Enhancing Science Process Skills Through AI-Based Virtual Laboratory in High School Physics Learning

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ABSTRACT
The advancement of technology, particularly Artificial Intelligence (AI), has significantly impacted various fields, including education. One of the AI-based applications that can be utilized in high school physics learning is the virtual laboratory. The use of virtual laboratories in physics education enables students to conduct interactive experiments without the limitations of physical tools and materials. This study aimed to analyze the effect of using virtual laboratories on students' science process skills in the topic of the kinetic theory of gases. The research method employed is an experimental approach with a one-shot case study with pretest-posttest design. The research instrument consists of a multiple-choice science process skills test with 15 questions, administered before (pretest) and after (posttest) the use of the virtual laboratory. The study results show the N-gain percentage of 40% suggests that the use of a virtual laboratory was less effective in enhancing students' scientific process skills. While the result of Wilcoxon signed-rank test 8,5 which can be concluded as there is a significant difference between the students' pre-test and post-test averages. These findings demonstrate that a virtual laboratory is less effective to enhance students' science process skills. Thus, the integration of AI technology in the form of a virtual laboratory should be combined with the right learning methods.

Keywords: *Artificial Intelligence (AI), virtual laboratory, science process skills*

1. INTRODUCTION

The rapid advancement of artificial intelligence (AI) today has progressed significantly, leading to its application in various fields of life. AI is a system capable of observing its environment, taking actions to maximize its chances of success, and learning from experience (Russell & Norvig, 2016). AI itself continues to be a vast and evolving field, adapting to the needs of the times.

One of the fields that has benefited from AI is education. AI can serve as a tool to enhance the quality of students' learning experiences. For teachers, AI can act as an assistant that provides interactive and easy-to-understand learning media, yielding significant results. In 21st-century skills, one of the competencies taught is digital literacy, which requires students to utilize technology, particularly in the learning process. The advancement of information and communication technology (ICT), which has given rise to AI, has significantly transformed the education sector, especially in teaching methods (Effendi & Wahidy, 2019).

A suitable application of AI in high school physics education is the virtual laboratory. Physics is often perceived as an abstract and difficult subject for students to grasp. Learning physics involves abstract processes that are not directly observable (Zulpar, 2020). The virtual laboratory is believed to be a solution to this challenge. A virtual laboratory is a computer simulation that allows students to conduct experiments virtually. It provides visualizations of abstract concepts that are otherwise difficult for students to imagine.

One of the abstract physics concepts is the kinetic theory of gases. This concept explains the behavior of gases based on the motion of their constituent particles. To gain a deep understanding of this concept, students need an interactive learning experience that engages multiple senses. Traditional experiments alone may not sufficiently help students grasp the concept. With a virtual laboratory, students can conduct experiments that are difficult or even impossible to perform in a real laboratory, such as directly observing the motion of gas particles.

Considering the rapid advancement of science and technology, students today are expected to possess strong scientific process skills. This shift moves the focus of learning from merely transferring concepts and facts to a process that requires scientific evidence and the development of attitudes and values (Semiawan et al., 1989).

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Virtual laboratories serve as relevant tools to meet this challenge. By providing a platform for virtual experiments, virtual labs enable students to develop scientific process skills through active exploration, variable manipulation, and observation of scientific phenomena, without the physical constraints of traditional laboratories.

Interviews with several high school teachers in Aceh revealed a crucial issue regarding the implementation of science education, particularly physics. It was identified that scientific process skills (SPS) are often overlooked in daily teaching practices. As a result, students inadvertently miss the opportunity to develop these fundamental competencies. Furthermore, a significant obstacle is the limited availability of laboratory equipment in most schools in the region, making it difficult for teachers to integrate experiments into the learning process. This situation causes students' learning experiences in class to be dominated by theoretical material delivery, without active engagement in practical activities that should serve as the foundation for a strong understanding of scientific concepts.

The virtual laboratory offers a solution for schools with limited equipment for conducting practical experiments. Virtual laboratories provide hands-on, interactive, and engaging experiences through animations and dynamic visuals. This approach aims to prevent boredom, motivate students to learn, facilitate effective concept comprehension, and ultimately enhance their cognitive abilities (Ramadhani & Nana, 2020). Some advantages of virtual laboratories include risk-free experimentation and the ability to offer learning experiences that are difficult to achieve in real life, either due to human visualization limitations or the unavailability of supporting facilities (Cobb et al., 2009).

Thus, this study aims to investigate the impact of virtual laboratory usage on improving scientific process skills in the kinetic theory of gases among high school students. The use of virtual laboratories is expected to provide a more engaging and interactive learning experience, making it easier for students to understand abstract concepts and enhance their scientific process skills.

2. METHODS

This study employs a quantitative approach. Quantitative data were obtained from the results of students' pre-tests and post-tests using the One-Shot Case Study research design. The study was conducted in a class at a high school in Aceh, with a total of 20 students. In this research, all students received the same treatment, followed by a test based on the given treatment. The One-Shot Case Study research design is presented in Table 1.

Table 1. One Shot Case Study Research Design

Pre-test	Treatment	Post-test
Y_1	X	Y_2

Description:
X = the treatment applied by implementing learning using a virtual laboratory.
Y1= the test given to students before the treatment/learning process.
Y2= the test given to students after the treatment/learning process.

The researchers began the study by conducting a survey at the school, interviewing the Physics subject teacher. The interview results provided information about the students' average scientific process skills. Subsequently, the researchers designed learning materials and assessments aligned with the research objectives and design, consisting of 15 multiple-choice questions. The research instrument was validated by experts and deemed suitable for testing.

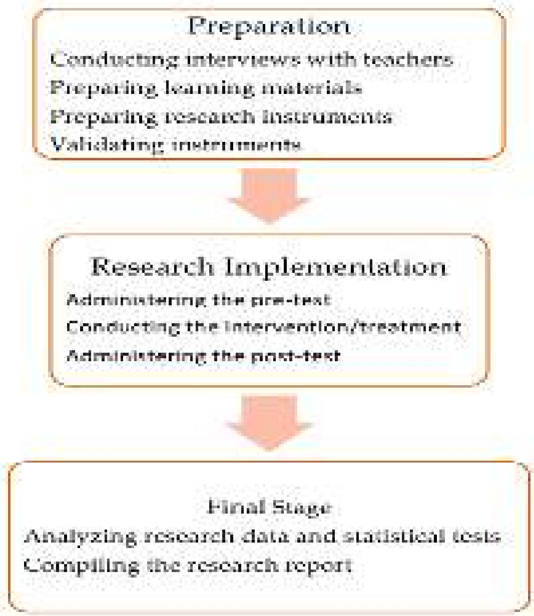

Figure 1. Research Flow

Next, the researchers conducted a pre-test, implemented the treatment by teaching the kinetic theory of gases using a virtual laboratory, and administered a post-test after the learning process was completed. The data collection techniques used were testing and documentation. The data analysis technique involved assessing students' scientific process skills through pre-test and post-test analysis using N-gain analysis and the Wilcoxon signed-rank test. The classification of N-gain scores can be seen in Table 2 below:

Table 2. N-Gain Score Category Classification

N-Gain Score	Category
$g \geq 0{,}7$	High
$0{,}3 \leq g < 0{,}7$	Medium
$g < 0{,}3$	Low

The categorization of N-gain test results is determined as shown in Table 3:

Table 3. Interpretation Category of N-Gain Effectiveness

N-Gain (%)	Interpretation
$g < 40$	Not Effective
$40 < g \leq 55$	Less Effective
$55 < g \leq 75$	Moderately Effective
$g > 75$	Effective

3. RESULTS & DISCUSSION

Based on the research conducted at a high school in Aceh, the pre-test and post-test scores of students were obtained as shown in Table 4.

Table 4. Students' Pre-Test and Post-Test Scores.

Data	Pre-test	Post-test
N	20	20
Min	13,3	6,7
Max	46,7	93,3
Mean	28,7	54,7
N-Gain Score		0,4
N-Gain Score (%)		40%

The pre-test results indicate that students' initial scientific process skills were relatively low. This is evident from the highest pre-test score recorded at 46.7, while the lowest score was 13.3. With an average pre-test score of 28.7, the data further supports the finding that students' scientific process skills were at a low level before the intervention.

After implementing the treatment using a virtual laboratory in learning the kinetic theory of gases, an increase in post-test scores was observed, with an average score reaching 54.7. The lowest post-test score was 40, while the highest was 93.3, indicating an improvement in students' scientific process skills. The calculated N-gain score of 0.4 suggests that this improvement falls into the moderate category based on the criteria in Table 2. However, the N-gain percentage of 40% suggests that the use of a virtual laboratory was less effective in enhancing students' scientific process skills.

Table 5. Wilcoxon Signed-Rank Test Results.

W value	W table
8,5	52
H_0 is rejected	

The collected data was then processed using the Wilcoxon signed-rank test. The test results showed W value is 8.5. Based on the criterion that if W value < W table, then H_0 is rejected and H_a is accepted, it can be concluded that there is a significant difference between the students' pre-test and post-test averages. Overall, these findings indicate that technology-based learning approaches, such as the use of virtual laboratories, were less effective in significantly improving students' scientific process skills.

Although the study results showed an improvement in students' scientific process skills, several challenges may have been encountered during the learning process, potentially influencing research bias, such as:

1. Students' digital literacy levels – Not all students have strong digital literacy. Those who are less familiar with using technology and AI in learning may struggle to operate the virtual laboratory.
2. Motivation and participation challenges – Some students may be less motivated to engage in technology- and AI-based learning, especially if they have little interest in science or are not accustomed to this learning environment.
3. Teachers' ability to manage the virtual laboratory – The effectiveness of learning with a virtual laboratory also depends on the teacher's ability to manage the technology. Teachers who are not well-trained in using virtual laboratories may face difficulties in delivering the material optimally.
4. Limitations of the learning model – The effectiveness of virtual laboratory-based practical learning also depends on the learning model used by teachers in the classroom. It is necessary to align the learning model with the virtual laboratory to optimize student engagement and understanding.

4. CONCLUSION

Based on the research data and analysis presented, the obtained N-gain score of 0.4 concludes that the use of a virtual laboratory in learning the kinetic theory of gases is less effective in improving students' scientific process skills. According to the results of the Wilcoxon signed-rank test, the virtual laboratory led to an increase in post-test scores compared to the pre-test. However, it did not fully support students in acquiring scientific process skills. Therefore, further research on this topic is needed, considering other variables in the future.

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