Improving the critical thinking skill of high school students: The context of tracker software applications

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This study aimed to improve students' critical thinking skills using the `Tracker` software application. The research design used was a pre-experimental design with a one-group pretest-posttest design model. The samples in this study were all students of class X Science 5, totaling 34 students. The simple random sampling technique was used. The data collection methods used were tests, documentation, and observation. The Wilcoxon and N-gain tests were used to analyze the data. The result of the Wilcoxon test using SPSS IBM 25 showed that the sig. 2-tailed was 0.000, meaning that the value was < 0.05 so that Ha was accepted. The N-gain results obtained were 70% and included in the medium category. Thus, this study proved that the use of the `Tracker` software improved students' critical thinking skills in the Work and Energy topic for class X Science 5 Public Senior High School 3 Yogyakarta.

Keywords: Critical thinking skills; `Tracker` software; high school students.

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1. Introducction

Education plays a significant role in preparing high-quality human resources in order to be able to build the nation's civilization. One of the qualities that are expected to exist in the next generation is a skill to master science and technology. Science is an important aspect of life related to the demands, challenges, and competitions in the era of globalization.

In addition, technology development in the era of the Industrial Revolution (IR) 4.0 brought its own challenges for humans. The era of IR 4.0 has brought the physical world into the digital world by visualizing real things in digital forms [1]. The IR 4.0 impacts various fields, including the world of education, especially in the physics subject.

Physics is one of the natural sciences that is widely used as a basis for other sciences. Physics is a science that studies natural phenomena and all the interactions related to them. As a science, physics is used as the basis for technology that continues to be developed [2]. Physics is one of the school subjects that plays an important role in education. Therefore, physics subject must be continuously improved and enjoyed by students [3].

The observation results made at Public Senior High School 3 Yogyakarta show that in the implementation of physics learning in class X Science 5, students have not been optimally active in solving problems given by the teacher while physics practices for Work and Energy topic is still carried out in the traditional way. Moreover, teachers only use `Google Classroom` for providing material and assignments, so that the use of technology is not optimal. The use of innovative information and communication technology in learning physics is very important. This is because technology can contribute to the quality of education so that it can be beneficial for teachers and students as well as being the basis of well-structured knowledge [4].

In the 21st century, technology plays an important role in the critical thinking skills of teachers and students [5]. This provides new insights in developing critical thinking skills through learning that is integrated with digital technology [6]. Aligned with [7], students' thinking should reach a higher level called critical thinking. Critical thinking skills are important for students to solve problems in science learning, so that learning objectives are achieved [8]. Learning with the help of digital technology can be combined with the guided inquiry model. The guided inquiry is a learning model that places students as subjects, which means that each student is encouraged to be actively involved in learning activities [9]. One way to realize this is by using the `Tracker` software.

The `Tracker` software is a tool designed to analyze an experiment in video form. This tool can help students in practice activities related to the movement of objects. So far, physics practice activities still use conventional methods by manual analysis. This has the potential for the data obtained to be less accurate. Through the `Tracker` software, students can analyze the movement of objects by displaying results in the form of tables and graphs. Analysis of the Tracker software is carried out by entering videos about natural phenomena, especially those related to the movement of objects such as distance, speed, acceleration, time, force, kinetic energy, potential energy, and gravitational field [10]. One example of the use of Tracker software is on the wave topics, *e.g.*: pendulum motion. The results obtained from [10] show that using `Tracker` software and manual calculations (formulas) do not produce a significant difference. Thus, the `Tracker`

software is more practical and effective when used in analyzing practical data.

The Tracker software can help analyze the movement of an object in the Work and Energy topics. This is because the topic is related to the motion of objects. In this case, we study the topic of Work and Energy in an inclined plane for high school students. Work and Energy are complex phenomena in physics learning because they are related to other concepts [11]. Through information obtained from the Tracker software, students are able to analyze and conclude the results of the inclined plane experiments. Tracker software helps students improve students' critical thinking skills. This is because in the inclined plane practice activity, students are trained to have skills in operating the Tracker software. Apart from that, students are trained to be able to understand concepts and formulas of the Work and Energy topics. In relation to critical thinking, through practice activities assisted by the Tracker software, students are able to observe, analyze data, and conclude. This is in accordance with [12], that students are categorized as critical thinkers if they can formulate questions, analyze, solve problems, and finally make decisions. Hence, with the help of the Tracker software, students' critical thinking abilities can be increased through the inclined plane practices on Work and Energy topics. However, students have not yet fully mastered critical thinking skills to solve a problem in the real world [13]. This is in line with a study in Ref. [14] that some students have low critical thinking skills. This is because students have difficulty analyzing and making inferences. A study from [15] also states that most students have low critical thinking skills. The task of teachers is to hone students' critical thinking skills in solving problems [16]. In order to achieve this, critical thinking skills in today's learning must be combined with digital literacy skills [17].

After making the inclined plane experimental video, students can apply the Tracker software to obtain information. From the information obtained, students are able to generate tables and graphs, *e.g.*: potential energy, force, power, mechanical energy, and kinetic energy. Hence, students are able to analyze and then conclude the results of the inclined plane experiment. This activity is one way to improve students' critical thinking skills. The ability to think critically is needed to explore situations, phenomena, questions or problems to develop hypotheses based on the information obtained so that students can conclude the truth. This is in accordance with the research of [18], that students possess critical thinking skills if they can formulate questions, analyze, solve problems, and finally make decisions.

The research done by [19] finds that students who received learning through guided inquiry-based laboratory experiments tended to have higher scores on various types of knowledge (conceptual, procedural test scores, and questions about science) and generally long-term retention better than students with traditional laboratory learning. This is because traditional experiments tend to take longer time in data collection, processing, and analyzing. Thus, the Tracker software is one of the solutions for maximum inquiry and investigation efficiency. Learning with inquiry can produce better learning for students. This is evident from the standardized test scores, which have a higher average when compared to traditional learning [20]. Furthermore, the results of research conducted by [21] state that online learning practices with Tracker software on partially elastic collision material can improve graphic interpretation skills. The analysis results of the average score of graph interpretation skills have increased with an N-gain of 0.39 and are in the moderate category. Therefore, based on the problems mentioned above, a study was conducted entitled: "Improving critical thinking skill of high school students: The context of the Tracker software application".

2. Research method

This was an experimental study. According to [22] experimental research methods were used to determine the effect of certain treatments on other controlled conditions. Hence, it can be understood that experimental research is always carried out by giving treatment towards research subjects and then seeing the effect of the treatment. The research design used was a pre-experimental design with a one-group pretest-posttest design model. This design was used because there was a pretest before the treatment was conducted. This design can be described in Table I.

This research was conducted from March to May 2023. Moreover, this study was done at Public Senior High School 3 Yogyakarta, which is located on Jl. Yos Sudarso No. 7, RT 05/RW 03, Kotabaru, Gondokusuman District, Yogyakarta City, Yogyakarta Special Region, 55224.

The samples in this study were students of class X Science 5, totaling 34 students. The simple random sampling technique was used. This sampling was done with the consideration that the students in the class were chosen randomly without looking at students' score, gender, and class. The samples in this study were students who were in the same class, received material based on the same curriculum, and received the same lesson time. Based on the simple random sampling technique, students of class X Science 5 were selected as the research sample.

This activity started with students taking a video of the inclined plane experiment. After obtaining the video, students used the Tracker software to find information. From the information obtained, students were able to determine the variables used in the Work and Energy topics. The variables

TABLE I. One group pretest and posttest design [22].

Pretest	Treatment	Posttest
01	X	02

Note: O1 was the pretest value before treatment with the Tracker software. X was the treatment done by applying the Tracker software. O2 was the posttest value after being given treatment.

measured in this study were potential energy, force, power, mechanical energy, and kinetic energy. The treatment in this study was the application of the `Tracker` software, while the dependent variable was the critical thinking skills with the indicator of students' knowledge (pretest and posttest).

The data collection methods used were tests, documentation, and observation. In the data analysis process, the Wilcoxon test was used to determine whether there was an increase in critical thinking skills while the N-Gain was used to determine the percentage of students' critical thinking abilities.

The analysis technique used was the difference test. A prerequisite test had been carried out before the different test was done, which was called the normality test. If the data were normally distributed, a parametric test namely the paired sample T-test would be performed. However, if the data obtained did not meet the prerequisites, a non-parametric test namely the Wilcoxon test on IBM SPSS 25 was performed. The different tests carried out in this study used the Wilcoxon test. The Wilcoxon test hypothesis was given as follows:

Ha: there was an increase in the critical thinking skills of class X Science 5 students.
Ho: there was no increase in the critical thinking skills of class X Science 5 students.

Furthermore, calculating the N-Gain score was based on the formula according to [23]:

$$\text{N-gain} = \left(\frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}} \right) \times 100. \quad (1)$$

TABLE II. N-Gain interpretation.

Percentage of N-Gain (%)	Interpretation
100 - 70	High
70 - 31	Medium
30 - 1	Low

The results of the N-Gain calculations were then interpreted based on the N-Gain interpretation table according to [24], which can be observed in Table II.

3. Result and analysis

Based on the results of the date analysis, it is found that the data are not normally distributed. Thus, a non-parametric test namely the Wilcoxon test is used with the help of SPSS IBM 25. This is done in order to determine the improvement in critical thinking skill. The results obtained can be observed in Table III.

TABLE III. Wilcoxon rank test results.

		N	Means Rank	Sum of Rank
Posttest-Pretest	Negative Rank	0^a	0.00	0.00
	Positive Rank	34^b	17.50	595.00
	Ties	0^c		
	Total	34		

Note: ^{a}Posttest pretest; ^{b}Posttest-pretest; and ^{c}Posttest = pretest

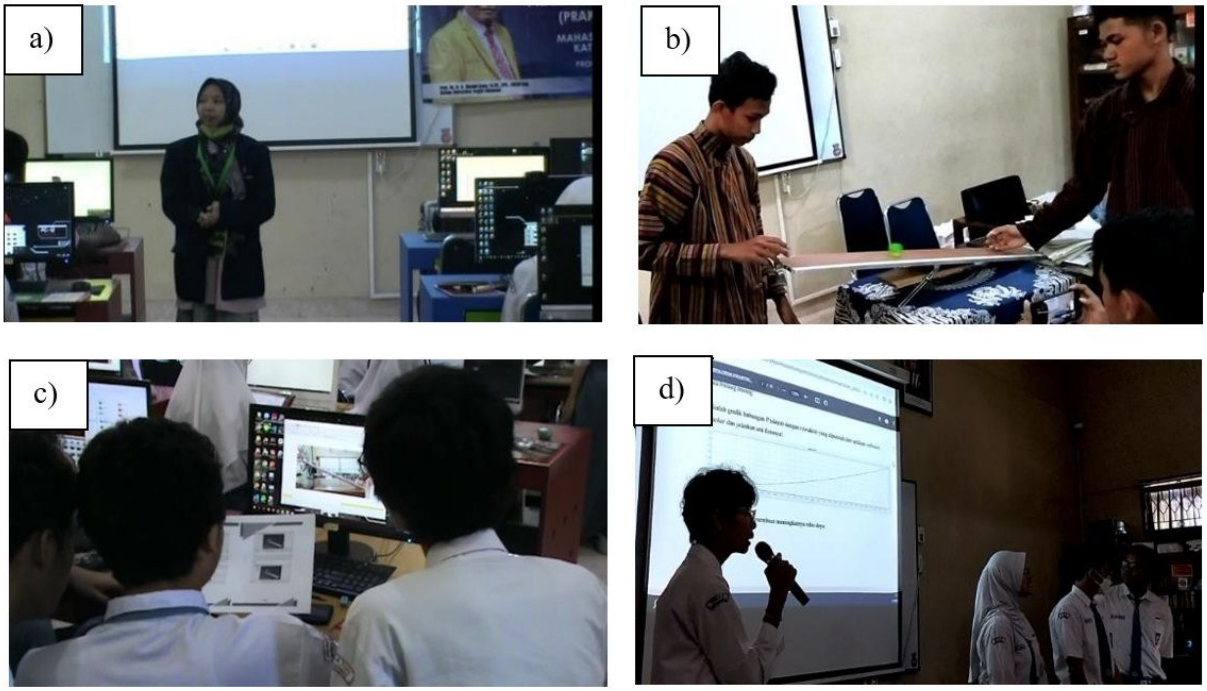

FIGURE 1. Various activities in this study: a) giving experimental instructions, b) taking videos, c) processing and analyzing data, and d) summarizing results.

TABLE IV. Results of the Wilcoxson test statistics.

	Posttest-Pretest
Z	-5.099[a]
Asymp. Sig. (2-tailed)	0.00

Note: [a]Based on negative ranks.

Based on the Wilcoxon test results with the help of IBM SPSS 25 in Table III, it can be seen that in the positive rankings there are 34 positive data (N). This means that 34 students experienced an improvement in critical thinking skill from pretest scores to posttest scores on Work and Energy material. Then, the mean rank or average increase is 17.50, while the total positive rank or sum of ranks is 595. Furthermore, the ties show zero (0), which means that there is no equal score between the pretest and posttest scores.

Based on the output test statistics in Table IV, it is known that asym. sig (2-tailed) of 0.000, which means that the value is < 0.05. This means that Ha is accepted and Ho is rejected. In other words, there is an improvement from the pretest to the posttest results of students' critical thinking skills. This happens because of the `Tracker` software treatment, where students are able to analyze and distinguish various kinds of graphical information, especially on Work and Energy topics. This is in accordance with the learning activities, which are documented in Fig. 1.

Figure 1b) shows that students were active in observation activities and taking video after being given instructions of using the `Tracker` software [Fig. 1a)], and also inserting the video into the `Tracker` software [Fig. 1c)]. The next activity was data processing by adding parameters in the `Tracker` software to determine the variables used, *e.g.*: potential energy, force, power, mechanical energy, and kinetic energy. Based on the information obtained, students were able to analyze and then conclude the results of the inclined plane experiment with the help of the `Tracker` software [Fig. 1d)]. In addition, learning was carried out using a guided inquiry model assisted by the Tracker software. This shows that applying the Tracker software improves students' critical thinking skills.

Furthermore, the data are analyzed using N-Gain to determine the percentage of students' critical thinking skills, which can be observed in Table V. Based on Table V, a value of 70% is obtained, which is included in the medium category. This means that students have the ability to understand the learning materials. The `Tracker` software is used during the learning process with the topics of Work and Energy. However, there were some students who did not understand the material presented. In addition, the `Tracker` software was a new thing for students. This is in accordance with the pretest and posttest results obtained, *i.e.*: 44 and 88, respectively. This means that there is an increase in the pretest to posttest results. The average results of the pretest and posttest can be seen in Fig. 2.

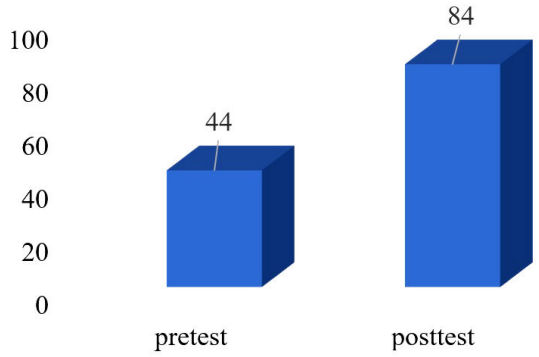

FIGURE 2. Average pretest and posttest results.

TABLE V. N-Gain analysis results.

	Lowest Score	Highest Score	N-Gain (%)	Category
Pretest	10	60	70	Medium
Posttest	80	100	70	Medium

4. Conclusion

Based on the results of the research above, it can be concluded that there is an improvement in students' critical thinking skills with the guided inquiry learning model using the `Tracker` software. Wilcoxon test results using SPPSS IBM 25 have sig. (2-tailed) value of 0.000, which means that there is an improvement in students' critical thinking skills in the Work and Energy topics. In addition, the N-gain test results have a percentage of 70% in the medium category. Furthermore, the pretest and posttest results show an average increase from 44 to 88.

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