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The effectivity of science manipulative based smart class virtual laboratory to improve science process skill

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Abstract

This study aimed to determine the effectiveness of using a smart class virtual laboratory based on Science Manipulative Learning with the dimensions of the Pancasila student profile through PhET Simulation and OLABS on the science process skills of PGSD students. This research is an experimental study with a research design of a nonequivalent control group design and sampling technique by purposive sampling. The sample in the study was PGSD students in semester 2 of the SD Science Laboratory course in Group J and M, totaling 50 people. Data collection techniques used tests and non-tests. Tests are used to measure science process skills through Pre-test and Post-test. Non-test is used to observe student activities during learning using a smart class virtual laboratory based on science manipulative learning through PhET Simulation with observation sheets and questionnaires. Data analysis techniques use the Normality Test of gain (Normalized-Gain), Homogeneity Test, Test the effect between variables using a Paired Sample T-test, and the effect between variables using an Independent T-test. The results and analysis can conclude that implementing Smart Class Virtual Laboratory Based on Science Manipulative Learning Dimensioned Pancasila Student Profile Through PhET Simulation and OLABS could effectively improve science process skills. This is evidenced by the pre-test and post-test N-Gain test values, which obtained a score of 0.8 with a high increases in the category.

INTRODUCTION

Background of the Study

Science learning is a vehicle for improving knowledge, skills, attitudes and values as well as responsibility for the environment. Science learning is also related to how to find out about nature systematically, so that science learning is not only mastery of a collection of knowledge in the form of facts, concepts or principles, but also a discovery process. Science learning has characteristics, namely a science that is entitled to processes, products, and attitudes, so that science learning should involve process skills and thinking processes through the scientific method in order to form mastery of concepts (Jannah et al., 2014). Therefore, laboratory activities that are practicum or experiments or observations are characteristic and integrated in the science learning process.

Laboratory activities in the nature of practicum or experiment or direct observation have a very important role, as a vehicle for developing basic skills of observing or measuring and other process skills. Furthermore, the laboratory as a vehicle to prove concepts or laws of nature so that it can further clarify the concepts that have been discussed previously, and the laboratory as a vehicle to develop thinking skills through the problem-solving process in order for students to find their own concepts. Through this role, the laboratory has been used as a vehicle for learning how to learn (Cahyaningtyas et al., 2019).

Science learning activities introduce three integrated activities, namely observation of natural phenomena (empirical activities through experiments), reasoning to explain the results of these observations, and testing the suitability of theories, concepts, principles, and laws with natural reality (verification activities through experiments) through learning in theory and practicum. The existence of a laboratory is one of the keys to success in introducing these three integrated activities. However, the Covid-19 pandemic that occurred in early 2020 had an impact on science learning itself. One of the impacts is the limited activities of students in utilizing the laboratory which results in the low science process skills of students (Anfa et al., 2021; Anggrella et al., 2021; Fathurrahmaniah et al., 2021).

Science process skills (KPS) are very important skills to develop students' scientific attitudes and problem-solving skills, so as to produce students who are creative, critical, open-minded, innovative and competitive in global science competition. Science process skills consist of 2, namely basic and integrated skills. Basic skills include observing, classifying, predicting, measuring, concluding, and communicating. Integrated skills include identifying variables, tabulating data, presenting data in graphical form, describing relationships between variables, collecting and processing data, analyzing research, formulating hypotheses, defining variables operationally, designing research or experiments.

Technical problems in the use of real laboratories can be overcome by simulating using virtual laboratories (Cahyaningtyas & Ismiyanti, 2022). The more often students practice / practicum, the more they will understand the teaching material, as well as provide a positive response and attract students' interest and interest in learning activities. The combination of the use of both, known as smart class virtual laboratory.

Smart class virtual laboratory is one form of technology that can be applied to empower Information and Communication Technology (ICT) through the use of virtual laboratory simulation in science learning carried out in real laboratories (Permana et al., 2016). All physical devices and components within the laboratory will become an integrated whole used to assist in monitoring, managing classrooms and laboratories in real time (Fanshuri et al., 2018).

Problem of The Study

Entering the endemic period, teaching and learning activities gradually returned to normal. However, practical learning activities in the Elementary School Teacher Education (PGSD) Study Program, Semarang State University still have obstacles, one of which is the limited practical equipment. This hampers students in carrying out practicum activities in the laboratory because there are no facilities that support these activities so that they cannot develop their KPS (Dewa et al., 2020).

Learning science about electricity is one of the branches of material that is considered difficult by students. This is evidenced by the preliminary study that electrical material is abstract material so it is not easy to understand. As many as 87% of students stated that electricity is a difficult material (Syahidi et al., 2019). The reasons that make electrical material difficult to understand include abstract material, lack of circuit analysis, and less than optimal practice (Hesti et al., 2020). In addition, this results in low student science process skills ranging from aspects of observing, interpreting observations, making hypotheses, designing experiments, conducting experiments, analyzing data, and communicating results. In addition, it results in the low application of mutual cooperation, critical and creative reasoning which is part of the realization of the Pancasila Student Profile.

Virtual laboratories can be part of the preparation and special training in real laboratory activities on measurement material using a push-piece and scrup micrometer, simple aircraft with the concept of lever / lever equilibrium, and electricity, so that it can be done repeatedly to train accuracy in observation without causing cost and safety problems. In addition, by applying simulation learning media that uses a practicum/experiment approach, the students will be able to learn how to use simulation learning media (Fithriani et al., 2016).

Research's State of the Art

Virtual laboratories have many advantages, among others, can save the cost of procuring experiments and improve student understanding, meaning that through virtual laboratories students can manipulate variables and collect data quickly and repeatedly. One of the interactive simulation media that has been widely used to support science learning in schools is PhET Simulation and OLABS (Online Laboratory) (Pratiwi et al., 2021). The use of PhET-Simulation and OLABS can be a virtual laboratory in science learning.

PhET is an interactive simulation software based on research and licensed free software (Cahyaningtyas et al., 2022). PhET simulation offers interactive simulations that allow learners to virtually run experiments, design scenarios, and observe the results. This approach allows learners to explore scientific concepts in a more intuitive and engaged way, providing a more immersive learning experience.

On the other hand, OLABS (Online Laboratory) is a virtual laboratory application that provides physics, chemistry, and biology materials and experiments that can be accessed anytime and anywhere. The OLABS application overcomes the time constraints felt by students when only accessing the real laboratory in a short time. Features such as real time simulation, accurate measurements and experimental flexibility make OLABS a valuable resource in integrating science learning into a digital learning environment.

Learning with the application of simulation methods to complement practicum activities is proven to improve students' science process skills on the material taught. Virtual laboratory is a form of laboratory with observation and experiment activities carried out using computer software with a display like real laboratory equipment (Ismiyanti et al., 2019). The analysis of student performance and participatory responses to these two platforms provides valuable insights into their potential use as learning aids that can improve the absorption and mastery of science materials. As part of the ongoing effort to improve the quality of science education, this research offers critical insights into the potential and constraints of adopting virtual laboratory technologies such as PhET-Simulation and OLABS in the context of science learning at the tertiary level.

Novelty Research Gap, & Objective

The use of virtual laboratories is one of the simulation learning media solutions before students learn the material directly in a real laboratory. The novelty of this topic lies in the utilization of simulation technology and virtual laboratories to create a more interactive, intuitive, and flexible learning experience especially in Science Learning at the college level.

Although the use of PhET-Simulation and OLABS in science learning shows great potential, there are research gaps that need to be explored further. Not many studies have discussed how the use of virtual laboratories using PhET simulation and OLABS. In addition, there has been no in-depth research that specifically looks at implementation challenges and strategies to maximize the effectiveness of PhET-Simulation and OLABS in improving science process skills in science learning outcomes at the university level. Therefore, further research is needed to examine more deeply the effectiveness of using virtual laboratories through PhET simulation and OLABS in science learning at the university level.

Based on the background described above and some research results conducted previously, it is necessary to conduct research on the Effectiveness of the Application of the Use of Smart Class Virtual Laboratory Based on Science Manipulative Learning with Pancasila Student Profile Dimensions through PhET Simulation and OLABS on Science Process Skills for PGSD students.

METODE

Type and Design

This research is an experimental study using a nonequivalent control group design, where the control and experimental groups are not randomly selected (Maulidiana et al., 2021). This design model is also drawn on two different groups, one experimental group is treated using a smart class virtual laboratory based on science manipulative learning and the control group uses power point media and YouTube. The population in this study were PGSD students in semester 2 in the 2022/2023 academic year who took the Elementary Science Laboratory course. The samples in the study were Group J and Group M students, totaling 25 students each. The research site was at the Ngaliyan PGSD campus, Faculty of Education, Semarang State University, Semarang City, Central Java with a research time of 8 months from April to November 2023.

Data and Data Sources

The instrument consisted of objective questions given during the pretest and posttest. These questions are used to determine the results of students' process skills, before and after treatment. The questions used for the pretest and posttest are the same, only the question numbers are different. The learning implementation observation sheet is an observation sheet used to check the implementation of all learning activities carried out at each meeting.

Data Collection Technique

The data collection technique used was a test in the form of a questionnaire. The test was used to measure students' science process skills. The instrument used was a subjective test in the form of multiple choice questions totaling 30 items. The questions were arranged based on learning objectives and indicators of science process skills, which include aspects of observing, interpreting observations, making hypotheses, designing experiments, conducting experiments, analyzing data, and communicating results.

Achievement of science skills ability with the following equation (Sukma et al., 2022):

$$KPS\ Percentage = \frac{\sum \text{Student scores}}{\text{Maximum score of items}} x\ 100\%$$

The percentage of science process skills is grouped into five categories which can be seen in table 1 below (Ismiyanti et al., 2023):

Table 1. Category of Science Process and Observation Skill

Percentage	Category
81% - 100%	Excelent
61% - 80%	Good
41% - 60%	Moderate
21% - 40%	Bad
0% - 20%	Too Bad

Data Analysis

The data analysis technique used in this study uses the normalized-gain formula, namely the increase in the results of the initial test and the final test of concept comprehension Meltzer in (Husein et al., 2015):

$$g = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}}$$

Criteria of N-gain levels can be seen in the following Table 2:

Table 2. Category of N-gain Level

Batasan	Kategori
g > 0,7	High
0,3 ≤ g ≤ 0,7	Moderate
g < 0,3	Low

Comparison of N-gain equivalents between experimental and control classes using t-test at a significant level of 5% after going through the normality test and homogeneity of data variance.

RESULT

The calculation of the N-gain value in each aspect of KPS aims to determine the improvement in each aspect after the application of virtual laboratory support with a directed inquiry learning model. As a result, there was an increase in all aspects of KPS. The N-gain value on each aspect of KPS is listed in Table 3 below:

Table 3. Category of N-Gain value for each aspect of Science Process Skill

Aspect of Science Process Skill	N-Gain			
	Experimental Class	Category	Control Class	Category
Observation	0,7	High	0,4	Moderate
Classification	0,8	High	0,5	Moderate
Measurement	0,9	High	0,2	Low
Prediction	0,8	High	0,3	Low
Conclusion	0,6	Moderate	0,3	Low
Communication	0,7	Moderate	0,5	Moderate
Average	**0,8**	**High**	**0,4**	**Moderate**

Based on table 3. shows the average N-gain of students' science process skills in the experimental group is in the high category with an average value of 0.8. Meanwhile, in the control group, the average N-gain value is included in the medium category with an average value of 0.4. It is known that of the six aspects of KPS observed in the experimental and control groups, the measuring indicator in the experimental group has the highest value of 0.9 while the lowest value of 0.2 (low category) is in the measuring indicator in the control class.

The calculated results of the N-gain score test above, show that the average value of the N-gain score for the experimental class is 0.8 including the high category. While the average N-gain score for the control class is 0.4 including the medium category. The students' process skills scores were then analyzed statistically with an independent sample t-test to determine the difference between the experimental and control class averages. The t-test results showed that the 2-way significance value of 0.000 <0.05. So there is a significant difference in point scores between the control and experimental groups.

This research data is in the form of student science process skills data obtained from the observation sheet of science process skills in the experimental class and control class. The recapitulation of classical students' science process skill scores on each aspect of science process skill is presented in Figure 1 below.

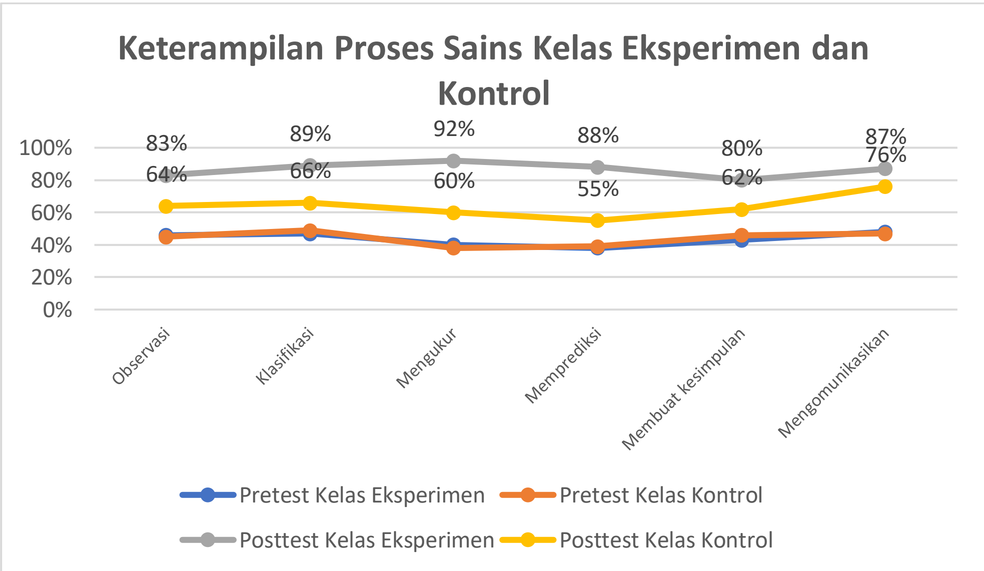

Figure 1. Science Process Skill Improvement Diagram: Pre-test and Post-test

Figure 1 above shows the percentage of KPS in the experimental and control classes before and after treatment. There is a significant difference in terms of the percentage value of each indicator in the experimental and control classes. The measuring indicator in the experimental class has the highest value of 92% with a very good category. Furthermore, the lowest value was found in the indicator of making conclusions in the control group with a value of 55% (sufficient category).

Based on this, it can be seen that the application of smart class virtual laboratory based on science manipulative learning with the dimensions of the Pancasila student profile through PhET Simulation and OLABS in the experimental class is better in improving science process skills compared to the control class.

DISCUSSION

Observing or observation activities provide more meaningful learning to students directly by observing events in their environment. The results of the study prove that science learning with the help of virtual laboratories observation skills have a very good category of 83% compared to learning with the help of YouTube and power points in the good category of 64%. This activity is very important and fundamental in the process of science process skills. The ability to make observations is the most basic skill in science and is the fulcrum and important for the development of other process skills (Devita Cahyani Nugraheny, 2018; Yuliati, 2016).

Classification skills are the process of grouping objects based on observable properties. Classification skills in the experimental group as a whole were in the excellent category with a percentage of 89%, while in the control group they were in the good category at 64%. This is because experimental class students get treatment using a virtual laboratory to conduct experiments in classifying objects independently.

Measuring skills consist of three indicators, namely measuring using units according to the level of accuracy, using standard measurements to describe objects and making comparisons. The results showed that the experimental class as a whole was in the excellent category with a percentage of 92%, while the control class was in the sufficient category with a percentage of 60%. The practicum carried out in the virtual laboratory has almost no significant obstacles because measuring instruments are available and the media is easily installed so as to minimize the occurrence of measurement errors, therefore students can more easily draw the right conclusions. It is in line with Nurdiansah & Makiyah, (2021) suggesting that laboratory-based learning can also involve students in obtaining learning experiences so that it can improve students' science process skills..

Prediction skills are the ability to use data/facts to formulate the next sequence of processes, calculate cases with patterns based on existing data and the ability to predict the next event/occurrence. The results showed that the experimental class as a whole was in the excellent category with a percentage of 88%, while the control class was in the sufficient category with a percentage of 55%. One of the factors for using virtual laboratories is very good because virtual laboratories can provide opportunities for students to do practicum either through or without the internet which allows students to be able to access independently and repeatedly. In similar, Andriani et al., (2024) suggested that The use of laboratories becomes effective learning because students can learn on their own actively without the help of instructors or assistants as it goes.

The ability to make conclusions is an interpretation of data / facts by linking the results of the theory with the results of the experiments carried out and being able to answer questions from the results of the experiments carried out. The results showed that the experimental class and control class as a whole were in the good category with a percentage of 80% and 62% respectively. The difference in the value of the ability to make conclusions before and after the application of the virtual laboratory and the use of YouTube and power point as a support for learning in the real lab occurs because through visual media, students get a representation of the material presented. The use of virtual media in learning is proven to be able to improve students' thinking skills because it can describe and explain abstract concepts and present a more complete physical process (Yahya & Fitriyanto, 2018).

Communicating skills are the ability to provide / describe experimental data in the form of graphs, diagrams or tables, compile reports systematically, coherently and clearly. The results showed that the experimental class and control class as a whole were in the good category with a percentage of 86.5% and 63.8% respectively. Most students have been able to communicate the results of experiments using graphs or diagrams clearly but are still lacking in compiling reports systematically. According to (Fitriana et al., 2019) Communicating skills actually refers to a group of skills, all of which are a form of systematic data reporting.

The use of PhET simulation supported by modules and good teaching plans can improve student achievement (Najib et al., 2022). Through laboratory activities, students are designed and directed to be directly involved in constructing science knowledge and skills through the science process (Fatimah, 2016; Nasution et al., 2014). In addition, the use of PhET virtual laboratory has a positive influence on students' critical thinking skills (Aca et al., 2020; Darwis & Hardiansyah, 2023; Suganya, 2022).

In general, the results of this study found that the use of virtual laboratories and YouTube and powerpoint can improve science process skills in the science learning process. However, the use of virtual laboratories using PhET simulation and OLABS has high effectiveness in developing students' science process skills. The completeness of features in PhET simulation media such as static images, animations, videos and simulations can keep students interested during the learning process (Rizaldi et al., 2020). Another factor that makes using Smart Class Virtual Laboratory based on Science Manipulative Learning through PhET Simulation and OLABS more effective is that educators can more easily explain to students about the meaning and form of the learning provided. In the end, it can attract students to make them ask various questions (Masita et al., 2020). This has resulted in increased student achievement in learning science and a keen interest in science development (Çetinkaya & Kırılmazkaya, 2022).

CONCLUSION

Based on the results and analysis data, it can be concluded that the application of Smart Class Virtual Laboratory Based on Science Manipulative Learning with Pancasila Student Profile Dimensions through PhET Simulation and OLABS on Science Learning material effectively improves students' science process skills. This is evidenced by the pretest and posttest N-Gain test values obtained a score of 0.8 with a high category increase. The increase in each aspect of students' science process skills has different categories, namely observation, classification, measurement and prediction skills have a high category, while making conclusions and communicating have a medium category.

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