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Critical Thinking Skills (CTS) through Augmented Reality Worksheets using The Inquiry-Scaffolding Models

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ABSTRACT

Critical thinking skills (CTS) are important for training in physics. This research aims to train students' CTS through augmented reality worksheets with the inquiry-scaffolding model. The research participants comprised 36 third-semester physics education students at UIN Walisongo Semarang. This research utilized a pre-experimental method employing a one-group pre-test post-test design. The enhanced CTS was assessed using the N-gain test. The analysis of students' CTS yielded four categories: very less critical, less critical, critical, and very critical. Implementing learning through augmented reality worksheets employing an inquiry-scaffolding model enhanced students' CTS by 0.30 with moderate criteria. The breakdown of students' CTS following the augmented reality worksheets with inquiry-scaffolding models showed a distribution of 19.44% less critical, 69.44% critical, and 11.11% very critical. From the research findings, it can be concluded that augmented reality worksheets using the inquiry-scaffolding model effectively train students' CTS in learning physics. Through learning with augmented reality worksheets, students are trained to analyze arguments, consider the validity of various sources, make inferences and general conclusions, and make decisions. Scaffolding procedure: explaining, modeling, and questioning can provide an overview of cause and effect, and abstraction of a concept as a provision to strengthen CTS.

Introduction

Looking forward to the 21st century, students must possess 16 skills broadly categorized into literacy, competencies, and character qualities (Vhalery et al., 2022). Education prepares students to confront the rapid changes in social culture, the workforce, business, and the swiftly advancing technology. One of the highly essential skills for the 21st century is CTS (Miterianifa et al., 2021). CTS is crucial and should be taught, including in the teaching of physics. CTS plays a role in analyzing, identifying, and evaluating various types of information to resolve physics-related issues (Velmovská et al., 2019).

CTS forms the fundamental cognitive abilities students must master as a cornerstone for problem-solving. These skills encompass various indicators, such as elementary clarification, base for a decision, inference, advanced clarification, supposition and integration, and auxiliary abilities. Auxiliary abilities do not directly construct CTS but play a crucial supportive role in their formation. CTS demands various activities to evaluate what is believed or assumed based on supporting evidence and subsequently draw conclusions. The ability to think critically focuses on deciding what to believe or do. CTS can be divided into five indicators: Elementary clarification or basic clarification, Basic support, Inference, advanced clarification, and Strategy and

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tactics (R. H. Ennis, 2015). These skills are necessary in facing the challenges of the 21st century.

Based on the learning observations during Fundamental Physics II lectures at the Physics Education program in UIN Walisongo Semarang, it's evident that the CTS of physics education students remains relatively low. The CTS test was applied to 36 students, with an average result of 39.62 in the less critical category. This is supported by many students who need help presenting appropriate arguments when explaining the relationship between physics concepts and everyday life events. At least five students gave correct arguments when the discussion was held. From the results of the initial test analysis of CTS on the primary clarification indicator, the sub-indicator of analyzing arguments, the score was 39.58. Moreover, this is further emphasized by the limited proficiency in solving physics problems, highlighting the importance of CTS as the foundational ability necessary for effective problem-solving processes.

Regarding problem-solving skills, a survey of 36 physics education students showed that 83.3% of students in UIN Walisongo Semarang encountered challenges in solving physics problems. The abstract and complex subject matter, requiring a high level of mathematical mastery, are the challenges in solving physics problems.

One of the topics in fundamental physics education involves electricity. Electricity is highly abstract since it cannot be directly observed with the naked eye except through specific technology. The concept of electricity is difficult to understand concretely because it cannot be seen or felt directly by humans. Students need help to form concepts clearly and concretely. When the concepts are still mastered, it will impact the ability to provide appropriate arguments. Practical activities related to electrical material can only be observed based on electronic device indicators—for example, the results of measuring current and voltage using a multimeter. The events are still abstract and require concrete visualization to help students in observation activities. Furthermore, students can assess the results of observations correctly. This can support CTS as a basis for a decision. This will further impact the skills of making inferences, defining terms based on specific criteria, and integrating the dispositions and other abilities in making and defending a decision. There's a need for cognitive support to assist students in understanding the topic of electricity. This assistance can be obtained through a scaffolding approach. Scaffolding is a learning theory proposed by Lev Vygotsky and is related to the concept of the ZPD. ZPD is a Zone of Proximal Development.

Scaffolding has been widely applied to enhance students' understanding of the subject matter. Scaffolding can be integrated with various simulation media to increase student understanding. Through the use of modeling procedures on scaffolding, such as the use of PhET Simulation, conceptual understanding can be improved. Using the scaffolding approach with PhET Simulation, students' conceptual comprehension and self-directed learning can be enhanced (Eveline et al., 2019). Moreover, scaffolding can be integrated with instructional media to improve students' scientific process skills (Saputri, 2021). Scaffolding holds excellent potential for integrating various media and tools to achieve specific objectives. Higher learning goals, such as attaining high-level thinking skills, including creative problem-solving and CTS, can also be achieved through scaffolding. Scaffolding can be integrated with physics simulations or inquiry-based learning models to enhance CTS (Ferty et al., 2019; Koes et al., 2020). Students' better conceptual understanding and critical thinking skills can be achieved using inquiry scaffolding (Wartono et al., 2019).

Achieving critical skills is inseparable from the learning process. The implementation strategy requires careful planning. Lesson planning involves the lecturer as the planner and implementing the lesson in the classroom. CTS can be cultivated through inquiry-based learning. Inquiry involves posing questions, investigating with empirical data, directly manipulating variables through experiments, and constructing comparisons using existing data sets (Duncan & Chinn, 2021).

Integrating scaffolding with inquiry-based learning can enhance the construction of scientific concepts. Inquiry scaffolding in physics education can improve CTS and conceptual understanding (Wartono et al., 2019). Inquiry scaffolding has been extensively developed by integrating it with technology. Several forms of inquiry scaffolding can be applied, such as inquiry scaffolding based on mobile technology, inquiry investigations through virtual and augmented reality, combining inquiry scaffolding with physical environments using augmented physics spaces, and integrating various forms and functions of scaffolding (Duncan & Chinn, 2021). Augmented reality and physics learning media can improve students' CTS (Nusroh et al., 2022).

The advancement of digital technology can be applied in education and utilized as a supportive tool for learning implementation. The use of digital technology in education is rapidly expanding. One such integration is inquiry scaffolding using augmented reality technology. The use of augmented reality in education is no longer strange. The primary purpose of using AR media is to present simulations and visualizations of abstract concepts. In recent years, AR media has been explored to help improve higher-order thinking skills (Bakri et al., 2019, 2020), abstract thinking skills (Nandyansah et al., 2020), and CTS (Nusroh et al., 2022). Through augmented reality spaces, students can further explore through inquiry-based activities. Augmented reality provides modeling of abstract physics concepts. Students explore physics concepts through this modeling assisted by various images and simulations. Providing simulations and modeling can provide scientific evidence, thus strengthening argumentation skills, assessing observation results, defining concepts, and making decisions regarding a physics problem presented.

A student worksheet needs to be prepared to support and organize students' learning experiences in the classroom. The student worksheet is crafted based on the inquiry-scaffolding model with the assistance of Augmented Reality as its scaffolding. Scaffolding in science education can be conducted through three strategies: providing explanations, modeling, and posing questions (van de Pol et al., 2010). Providing scaffolding in the form of modeling can be applied using augmented reality media. Using augmented reality as scaffolding through simulation and modeling can improve student learning achievement and help students focus on the material. Apart from that, AR with scaffolding can also interact to improve higher thinking skills (Ibanez et al., 2016). Furthermore, augmented reality is presented in worksheets as scaffolding to improve higher-order thinking skills (Bakri et al., 2020).

This research uses the inquiry-scaffolding model to train the CTS through augmented reality worksheets. The novelty of this research is improving CTS through the use of augmented reality (AR) worksheets supported by the inquiry-scaffolding model. This approach integrates AR technology with an inquiry-based learning model to sharpen CTS through investigative activities. Providing scaffolding strategies through explaining, modeling, and questioning integrated with worksheets provides clear and gradual guidance for students in developing CTS. This treatment gives students a robust framework for dealing with complex problems.

This research will also evaluate the impact of AR Worksheets and the Inquiry-Scaffolding model on increasing student CTS. The augmented reality worksheets with the inquiry-scaffolding model are implemented on electricity, specifically Kirchhoff's Law. The material selection is based on the student achievement in previous results of this material. Students can solve simple problems. However, they cannot clearly explain the conceptual reasons underlying the answer. Students need help to answer complex problems correctly. Strengthening concepts and training CTS to support students' comprehensive understanding is necessary.

Methods

This is a pre-experimental method. The AR Worksheet was implemented using a one-group pre-test and post-test design. The research participants comprised 36 third-semester physics education students at UIN Walisongo Semarang. This research uses a saturated sample. The research sample received material on Kirchhoff's laws in fundamental physics II lectures so that the measured results of improving CTS can be seen clearly.

Based on the pretest-post-test results, the N-gain test was used to improve CTS. The test is a CTS test in the form of essay questions consisting of five questions whose validity and reliability have been tested. Each question represents an indicator for Elementary clarification or base clarification, Basic support, Inference, advanced clarification, and Strategy and tactics.

Normality test using the JASP. The normality test is based on the Shapiro-Wilk Test. The normality test hypothesis is as follows.
H_0 : Data is normally distributed
H_a : Data is not normally distributed

This test uses α = 0.05, and the decision-making is as follows.
H_a accepted if $\alpha \geq P_{value}$
H_a rejected if $\alpha < P_{value}$

Determine the value of increasing students' CTS using Equation 1.

$$N\ Gain = \frac{S_{posttest} - S_{Pretest}}{S_{ideal} - S_{pretest}} \quad (1)$$

The interpretation of normalized gain can be seen in Table 1, and the total score of CTS can be categorized into three categories (low, medium, and high) based on the normal distribution theory, as shown in Table 2.

Table 1
N-Gain Interpretation

No	Score N-Gain (g)	Criteria
1	$\langle g \rangle \geq 0{,}7$	High
2	$0{,}7 > \langle g \rangle \geq 0{,}3$	Medium
3	$\langle g \rangle < 0{,}3$	Low

(Hake, 1999)

Table 2
Categories of Students' Critical Thinking Skills (CTS)

No	Interval	Category
1	$00,00 \le x < 25,00$	Very Less Critical
2	$25,00 \le x < 50,00$	Less Critical
3	$50,00 \le x < 75,00$	Critical
4	$75,00 \le x \le 100,00$	Very Critical

Result and Discussions

The application of AR worksheets with an inquiry-scaffolding model increases the students' CTS. The results of the CTS test can be seen in Table 3.

Table 3
Pre-test and Posttest Results of Student Critical Thinking Skills (CTS)

No	Description	Pre-test Score	Post-test Score
1	Mean	40,35	58,16
2	Minimum	12,50	33,75
3	Maximum	83,75	93,75

Pre-test and post-test data were normally distributed based on the Shapiro-Wilk Test. The results of the Shapiro-Wilk test can be seen in Table 4.

Table 4
Data Normality Test Results

No	Description	Pre-test	Post-test
1	α	0,050	0,050
2	P-value	0,425	0,454
3	Normality distribution	Normal	Normal

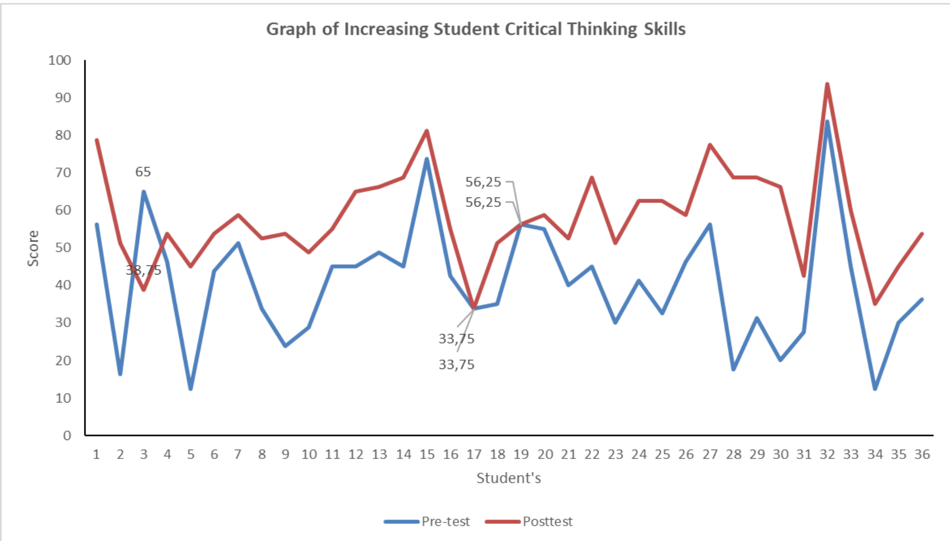
The pre-test and post-test data have been tested for data normality using the JASP application. Table 5 shows the results of the increased test with the N-Gain test.

Table 5
N-Gain Test Result

No	Description	
1	Pre-test	40,35
2	Post-test	58,16
3	Ideal Score	100,00
4	N-Gain	0,30
5	Criteria	Medium

Based on Table 5, it was found that students' CTS increased by 0.30 in the medium category. The distribution of increased CTS among students can be seen in Figure 1.

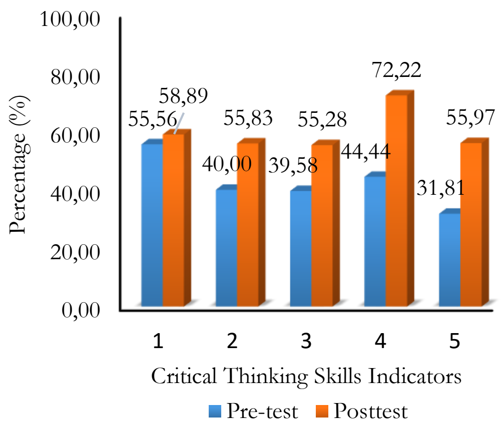
Figure 1
Distribution of Improvement in Students' Critical Thinking Skills (CTS)



In Figure 1, three pieces of data are marked. The marked data are numbers 3, 17, and 19. In data number 3, the CTS test results decreased. Data in numbers 17 and 19 did not increase or decrease. This means the initial and final learning results remain the same with a score. Apart from these three data, all students experienced an increase in their CTS test results.

The CTS of physics education students at UIN Walisongo Semarang for each indicator can be seen in Figure 2.

Figure 2
Diagram Percentage Achievement of Critical Thinking Skills (CTS)



Description:
1 : Basic Clarification
2 : Base for a decision
3 : Inference
4 : Advance clarification
5 : Supposition and Integration

The highest CTS in the initial test is the primary clarification indicator. In the final test, the highest achievement was in the advance clarification indicator. Student CTS increased in all indicators, with details in Table 6.

Table 6
Improving Critical Thinking Skills (CTS) on Each Indicator

No	CTS Indicator	N-Gain	Criteria
1	Basic Clarification	0,1	Low
2	Base for a decision	0,3	Medium
3	Inference	0,3	Medium
4	Advance clarification	0,5	Medium
5	Supposition and Integration	0,4	Medium

The first indicator of CTS is primary clarification. Basic clarification skills are focusing on problems, analyzing arguments, and asking for or clarifying answers. Basic clarification is an indicator of the highest CTS in the initial conditions that students have. This indicator saw the smallest increase compared to other indicators. In this question, 26 students answered correctly, 10 gave correct arguments, 15 gave inaccurate arguments, and one gave no arguments. Ten other students answered incorrectly with inappropriate arguments. This shows that students need help understanding the concept. CTS relates to understanding concepts. Understanding concepts is an initial ability needed in problem-solving and critical and creative thinking (Wartono et al., 2019).

The next indicator, namely the base for a decision, is a skill for assessing the credibility of a source, observing data, and assessing observation results. This skill is trained through data retrieval activities to solve problems in the given single- and multi-loop circuits. A virtual laboratory simulation facilitates this activity. Practical activities through PhET simulation can improve science process skills, including skills in observing data (Saputri, 2021).

The inference indicator experienced an increase in the moderate category. Inference skills are making connections between one concept and another, making deductions, and assessing assessment results. Inference skills are trained through learning activities presented in augmented reality worksheets and through scaffolding procedures in the form of modeling and questioning provided. CTS can be improved through computational modeling based on models (Jonny et al., 2020).

The advance clarification indicator experienced the most significant increase, with a score of 0.5. These skills include defining terms, assessing a definition based on certain criteria, and attributing unstated assumptions. This skill is trained through explaining, modeling, and questioning procedures. Providing activities through inquiry syntax can train students' CTS. The inquiry-based learning model was developed into a clarity learning model (CLM), which can increase advanced clarification critical thinking abilities in physics learning (Saputro et al., 2022).

Supposition and integration skills involve integrating dispositions with other abilities to make a decision. This skill is very useful in decision-making when solving a problem. Scaffolding is applied in practicing this skill by asking questions. Overall, CTS indicators can improve. The highest increase occurred in the advance clarification indicator, and the lowest increase was in basic clarification.

Final data analysis of student CTS categories can be seen in Table 7. There are no students who are categorized as very uncritical. The class average is declared to have CTS in the critical category.

Table 7
Students Critical Thinking Skills (CTS) Criteria

No	Criteria	Number of Percentages
1	Very Less Critical	0.0
2	Less Critical	19.44
3	Critical	69.44
4	Very Critical	11.11

19.44% of students were categorized as less critical, 69.44% critical, and 11.11% very critical. Even though only 11.11% of students were categorized as very critical, most were classified as critical. 19.44% of students in the less critical category, based on the initial test results, consisted of two students in the very less critical category, four students in the less critical category, and one student in the critical category. Student CTS increased except for one student whose initial category was critical. Based on the analysis of the final test answer sheets on basic clarification questions, all of them gave wrong answers without any arguments or with wrong arguments. This shows that the student needs to understand the concept better. Understanding concepts is an initial ability needed in problem-solving and critical and creative thinking (Wartono et al., 2019).

AR worksheets positively impact improving students' CTS through the inquiry-scaffolding model. Explaining in scaffolding provides insight into various arguments for the problems presented. Modeling provides visualization and simulation of abstract concepts through AR media so that students understand the physical events. At the end of each activity, questions are followed to encourage students to think deeper and look for appropriate arguments.

Through inquiry syntax, students are trained to focus on problems, formulate hypotheses, collect data, test hypotheses, and conclude. These stages require skills in providing arguments, making observations and assessing these observations, making inferences, defining terms based on criteria, and making decisions in solving problems.

Conclusions

Augmented reality worksheets with an inquiry-scaffolding model can train the CTS of physics education students at UIN Walisongo Semarang with an n-gain score of 0.30 in the medium category. Profile of CTS of physics education students at UIN Walisongo Semarang after learning using AR Worksheets with the inquiry-scaffolding model is categorized as significantly less critical with a percentage of 0.00%, 19.44% less critical, 69.44% critical, and 11.11% very critical. Augmented reality worksheets are structured with inquiry syntax and apply scaffolding procedures, namely explaining, modeling, and questioning, so that the student's final skills in each indicator of CTS, namely basic clarification, the base for a decision, inference, advance clarification, and supposition and integration, are increasing.

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