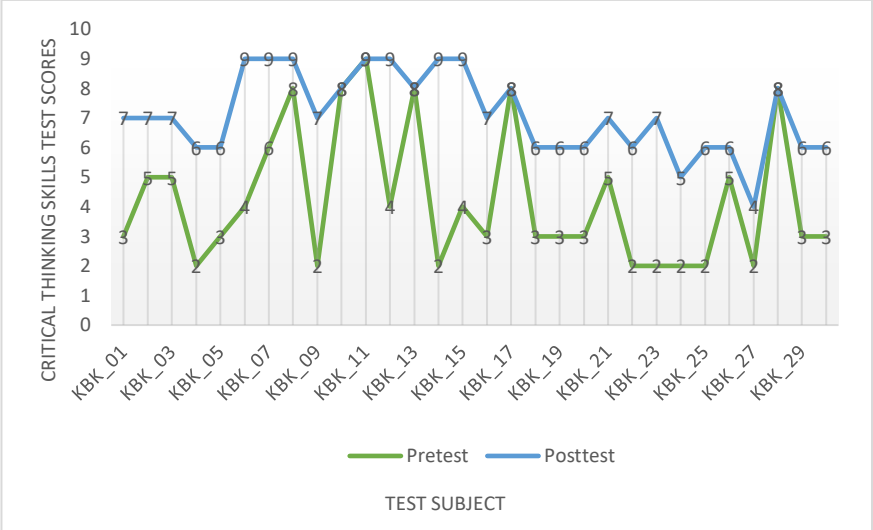

Figure 4 Pretest and post-test critical thinking skills

Based on Figure 4, 25 students experienced increased critical thinking skills after applying integrated physics teaching materials in a Virtual Laboratory PhET Simulation. However, five students did not experience increased critical thinking skills after applying integrated physics teaching materials Virtual Laboratory PhET Simulation, namely KBK_10, 11, 13, 17, and 28. Based on the analysis of the answers from the five students who did not experience an increase, the results showed that students could answer an average of 8 to 9 questions correctly. Students still cannot master critical thinking skills on the analysis, inference, and explanation indicators. This can be seen from the analysis of student answers from the pretest and post-test results, which show that these five students need more in-depth material and time to train their critical thinking skills, especially regarding analysis, inference, and explanation indicators.

Therefore, overall, the average N-Gain value of the pretest and post-test of critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto is 0.44, which is in the moderate category with an interpretation of the categorization of the effectiveness of the gain score of 43.71% which means that the critical thinking skills test is in the fairly effective category. Thus, it can be concluded that there is an increase in the critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto, which is in the moderate category with a fairly effective critical thinking skills test that is able to improve student's critical thinking skills.

Table 14 analyzes the improvement of students' critical thinking skills based on the critical thinking skills categories used in this study.

Table 14 Analysis of students' critical thinking skills for each indicator

Indicator	Average Pretest Score	Average Posttest Score	Percentage Improvement Score
Interpretation	1.23	1.63	20.00%
Analysis	0.87	1.40	26.67%
Inference	1.37	1.70	16.67%
Evaluation	0.60	1.17	28.33%
Explanation	0.17	1.23	53.33%

An illustration of improving students' critical thinking skills is clearly shown in Figure 5.

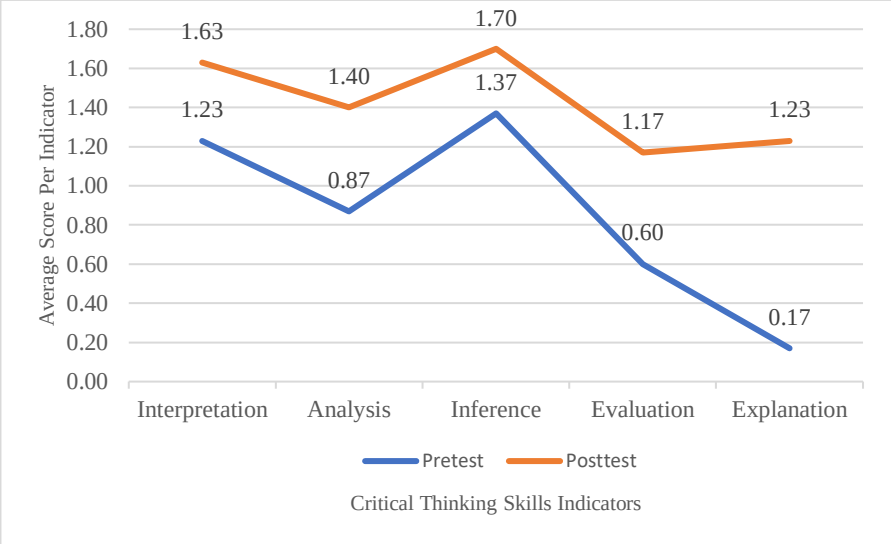

Figure 5 Percentage graph of improvement in students' critical thinking skills for each indicator

Based on Figure 5, the highest increase occurred in the fifth indicator, namely the explanation indicator, with an average score of 0.17 to 1.23. While the lowest increase occurred in the inference indicator, namely an average score of 1.37 to 1.70. The evaluation indicator experienced the second-highest increase: an average score of 0.60 to 1.17. Then, the analysis indicator, namely an average score of 0.87 to 1.40, and the interpretation indicator, an average score of 1.23 to 1.63. This is, of course, related to the tendency of students towards the five indicators of critical thinking skills in the physics problems they work on. In addition, this is also caused by the practice of working on questions that can be continuously carried out by students wherever they are using the integrated physics teaching materials Virtual Laboratory PhET Simulation, both online and offline, with the number of questions that have been adjusted as indicators of critical thinking skills.

Finally, this research studies the development of integrated physics teaching materials in Virtual Laboratory PhET Simulation. The development model used is the 4D instructional design model. This model consists of four stages: defining, designing, developing, and disseminating. The characteristic of the 4D instructional design model is that the development is carried out because of the identification of student needs that are still not in accordance with the proper conditions as the learning objectives in the Independent Curriculum. This characteristic is in accordance with the research conducted, namely the development of integrated physics teaching materials Virtual Laboratory PhET Simulation to improve students' critical thinking skills.

This development research aims to analyze the results of the development of integrated physics teaching materials Virtual Laboratory PhET Simulation, practitioners' assessment of integrated physics teaching materials Virtual Laboratory PhET Simulation, and the improvement of the critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto after the implementation of integrated physics teaching materials Virtual Laboratory PhET Simulation.

The results of the agreement index of the three experts regarding the validation of the integrated physics teaching material items of the Virtual Laboratory PhET Simulation. The analysis results obtained that the integrated physics teaching material of the Virtual

Laboratory PhET Simulation was declared valid and worthy of being continued to the trial stage. This analysis's results align with the research conducted by Wicaksono (2016). His research showed that the development of learning devices developed by researchers was worthy of being used in learning, as seen from the results of the device's validity, which received a good category. Furthermore, research conducted by Larasati et al. (2022) in class X TITL 1 at SMKN 3 Surabaya showed that the media research results were valid or good. Meanwhile, the results of student responses were in a good category, and using Android-based media helped students understand the material independently. Research conducted by Noviana (2022) in class XI MIPA Makassar Raya showed that virtual laboratory-based learning media was declared valid (V value> 0.4 based on Aiken's V expert analysis test).

The physics teaching materials integrated with the Virtual Laboratory PhET Simulation, which were declared valid by experts, were then given to practitioners to assess the implementation and usefulness of the physics teaching materials developed. Practitioners in this study were 21 physics subject teachers at the Gowa Regency Senior High School level who were members of the Jeneponto Regency Physics Subject Teachers' Conference (MGMP). The characteristics of the Physics Teachers who were used as practitioners in assessing physics teaching materials were, of course, in accordance with their scientific competence in the level of education they had taken, namely the Physics Education Department. So that the knowledge related to education they had obtained in college became a strong foundation in carrying out their duties as educators in transferring their knowledge to students. In addition, these physics teachers have taught physics material in schools for quite a long time. This is evidenced by joining these Physics Teachers into the Jeneponto Regency Physics Subject Teachers' Conference group, whose members may only be included if their teaching period has fulfilled a minimum of two years of service as Physics Teachers.

Physics teaching materials are assessed by practitioners using a validated and declared valid questionnaire. The practitioner assessment questionnaire consists of four assessment aspects, namely the aspects of content feasibility, presentation feasibility, language feasibility, and graphic feasibility. Each assessment aspect consists of ten statement items assessed by practitioners to assess physics teaching materials.

Based on the practitioner assessment analysis results, it was concluded that the twenty-one practitioners, on average, gave a very good assessment of the integrated physics teaching materials of the developed Virtual Laboratory PhET Simulation. This indicates that the developed physics teaching materials are stated to be practical. This is also compared to physics teaching materials in the form of reading books used in schools that have not been able to accommodate the improvement of students' critical thinking skills, especially abstract materials that require virtual practicums.

The results of this assessment are supported by direct responses from practitioners when assessing the developed physics teaching materials. This analysis's results align with research conducted by Noviana (2022) in class XI MIPA Makassar Raya. Her research shows that virtual laboratory-based learning media is practical (through the results of teacher responses that are in the very good category or the responses given are positive).

In this study, physics teaching materials were declared effective when the critical thinking skills test scores of 30 class XI MIPA 5 students increased. Based on the analysis of the improvement of students' critical thinking skills, five students experienced an increase in the high category, 18 students experienced an increase in the medium category, and two students experienced an increase in the low category. Judging from the indicators of critical thinking skills measured in this study, on average, students answered only up to 1 question correctly on the explanation indicator before applying physics teaching materials. This shows that students cannot present the results of a person's assessment

convincingly or coherently. This is also supported by the evaluation of physics subject teachers who argue that students are less capable of presentation, especially when it comes to deeper things related to problems in everyday life. For example, factors that influence certain movements.

After implementing the integrated physics teaching material Virtual Laboratory PhET Simulation, the explanation indicator of students increased by around 53.33% and became the indicator with the highest increase. Participants could present the results of a person's assessment in events related to everyday life convincingly and coherently with sub-skills in the form of explaining observation results, justifying procedures, and conveying arguments. This is supported by research conducted by Wicaksono (2016), which shows that the effectiveness of the learning device shows the achievement of learning objectives, namely based on the results of the Critical Thinking Ability Test (CTAT) and student activities show the influence of PhET and simple KIT media during the learning process on students' TKBK. In other words, students' critical thinking skills have increased significantly, so the development of integrated learning devices for the material of gas kinetic theory PhET and simple KIT can be used to train students' critical thinking skills. Furthermore, research conducted by Adelita Putri Noviana (2022) in class XI MIPA Makassar Raya showed that virtual laboratory-based learning media was declared effective (the percentage of results of practical activities and physics learning test results was 60% above the minimum score).

Five students did not experience increased critical thinking skills after applying the integrated physics teaching material Virtual Laboratory PhET Simulation based on the test score results. Meanwhile, a study conducted by Indro Wicaksono (2016) showed that the learning objectives were achieved, namely based on the results of the Critical Thinking Ability Test and student activities, which showed an increase in scores from the pretest and post-test results with the analysis of the N-gain value obtained a value above 0.6 which indicates the influence of PhET and simple KIT media during the learning process on students' CTAT. Students' critical thinking skills have increased significantly. Hence, the development of learning devices for the integrated PhET and simple KIT gas kinetic theory material is feasible to be used to train students' critical thinking skills. Based on a comparison between the results of this study and previous studies, it can be identified that other factors cause the five students' critical thinking skills not to increase.

Critical thinking skills will be difficult to develop if students do not consciously try to develop them during learning. Students need time to practice their critical thinking skills, both in learning activities and outside of learning activities. Critical thinking cannot be acquired quickly without practice or habituation (Sihotang, 2019). Physical condition, motivation, anxiety, habits and routines, intellectual development, consistency, and feelings affect a person's level of critical thinking (Wayudi et al., 2020).

Critical thinking is not necessarily present in someone from birth. However, critical thinking is a skill that can be developed through students' direct experience in dealing with problems. So, if students are accustomed to being given questions based on critical thinking skills, their critical thinking skills will be able to develop. In addition to doing continuous practice, students also need to develop their critical thinking skills by continuing to explore information or knowledge that does not only come from teachers but also utilizes information technology outside of learning (Sarip et al., 2022). However, the facts in the field generally show that physics subjects at the high school/vocational school level are considered difficult subjects. This can be seen from the physics scores that are often still incomplete in each student's test, and students' critical thinking skills are still low, which is proven when the learning process takes place, students solve questions only in one way, namely the one taught by the teacher (Irwan et al., 2021). On the other hand, everyone's

critical thinking skills are different. Even for identical twins. The cause is in line with the previous opinion of scientists (Wasahua, 2021).

Overall, the average N-Gain value of the pretest and post-test of critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto was 0.44, which is in the moderate category with an interpretation of the gain score effectiveness categorization of 43.71%, which means that the critical thinking skills test is in the fairly effective category. So there is an increase in the critical thinking skills of class XI MIPA 5 students of SMAN 5 Jeneponto, which is in the moderate category with a fairly effective critical thinking skills test that is able to improve students' critical thinking skills. This is in accordance with the opinion that the advantages of a virtual laboratory include (1) improving creative thinking skills and scientific problem-solving and (2) developing skills in the field of ICT without ignoring laboratory knowledge. In addition, physics problems are often encountered in everyday life. Therefore, physics plays an important role in training students to master knowledge, concepts, and principles of physics and master scientific skills and processes, including critical thinking skills (Sukiminiandari et al., 2015). Thus, the Virtual Laboratory PhET Simulation developed in relation to physics learning can help train students in solving problems and ultimately improve students' critical thinking skills.

CONCLUSION

The following conclusions were obtained based on research results and limited trials of the integrated physics teaching materials Virtual Laboratory PhET Simulation in class XI MIPA 5 of SMA Negeri 5 Jeneponto. 1) Theoretically, the results of the validity analysis of the integrated physics teaching materials Virtual Laboratory PhET Simulation are in the valid category so that they can be declared suitable for use. The physics teaching materials that have been developed are in the form of digital teaching materials with the characteristics of teaching materials in the form of physics materials integrated with Virtual Laboratory PhET Simulation and evaluations in the form of quizzes according to critical thinking skills indicators packaged in the form of PowerPoint with iSpring Free 11 to improve students' critical thinking skills; 2) Empirically, the practitioner's assessment of the integrated physics teaching materials Virtual Laboratory PhET Simulation developed is in the very good category and is quite practical. This shows that practitioners positively respond to the integrated physics teaching materials Virtual Laboratory PhET Simulation developed, and 3) The increase in students' critical thinking skills after applying the integrated physics teaching materials Virtual Laboratory PhET Simulation analyzed with N-Gain is in the moderate category. The interpretation of the effectiveness category is quite effective. This means there is an increase in the critical thinking skills of class XI MIPA 5 students of SMA Negeri 5 Jeneponto.

The developed integrated physics teaching materials of Virtual Laboratory PhET Simulation have limited discussion materials on certain materials. The analysis of its needs is only in one school. Therefore, further developers or researchers are expected to be able to expand the scope of the development of integrated physics teaching materials of Virtual Laboratory PhET Simulation, including the scope of the discussion materials.

The integrated physics teaching materials of Virtual Laboratory PhET Simulation that were developed focus on the problems in the reference books of the Merdeka Curriculum used. Therefore, teachers are expected to be able to develop their problem focus on problems that are very close to the daily lives of students so that the physics learning given to students is more in-depth and memorable. The integrated physics teaching material Virtual Laboratory PhET Simulation that was developed has a limited number of practice questions. Therefore, it is expected that students can train their critical thinking skills more massively.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Individual authors' contributions to manuscript preparation are defined by the following criteria: Conceptualization, Methodology, formal analysis, writing—preparation of the original draft, writing the manuscript, and others.

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