Using Multimedia Interactive Web Blog Science Virtual Laboratory to Improve Students' Critical Thinking and Concept Mastery

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Article History:
Received: Aug 07, 2023
Revised: Sep 07, 2023
Accepted: Dec 24, 2023
Online First: Jan 02, 2024

Keywords:
Concept Mastery,
Critical Thinking Ability,
Multimedia,
Virtual Laboratory.

Kata Kunci:
Laboratorium Virtual,
Multimedia,
Penguasaan Konsep,
Kemampuan Berpikir Kritis.

How to cite:
Andriani, A. E., Sulistyorini, S., & Sunarso, A. (2024). Using Multimedia Interactive Web Blog Science Virtual Laboratory to Improve Students' Critical Thinking and Concept Mastery. *Edunesia : Jurnal Ilmiah Pendidikan*, *5*(1), 461-473.

Abstract: The presence and condition of laboratories are critical factors in the success of learning activities through practical work, thereby improving student motivation and interest in learning. This research aims to determine the utilization of a virtual laboratory in improving critical thinking skills and mastery of science concepts for Elementary School Teacher Education (PGSD) students. The research used an experimental method utilizing a quasi-experimental design, specifically a nonequivalent control group design. Purposive sampling was the chosen sampling technique, and the research sample comprised 42 second-semester students from the Elementary School Teacher Education Department enrolled in the Elementary School Science Laboratory course. The samples were intentionally divided into two groups: Group K, the experimental group, and Group O, the control group. A multiple-choice test served as the data collection instrument. The collected data were analyzed using the N-Gain formula and t-test. The N-Gain results for concept mastery in the experimental group are 0.5%, and in the control group, it is 0.3%. Meanwhile, the average score for critical thinking skills in the experimental group is 80.77, and the average score for the control group is 76.31. Therefore, using a virtual laboratory affects students' mastery of concepts and critical thinking skills in Natural Science.

Abstrak: Keberadaan dan kondisi laboratorium menjadi kunci utama keberhasilan kegiatan pembelajaran melalui praktikum sehingga mampu meningkatkan motivasi dan minat belajar bagi mahasiswa. Tujuan dari penelitian adalah untuk mengetahui pengaruh laboratorium virtual dalam meningkatkan kemampuan berfikir kritis dan penguasaan konsep IPA bagi mahasiswa PGSD. Penelitian ini merupakan penelitian eksperimen menggunakan metode penelitian quasi experiment, menggunakan desain penelitian nonequivalent control group dan pengambilan sampel dilakukan melalui purposive sampling. Sampel penelitian terdiri dari mahasiswa semester 2 Jurusan Pendidikan Guru Sekolah Dasar yang mengambil mata kuliah Laboratorium IPA SD sebanyak 42 sampel dengan pembagian Rombel K sebagai kelompok eksperimen dan rombel O sebagai kelompok kontrol. Instrument yang digunakan untuk pengumpulan data adalah tes yang dibuat dalam bentuk pilihan ganda. Data yang diperoleh dianalisis dengan rumus statistic N-Gain dan uji-t. Hasil N-Gain penguasaan konsep kelompok eksperimen sebesar 0,5% dan kelompok kontrol 0,3%. Sementara itu, rerata nilai kemampuan berpikir kritis kelompok eksperimen sebesar 80,77 dan rerata nilai kelompok kontrol sebesar 76,31. Oleh karena itu, dapat disimpulkan bahwa penggunaan laboratorium virtual berpengaruh terhadap penguasaan konsep dan kemampuan berpikir kritis mahasiswa pada materi Konsep IPA.

https://doi.org/10.51276/edu.v5i1.704

A. Introduction

Critical thinking skills in Indonesia, as assessed by the Programme for International Student Assessment (PISA), are observed to be relatively low. This is evident from the 2018 PISA evaluation results, where Indonesia ranked 72 out of 79 participating countries. PISA is a measurement tool to evaluate literacy, numeracy, and science abilities among 15-year-old students worldwide. According to the PISA findings, Indonesian students' literacy skills ranked 64th, numeracy skills ranked 67th, and science skills ranked 70th. Thus, these evaluation results depict Indonesian students' challenges in comprehending and analyzing information, solving problems, and cultivating creative thinking skills (OECD, 2019).

According to Maulidya (2018), thinking involves various activities that utilize concepts and symbols as substitutes for objects and events. Critical thinking is analyzing situations based on facts and evidence to conclude. Students must cultivate the necessary thinking skills to prepare for present and future challenges and concerns (Manurung et al., 2023). Developing critical thinking skills is essential for solving problems and more effectively concluding various possibilities (Syafitri et al., 2021).

Critical thinking is a skill inherent in every individual, involving the analysis of ideas or concepts with a focused approach to acquiring pertinent knowledge about the world through the assessment of evidence. According to Adinda, as cited in Irdayanti (2018), individuals capable of critical thinking can conclude what they know, understand how to use the information to solve problems, and seek relevant sources to support problem-solving.

According to Saifina & Tanjung (2020), every learning process begins with introducing concepts to provide students with a solid foundation to achieve other fundamental skills such as reasoning, communication, and problem-solving. When understanding concepts is sound, learners can grasp and remember various learned concepts and express them in easily understandable forms. The selection of appropriate models, methods, and learning strategies will assist students in achieving optimal learning outcomes, including conceptual (Dewi & Ibrahim, 2019).

The development of critical thinking skills and students' understanding/mastery of Natural Science (IPA) materials can be achieved through laboratory activities (Yulianto et al., 2014). Kelengkapan yang tidak memadai dari alat-alat praktikum dapat menyebabkan penurunan intensitas pelaksanaan praktikum. Inadequate laboratory equipment can lead to a decrease in the intensity of laboratory activities. Efforts to address low laboratory activity intensity can be made by utilizing Information and Communication Technology (ICT) to present virtual laboratories (Permana et al., 2016). With this approach, students can access and participate in laboratory activities through simulation or virtual environments, enhancing accessibility and flexibility in practical learning.

Learning Natural Science (IPA) serves as a platform to improve knowledge, skills, attitudes, values, and responsibility towards the environment. Natural Science learning is also related to a systematic search process with various strategies resulting in a dynamic knowledge collection (Arief, 2021). Natural Science learning should involve process skills

https://doi.org/10.51276/edu.v5i1.704

and thinking processes through scientific methods to establish conceptual mastery. Essentially, Natural Science learning requires the existence of a laboratory as part of its practice. The laboratory is pivotal in implementing natural science learning, allowing students to engage directly with and apply the material they are studying in natural science (Agustina, 2018).

A laboratory is designed to train students in conducting experiments, demonstrations, research, and cultivating a scientific attitude. Practical activities, such as laboratory work, can improve motivation and learning interest among students (Bahtiar, 2017). Essentially, laboratory work is inseparable from the learning process in natural science education. According to Cain and Evan, as cited in (Asna & Sumilah, 2017), science encompasses four elements: content or products, processes or methods, attitudes, and technology. All these elements should be integrated into the learning process. Science education should cover concepts, principles, or theories and include the scientific processes taught through practical activities.

Difficulties emerge when the essential role of the laboratory in the teaching and learning process is impeded by constraints in available facilities and infrastructure, along with insufficient adaptability to technology utilization in the context of online learning. The absence of laboratory practical activities significantly affects students' experiences conducting experiments and research stages and hampers their skills using various laboratory equipment (Saraswati & Mertayasa, 2020).

During the COVID-19 pandemic, the delivery of conceptual content for natural science (IPA) practical activities in the Elementary School Teacher Education Program (PGSD) at Universitas Negeri Semarang was limited to learning materials. Subsequently, students simplified the concepts of modified practical activities and adjusted to their surroundings' available tools and materials through recording activities. These recordings were then edited and shared on YouTube channels or Google Drive. The YouTube or Google Drive links were distributed to class communication platforms, where other students observed and discussed them in groups. This led to discontinuing in-person laboratory practical activities, significantly affecting students' experiences conducting experiments and research stages.

The decline in students' skills in using various laboratory equipment is a concern, particularly as the role of the laboratory in the teaching and learning process in natural science education is hindered by limitations in available facilities, infrastructure, and the low adaptability to technology use during online learning. Such conditions reduce direct practical activities, depriving students of the expected experience and knowledge. Additionally, if students merely listen to explanations and prioritize completing material without considering the importance of student activities, they may need a comprehensive understanding to memorize concepts. However, interactive multimedia can affect students' engagement and knowledge (Oktavia, 2020).

Current research efforts to develop practical learning focus on integrating information technology, particularly virtual forms (Alatas, 2018). A virtual laboratory

https://doi.org/10.51276/edu.v5i1.704

involves observation or experimentation using software running on a computer, encompassing all the necessary equipment within the software (Dwiningsih et al., 2018). A virtual laboratory is described as an interactive multimedia object. The videos, animations, and other elements in virtual laboratory media are highly interactive and user-friendly, making the learning experience enjoyable. Virtual laboratories represent complex and new digital forms of multimedia objects designed for implicit or explicit learning objectives (Hermansyah et al., 2015; Ismail et al., 2016). Interactive multimedia objects comprise various heterogeneous formats, including text, hypertext, sound, images, animations, videos, and graphics (Bajpai & Kumar, 2015; Gunawan et al., 2017; Sypsas & Kalles, 2018).

According to Darby-White et al (2019), virtual laboratories have enhanced students' understanding. Additionally, it can improve students' critical thinking (Rokhim et al., 2020). In practical activities, virtual laboratories provide educational applications through computer or smartphone-assisted physical and chemical simulations and replicas of natural phenomena and experimental conditions (Widowati et al., 2017).

In general, this research aims to improve students' critical thinking skills and conceptual understanding within the scope of natural science education. Specifically, the study aims to investigate the effect of virtual laboratories on improving critical thinking abilities and mastery of natural science (IPA) concepts among Elementary School Teacher Education Program (PGSD) students.

B. Method

This research used an experimental design using a quasi-experimental research method with a nonequivalent control group design. The sampling technique utilized purposive sampling. The study was conducted at the Elementary School Teacher Education Program (PGSD) Ngaliyan campus, Faculty of Education, Universitas Negeri Semarang, Semarang City, Java Tengah. The subjects of this research were second-semester Elementary School Teacher Education Program (PGSD) Ngaliyan students in the academic year 2021/2022. The sample consisted of 42 participants, specifically students in the second semester of the Elementary School Teacher Education Department enrolled in the Science Laboratory course in Class K as the experimental group and Class O as the control group. The data collection instrument employed was a multiple-choice test. The data analysis techniques included normalized gain, homogeneity test, paired sample T-test to examine the effect between variables, and independent T-test to assess the effect between variables.

https://doi.org/10.51276/edu.v5i1.704

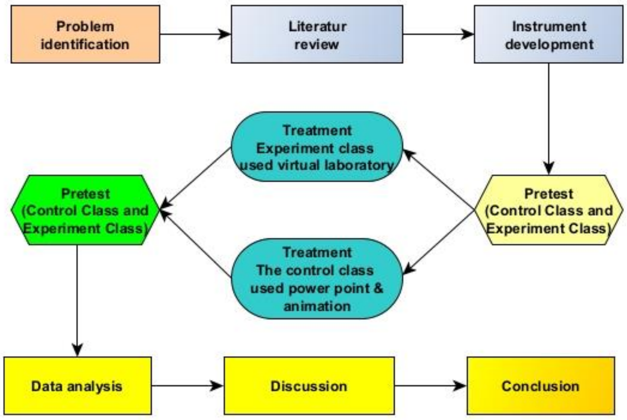

Figure 1. Research Method Flowchart

C. Result and Discussion

Result

The research aimed to explore the utilization of virtual laboratories in improving students' mastery of science concepts and critical thinking abilities.

Figure 2. Researcher Demonstrating the Virtual Laboratory

As illustrated in Figure 2, the researcher explained the interface and the process of accessing the Virtual Science Laboratory application to the students. The application comprises main page components, user instructions, content, evaluation, and developer profiles. The main page includes the material title and student identity information, including name and class. The user instructions section contains icons and button functions to guide students and provide an overview of accessing the application. The content section incorporates a blend of learning media, including text, images, instructional videos, and a virtual laboratory featuring the practice of determining human blood types. Integrating various media in the content aims to facilitate students' critical thinking skills and concept mastery. The final section is the evaluation, which consists of practice questions to deepen students' understanding.

https://doi.org/10.51276/edu.v5i1.704

Figure 3. Access to the Virtual Laboratory: Group Discussion

Based on Figure 3, students access the Multimedia Interactive Weblog Science Virtual Laboratory application through group discussion activities that facilitate critical thinking and concept mastery. Thinking critically is essential for students to analyze problems and seek solutions related to the human circulatory system, mainly blood grouping. Moreover, using this application in group discussions can facilitate students' understanding of the basic concepts of blood types.

1. Students' Concept Mastery Utilizing Virtual Laboratories and Those Not Utilizing Virtual Laboratories

Before conducting the second round of lessons, both classes underwent a pre-test using 40 questions to assess students' concept mastery. The collected data was then processed, and the results of the pre-test for concept mastery in both class groups are presented below:

Table 1. Pre-test Concept Mastery Data Processing Results

Data	Class	
	Experiment	**Control**
N	21	21
Highest Score	72	77
Lowest Score	51	45
Average Score	63,3333	64,5714
Std. Deviation	6,55998	8,76112
Sig. Normality	0,214	0,571
Sig. Homogeneity	0,442	
Independent T-test Sig. (2-tailed)	0,448	

Table 1 reveals that the average concept mastery score for the experimental class is 63.33, whereas the control class has an average concept mastery score of 64.57. Both experimental and control classes exhibit normal distribution and homogeneous variation in concept mastery scores. As a result, the Independent t-test Sig (2-tailed) is employed for decision-making. The t-test results suggest no significant difference in students' concept

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mastery between the experimental and control classes. Consequently, the subsequent analysis will concentrate on the data derived from the post-test scores. The table presents the data processing results for post-test concept mastery scores in the experimental and control classes.

Table 2. Post-test Concept Mastery Data Processing Results

Data	Class	
	Experiment	**Control**
N	21	21
Highest Score	92	87
Lowest Score	72	65
Average Score	81,8571	75,8095
Std. Deviation	5,14087	6,44685
Sig. Normality	0,445	0,063
Sig. Homogeneity	0,179	
Independent T-test Sig. (2-tailed)	0,002	

Based on Table 2 above, it is apparent that the dataset for learning outcomes in the experimental group consists of 21 students, and the control group also comprises 21 students. The experimental group's average post-test concept mastery score is 81.86, while the control group's average concept mastery score is 75.81. Descriptively, there is a discernible difference in the average learning outcomes between the experimental and control groups. Both experimental and control classes exhibit normal distribution and homogeneous variation in concept mastery scores. Consequently, the decision-making test is the independent t-test Sig (2-tailed). The results of the independent t-test Sig (2-tailed) with a value of 0.002, which is <0.005, indicate a significant difference in students' concept mastery between the experimental and control classes.

Based on the achieved learning outcomes, it is evident that learning using virtual laboratory media on the Circulatory System material can assist students in understanding the content, resulting in good outcomes. This is evident from the average score obtained by students, which is 81.86, exceeding the course passing grade of 70. In a classical sense, natural science learning using virtual laboratory media thrives. Tables 1 and 2 show that the average post-test score is 5.14%, decreasing from the average pre-test score of 6.56% by 1.42%. The calculation of the N-gain test results in this research is presented in Table 3.

Table 3. N-gain Test Results

Group	Average Score	Minimum	Maksimum	N-gain	Criteria
Experiment	0,5092	0,26	0,73	0,5	Moderate
Control	0,2793	-0,20	0,50	0,3	Moderate

Based on the N-gain score calculation results in Table 3, it is evident that the average N-gain score for the experimental class (virtual laboratory) is 0.5, while the N-gain score for the control class is 0.3. This indicates that the criteria for the N-gain test in the

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experimental and control groups are the same, categorized as moderate. Although we can observe from the minimum and maximum score values in the experimental and control groups, there is a better improvement in the experimental class than in the control class.

2. Critical Thinking Skills Utilizing Virtual Laboratories and Not Utilizing Virtual Laboratories

Students' critical thinking skills were assessed through questionnaires and supported by observation sheets. Questionnaire results were obtained after distribution to students before and after implementing the experimental learning method. The criteria for critical thinking skills were based on predefined indicators, including the ability to ask questions, respond to questions, analyze arguments/opinions, solve problems, and draw conclusions. The questionnaire results are presented in Table 4 below.

Table 4. Pre-test and Post-test Critical Thinking Questionnaire Results for Experimental and Control Groups

No.	Group	Pre-test		Post-test	
		Average Value	Criteria	Average Value	Criteria
1	Experiment	64,82	Less Critical	80,77	Kritis
2	Control	65,06	Sufficiently Critical	76,31	Sufficiently Critical

Table 4 presents the results of the pre-test and post-test critical thinking questionnaires for the experimental and control groups. The average score for the experimental group in the pre-test is 64.82, categorized as critical thinking, while the control group has an average score of 65.06, indicating a moderately critical level. The pre-test average scores for the experimental and control groups are supported by the observed ability to think critically through direct observation. After administering the treatment to the experimental group using the virtual laboratory, the average post-test score was 80.77, categorized as critical thinking, while the control group's average post-test score was 76.31, falling into the category of moderately critical thinking.

Discussion

In the study, the researcher divided participants into two groups, experimental and control groups, implementing pre-tests and post-tests. The analysis findings reveal that the conceptual mastery of the experimental group, exposed to learning through a virtual laboratory, displayed a higher average score than the control group, which received instruction through PowerPoint and animations. Specifically, the average score was 81.86 for the experimental group and 75.81 for the control group.

The attainment of n-gain results means that practical activities with the virtual laboratory significantly aid learners in making decisions to seek truth and draw accurate conclusions. In other words, practical learning utilizing the virtual laboratory is effective. Virtual laboratories assist learners in comprehending the learning materials. Other studies also indicate that students utilizing virtual laboratories achieve higher N-gain scores

https://doi.org/10.51276/edu.v5i1.704

regarding critical thinking abilities than those using conventional learning methods (Listiantomo & Dwikoranto, 2023).

The difference in the average scores between the experimental and control classes is attributed to using different learning media. Learning through a virtual laboratory provides a distinct learning experience for students, making the process more engaging. This finding is consistent with Siswanto et al (2016), who explained that electronic laboratories can improve students' understanding of concepts. The capabilities of the virtual laboratory as a learning media demand students to be more actively involved in comprehending material concepts through virtual experiments, in contrast to the control class, which merely focuses on explanations from the instructor.

Virtual laboratories offer the opportunity for learners mainly to engage in practical experiments either online or offline, allowing them to conduct experiments without the need to be physically present in a laboratory. This feature contributes to effective learning as students can actively engage in self-directed learning without the assistance of an instructor or assistant, following a system that operates seamlessly. The web-based display format significantly aids students in independently participating in experiments (Bajpai & Kumar, 2015; Sypsas & Kalles, 2018). Moreover, virtual laboratories enable remote access to various resources, including measurement instruments, video cameras, microphones, electrical and mechanical circuits, chemical reactions, biology experiments (science), and other related tools (Aripin & Suryaningsih, 2020).

Engaging with virtual laboratory media independently can enhance students' critical thinking skills. Zulhelmi et al (2017) added that virtual laboratories can motivate students to analyze, critique, and draw conclusions, improving their critical thinking skills. This aligns with the findings of Kapilan et al (2021), suggesting that the use of virtual laboratories in practical activities can visualize abstract concepts, making them more concrete. This, in turn, challenges students to analyze, critique, and draw conclusions regarding the concepts being studied.

From this study, it is evident that the use of virtual laboratories can improve students' conceptual mastery. This is consistent with Gunawan et al (2017), who state that virtual laboratories can improve conceptual mastery and critical thinking skills. Furthermore, Gunawan et al (2017), Sari et al (2022), and Sypsas & Kalles (2018) state that critical thinking involves self-regulation in decision-making, resulting in interpretation, analysis, evaluation, and inference, as well as the presentation using evidence, concepts, methodologies, criteria, or contextual considerations that form the basis of decision-making.

D. Conclusion

Based on the findings and analysis presented, multimedia interactive web-based virtual laboratories can improve the critical thinking skills and conceptual understanding of Elementary School Teacher Education (PGSD) students in science. Students who utilized virtual laboratories during practical sessions exhibited a higher N-gain compared to those who used PowerPoint and animations for their practical sessions.

https://doi.org/10.51276/edu.v5i1.704

The conclusion of this research suggests several corresponding implications. First, learning by utilizing virtual laboratories should be considered an alternative method for Elementary School Teacher Education Program (PGSD) students, particularly in teaching natural science (IPA), specifically the circulatory system. Second, to maximize students' conceptual mastery and critical thinking abilities, it is recommended that students cultivate a habit of reading books and using online technology for project development and improving their thinking skills.

The researchers recommend that educators and future researchers explore alternative media to support learning, especially for subjects that require practical applications. Educational institutions, both campuses and schools, are encouraged to improve their facilities and infrastructure to support innovative learning processes.

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