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The development of physics learning tools to improve critical thinking skills

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ABSTRACT

One of the essential physics skills for students in today's era is critical thinking skills. This study offered physics learning tools with a scientific approach to improve critical thinking skills. The purpose of this research was to produce learning documents in the form of lesson plans, teaching materials, and Lorentz force physics test instruments with a scientific approach in improving students' critical thinking skills. This was research and development with a 4D model and steps, including the defining stage, namely the initial stage, to identify the problem. Then, the designing stage was carried out by developing the initial draft of learning tools and research instruments. Afterwards, the developing stage was the initial draft of the improvement stage based on the validation of experts, practitioners, limited trial, and piloted. The data collection instruments in this study consisted of validation sheets, test instruments to measure the implementation of teaching materials, observation sheets to observe teacher and student activities, tests to measure critical thinking skills, and questionnaire responses. The results proved that learning tools developed with a scientific approach improve students' critical thinking skills. Thus, scientific-based physics learning tools is recommended to be used as teaching materials for physics students to improve students' critical thinking skills.

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1. INTRODUCTION

Education is an essential element in the development of a nation. The presence of education to create intelligent human resources with character is essential to make changes towards a more advanced and quality nation [1]. Since education is vital for everyone, the government encourages teachers to design, take action, and evaluate the learning process. Teachers must be innovative in developing learning tools so that learning becomes effective, not only memorizing concepts but also building knowledge and improving students' thinking skills [2], [3]. It is included in modifying teaching materials which is one of the components that determine the achievement of learning objectives [4].

Physics is one of the fields of science that is still considered difficult for students because it relates to abstracting calculations [5]–[7]. Physics learning materials that are still considered difficult by students include Newton's Laws [8], [9], Elasticity [10], [11], Light [12], Free body diagrams [13], [14], Electricity and Magnetism [15], Static fluid [16], Circular motion [17], Projectile motion [18], Force and motion [19], Temperature and heat [20], Vector [21], [22], Lorentz force [23] and many another physics material. Students' motivation to learn physics is still shallow because teachers do not instill appropriate scientific

concepts and strategies in teaching physics [24]. The current curriculum requires students to be active and creative [25], [26]. This situation causes teachers to make major changes in the learning process in the classroom by using appropriate models, methods, and strategies in directing students to study independently and understand what is being learned.

The most fundamental problem is the lack of learning tools such as teaching materials in every learning process. One alternative to improve learning conditions is to improve learning tools. This toolkit was developed based on the scientific approach recommended by the current government. In addition to learning tools, teaching materials are also developed. Teaching materials are made to teach students to learn independently to be more active in learning and the teacher as a facilitator. Teaching materials are prepared based on a scientific approach and are expected to help students improve critical thinking skills. Therefore, teachers can find out to what extent students' critical thinking skills. The instrument is arranged based on the criteria of critical thinking skills. Critical thinking skills need to be applied continuously in the learning process [27]. The emphasis is instilling skills to the future golden generation who continue their studies to college and even the world of work. The aim is to produce students who are competent and skilled in solving physics problems in everyday life. The results of the study show that 70% of high school graduates lack good competence regarding critical thinking skills and for 4 years students only have 28% critical thinking skills [28]. Factors that cause students' critical thinking skills are less weak and less empowered by teachers. Therefore, teachers must have good competence in designing learning [29]. Critical thinking skills are considered to play a central role in logical thinking, decision making and problem-solving, and every learning process [30].

Critical thinking skills have been identified as critical general skills that contribute to academic and career success in the 21st century. Critical thinking includes cognitive, noncognitive, or combining the two skills applicable across a wide range of specifics. Meanwhile, many workplaces in companies and educational institutions have become candidates for workers with high-quality critical thinking skills over the past few years. For years, educators and employers worldwide have expressed concern about whether college graduates are well equipped with these skills and whether they are ready to compete in the twenty-first century. The Association of American Colleges and Universities and the US Department of Labor, through educators and psychologists, view critical thinking as a skill that can be achieved through training [31].

Universities are expected to help develop students' critical thinking. Policy makers and accrediting agencies recognize the importance of developing critical thinking skills, as evidenced by the greater emphasis on critical thinking training as general learning. In order to meet these mandated standards or criteria and demonstrate their own worth, some institutions seek to encourage the development of critical thinking with better teaching practices [32]. The results of the study prove that critical thinking skills are a trigger in improving creative thinking skills and student learning outcomes. The results of the study of science learning in Maluku and Ambon City prove that it is still in a low category [33]. Based on existing records, a learning tools was developed which is one of the breakthroughs that is expected to improve critical thinking skills with a scientific approach. Therefore, the purpose of this study was to produce learning documents in the form of lesson plans, teaching materials, and Lorentz force physics test instruments with a scientific approach in improving students' critical thinking skills.

2. RESEARCH METHOD

This research developed a product and test the validity, legibility of the product in achieving its goals. The developed and tested product for validity in this study was a learning tool that included a lesson plan (RPP), teaching materials, and critical thinking skills test questions. The learning tools development model used was a modification of the 4D model. The 4D model consists of four stages: defining, designing, developing, and deploying [34]. The purpose of this is to produce good learning tools through the development process. The study was conducted at Junior High School 7 Ambon, Indonesia with a small-scale trial of 30 students, 55 students, and a large-scale trial of 120 students.

The research instruments were: i) Validation sheets were used to obtain data about the quality of the tools, which consisted of validation sheets of learning implementation plans; ii) Room tests were used to determine the level of readability of teaching materials so that the information obtained by scientific teaching materials was easily understood by students or not; iii) Tests were used in research to measure students' critical thinking skills after the material was taught at each meeting; and iv) Student questionnaire response sheets containing questions about learning tools. The data analysis techniques include: i) Analysis of the data from the validation results, the validator wrote his assessment, on each validation sheet; ii) Analyzes the data on the results of the readability test; iii) Analyzes the improvement of students' critical thinking skills; and iv) Analyzes data on student responses to learning tools.

3. RESULTS AND DISCUSSION

The determined stage was a preliminary analysis, including: i) Analyzing problems in learning physics at school before looking for solutions; ii) Task analysis was to identify the primary skills needed in learning, according to the results of the subject analysis. This analysis was based on core competencies and achievement indicators according to the Indonesian 2013 curriculum; iii) Concept analysis aimed to show the parts that students will learn. The results of the analysis of subjects were developed based on the Indonesian 2013 curriculum. The results of the concept analysis were in the form of concept analysis mapping and concept maps.

In designing learning tools, the design phase included learning implementation plans, teaching materials, and critical thinking skills tests. The activities carried out at this stage consist of three essential steps: i) Selection of media: The results of the selection of learning media were determined by the media needed to implement learning, namely teaching materials; ii) Format selection: The selection of the learning tools format used referred to Indonesian Regulation of the Minister of Education and Culture (*Peraturan Menteri Pendidikan dan Kebudayaan*/*Permendikbud*) Number 65 concerning Process Standards. The results of the selection of the format of teaching materials developed consisted of learning instructions, competencies to be achieved, supporting information, exercises, work instructions or worksheets, and evaluations. The test questions were designed in the form of essay questions based on six categories of critical thinking skills: hypothesizing, classifying, observing, measuring, analyzing, and evaluating; iii) Preliminary design of the tools. This stage produces an initial draft in the form of a first draft consisting of a lesson plan, teaching materials, and a test of critical thinking skills. Then, in the development stage, learning tools were developed. Learning tools that have been revised adhering expert validation. The tools developed were learning media, teaching materials, and critical thinking ability test questions.

3.1. Expert validation results

The learning tools developed were validated by five experts. The average research tool can be seen in Table 1. The results of the validator assessment of each learning tool, namely learning media are 2.98, teaching materials are 3.48, and test questions are 2.8. Consequently, learning tools, teaching materials, and test questions are in a good category. Therefore, they can be used with some revisions. Then, all learning tools were revised based on critics and suggestions from the validator. Eventually, the validation of the learning tools was valid and categorized as very good qualifications so that the learning tools could be used in actual classes. Learning tools are said to be good if they meet valid criteria and are validated by several experts and practitioners, which can then be applied in learning [35]. This revised learning tool is called draft II. This supports previous research, which explains that development research needs input and review from experts in the field. The goal is that there is a misconception and can be used in the community, specifically the school community, teachers, and students. In addition, the developed instrument has been declared valid and reliable, so the instrument is suitable to be applied to students [36]. Furthermore, an instrument is said to be valid when it measures what it is supposed to measure. In other words, when an instrument accurately measures each specified variable, it is considered a valid instrument for that particular variable [37]. Therefore, a good instrument must be valid and reliable so that the study results can be trusted. Thus, reliability and validity should be checked and reported, as well as references cited for each assessment instrument used to measure a subject [38].

Table 1. The results of the validation of learning tools experts

Product	Expert					Average	Criteria
	1	2	3	4	5		
Learning media	3	2.9	3	3	3	2.98	Good
Teaching materials	4	3.6	4	3.4	2.7	3.5	Very good
Test questions	2.9	3	2.9	2.9	2.5	2.8	Good

3.2. Readability test

After being validated by five experts, the researchers revised the tools based on experts' advice. The second draft was piloted on a small scale to test the readability of teaching materials. Based on the results of the readability test conducted on six students, the data obtained as shown in Table 2. The results of data analysis obtained a readability score of 73.2%. Based on these criteria, physics teaching materials integrated with a scientific approach are included in the category of being easily understood by students. Teaching materials with readability criteria are easy to understand, can be used by students to study independently.

Table 2. Readability test result

Respondent code	Maximum score	Total score obtained	Score (%)	Readability criteria
UCK-1	25	21	84	Easily understood
UCK-2	25	22	88	Easily understood
UCK-3	25	23	92	Easily understood
UCK-4	25	22	88	Easily understood
UCK-5	25	23	92	Easily understood
UCK-6	25	21	84	Easily understood
Average	25	18.3	73.2	Easily understood

3.3. Critical thinking skills test

Learning tests were conducted to determine the level of students' critical thinking skills. Data on students' critical thinking skills apply an integrated learning approach with a scientific approach measured using a learning test. Qualifications for improving students' critical thinking skills are shown in Table 3.

Table 3. Qualifications for improving students' critical thinking skills

Academic score	Frequency	Category
$g>0.7$	7	High
$0.3<g<0.7$	14	Middle
$g<0.3$	2	Low

The results of the N-gain test illustrate that students have succeeded in the learning process developed by scientific approach and can improve students' critical thinking skills. Scientific is an approach that emphasizes the use of students' critical thinking skills [39]. The efforts made by the government have not shown maximum results for students because the low critical value of students' thinking skills is caused by several deviations from the rules that have been set. This can be seen from the number of students who only memorize concepts, take notes on what is conveyed by the teacher, look passive, and rarely use prior knowledge as the basis for planning lessons in solving science problems. Table 4 shows that most of the students are at the middle and high levels, while only a few are at the low level. Students' critical thinking skills can be developed through a scientific approach that can maximize their own learning goals, namely achieving a deep understanding of what learned through a series of directed and precise processes. Therefore, the truth about it can be justified with a scientific approach and can solve that problem. The scientific learning process is considered one of the weapons or approaches used in learning in Indonesia today. This learning can encourage students to think critically, analytically, and logically in identifying a problem, understanding, solving problems from a case, and applying learning materials well [40].

Table 4. Achievement of n-gain scores on the criteria of critical thinking skills

Observed ability	Gain score	Criteria
Hypothesis	0.45	Middle
Measure	0.75	High
Classify	0.46	Middle
Observe	1.90	High
Analyze	0.71	High
Evaluate	1.14	High

Based on the gain score obtained from each aspect of students' critical thinking skills as measured through test result, it can be concluded that, six aspects of students' critical thinking skills can be improved through learning tools that are integrated with a scientific approach. According to the stated physics learning objectives, teaching materials are structured to improve students' critical thinking skills [41], [42]. Learning tools that are integrated with a scientific approach in learning physics aim to develop students' critical thinking skills through several aspects, namely hypothesizing, classifying, observing, measuring, analyzing, and evaluating. The fact has previously explained that critical thinking skills are one of the most critical aspects in solving real-world problems. Scientists have studied critical thinking skills for about a hundred years, and nearly everyone who works in the field has produced thinking skills that they see as the basis for critical thinking for success in the world of work [43].

3.4. Student response questionnaire

After students follow the learning process using the developed tools, students filled out a response questionnaire. The percentage of student responses to the scientific approach integrated learning tool, by providing a student response questionnaire to 21 students obtained data as presented in Table 5. At the end of the trial, students who became the research object filled out student response questionnaires. This shows that most students give a positive response to the learning tools that have been prepared. It was found that the average total student response was 87.8% which indicates an effective classification. Students show a positive response to the teaching materials used. However, there are questions in the teaching materials that are difficult for students to understand. This is due to the different cognitive levels of students.

Table 5. Results of student responses to the questionnaire and learning implementation

Learning media	Students' responses				
	Very agree	Agree	Hesitate	Disagree	Very disagree
1. Learning materials					
a. Teaching materials are made, look interesting and understood by students.	33	66	0	0	0
b. Can guide students to learn independently	23	76	0	0	0
c. The questions in the teaching materials are easy to understand.	23	33	42	0	0
d. The steps of student work are very clear, so students can easily complete them.	38	61	0	0	0
2. Implementation of learning					
a. The atmosphere in the classroom feels new and fun	38	61	0	0	0
b. Learning carried out with a scientific approach makes students active.	47	52	0	0	0
c. Students are interested in following the next lesson, such as the one just followed.	28	71	0	0	0
d. The teacher does not dominate learning, and students are free to develop their ideas in understanding the material being taught.	0	52	47	0	0
Percentage (%)	28.8	59	11.1	0	0

The implementation of learning was also responded well by students. Based on the classification, it can be concluded that the arranged learning tools are effective in learning. This study supports the previous research that experts still debate the concept of human intelligence. Therefore, it is still collecting data and surveys about the quality of learning in the world. Cognitive development and teaching and learning processes refer to a significant relationship between family involvement and students' academic success. This is because the mother's academic qualifications emerged as a better predictor of the cognitive performance of the relatives. However, within families, there is evidence that family socioeconomic status influences children's academic performance, with the most prominent influence being in childhood. Research has shown that high socioeconomic conditions can be a positive indicator for children's cognitive improvement. In addition, it allows access to more space and fun educational and cultural materials [44].

4. CONCLUSION

The research confirmed that integrating integrated learning tools with a scientific approach can improve students' critical thinking skills. Thus, scientifically based physics learning tools can be recommended to be developed and to be used as teaching materials for physics students in the junior high school level. It is useful to improve students' critical thinking skills. Physics subject teachers may develop learning tools using a scientific approach in other subjects. Learning physics with a scientific approach needs to be applied and considered as an alternative. The resulting learning tools need to be tested in other schools, with various conditions in order to obtain genuinely quality learning tools.

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