Journal of Education Technology
Volume 7, Number 4, 2023, pp. 590-598
P-ISSN: 2549-4856 E-ISSN: 2549-8290
Open Access: https://ejournal.undiksha.ac.id/index.php/JET

Application of a Virtual Laboratory Containing Ethnoscience to Enhance Students' Critical Thinking Skills

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ARTICLE INFO

Article history:
Received June 13, 2023
Revised June 15, 2023
Accepted November 10, 2023
Available online November 25, 2023

Kata Kunci:
Laboratorium Virtual, Kemampuan Berpikir Kritis, Etnosains

Keywords:
Virtual Laboratory, Critical Thinking, Ethnoscience

DOI:
https://doi.org/10.23887/jet.v7i4.68713

ABSTRAK

Kemampuan berpikir kritis merupakan kemampuan dasar yang harus dimiliki siswa abad ini. Kemampuan tersebut juga ditekankan dalam Kurikulum Mandiri yang diterapkan di Indonesia. Namun terdapat kendala yaitu sekolah belum mempunyai laboratorium untuk melaksanakan kegiatan praktikum biologi. Berdasarkan permasalahan tersebut maka tujuan penelitian ini adalah mengembangkan media pembelajaran laboratorium virtual dengan muatan etnosains pada mata pelajaran biologi untuk meningkatkan kemampuan berpikir kritis siswa. Penelitian ini merupakan jenis penelitian pengembangan (R&D) yang menerapkan model pengembangan ADDIE. Proses pengembangannya melibatkan kerjasama dengan ahli media, ahli materi dan siswa. Metode pengumpulan data yang digunakan adalah instrumen tes dan angket. Metode analisis yang digunakan adalah kuantitatif dan kualitatif. Hasil penelitian ahli media menunjukkan bahwa media layak digunakan dengan penilaian sebesar 92%. Hasil penilaian ahli materi menunjukkan konten layak digunakan dengan penilaian 88%. Hasil uji keefektifan menunjukkan nilai sig sebesar 0,000, dimana terdapat perbedaan nyata kemampuan berpikir kritis siswa sebelum dan sesudah perlakuan. Hasil uji N gain menunjukkan efektivitas media pembelajaran dalam meningkatkan keterampilan berpikir kritis sebesar 47% termasuk dalam kategori sedang. Media laboratorium yang dikembangkan diharapkan dapat memberikan kontribusi terhadap variasi media pembelajaran yang sesuai dengan Kurikulum Mandiri yaitu memasukkan unsur penalaran kritis dan keberagaman global.

ABSTRACT

The ability to think critically is a basic ability that students of this century must have. This ability is also emphasized in the Independent Curriculum which is being implemented in Indonesia. However, there is a problem, namely that the school does not have a laboratory to carry out biology practical activities. Based on these problems, the aim of this research is to develop virtual laboratory learning media with ethnoscience content in biology subjects to improve students' critical thinking abilities. This research is a type of development research (R&D) that applies the ADDIE development model. The development process involves collaboration with media experts, material experts and students. The data collection method used was test instruments and questionnaires. The analytical method used is quantitative and qualitative. The results of research by media experts show that the media is suitable for use with an assessment of 92%. The results of the material expert assessment show that the content is suitable for use with an assessment of 88%. The results of the effectiveness test show a sig value of 0.000, where there is a real difference in students' critical thinking abilities before and after treatment. The results of the N gain test show that the effectiveness of learning media in improving critical thinking skills is 47%, which is included in the medium category. It is hoped that the laboratory media developed can contribute to variations in learning media that are in accordance with the Independent Curriculum, namely including elements of critical reasoning and global diversity.

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1. INTRODUCTION

21st century learning demands that students can develop various skills. In the 21st century, individuals need to acquire three distinct sets of skills. In the 21st century, students need a set of essential abilities categorized into three main areas: skills for learning and innovation, skills for literacy, and skills for life. Within the domain of learning and innovation skills, there exist four crucial proficiencies that students should possess. These include the capacity for critical thinking, effective communication, collaborative teamwork, and the ability to think creatively. These four skills are needed by students to be ready to face increasingly the intricate life and professional settings of the 21st century (Demircioglu et al., 2022; Pardede, 2020). Critical thinking abilities hold significance in individuals to have because they can help in making decisions and judgments when someone receives conflicting information. With critical thinking skills, students will absorb, examine, and disseminate the information obtained, and find out stronger evidence. Critical thinking skills are currently also being emphasized

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in the *Kurikulum Merdeka* currently used in Indonesia, namely in the Pancasila Student Profile where students must have critical reasoning skills (Dewi, 2022; Orhan & Çeviker Ay, 2022). Based on the research results previous study shows that students' critical thinking abilities in Indonesia are still low (Hasanah et al., 2020; Utami et al., 2018). The limited capacity for critical thinking among students is evident in the outcomes of PISA (Program for International Student Assessment) which shows that students' high-level thinking skills in Indonesia in 2015 were ranked 69th out of 75 countries. This shows that students in Indonesia have not been trained to think critically and think at a higher level which causes Indonesia to still be below the average of other countries (Bosica et al., 2021; Saputri et al., 2019).

Following up on the PISA results, a test was carried out to verify the CT skills of students at Kanisius Harapan Tirtomoyo High School. The test results show that the average critical thinking skills of students is 28%, which is the low category. Students' ability to carry out basic clarification was 48%, basic decision-making ability was 16%, inference ability was 20%, and advanced clarification ability was 20%. Several methods can be used in learning to enhanced students' critical thinking skills, including cooperative learning, problem-based and project-based learning models, case studies, oral presentations, as well as direct learning activities such as experiment-based learning, and simulations, and others (Bezanilla et al., 2019; Orhan & Çeviker Ay, 2022). Science learning, such as biology, often involves observation, exploration, research, problem-solving, information gathering, practical activities, and other activities. This activity will also enhance students' critical thinking skills (Antonia et al., 2022; Jerrim et al., 2020). In science learning, to be able to enhanced science process skills and scientific literacy, which are the goals of science learning, learning activities should be able to provide direct experience for students or experiment-based learning.

After conducting an interview with the biology teacher at Kanisius Harapan Tirtomoyo High School regarding the learning activities that had been carried out at the school, several problems occurred in the learning process, namely that the school did not have a biology laboratory that students could use to carry out practical activities, learning was still conventional where teachers teach using the lecture method, and the use of technology in learning is not optimal because it is only used as a means of communication and collecting school assignments. Based on the problem of not having a laboratory in schools, there is an alternative solution to overcome this problem, namely by using a virtual laboratory. Virtual laboratories can be used as an alternative to support experiential learning. This virtual laboratory environment allows students to design and conduct virtual experiments, process data, and analyze and interpret experimental results (Hartog et al., 2009; Verstege et al., 2019). Virtual laboratories are technology designed to simulate laboratory activities as closely as possible to physical/real laboratory activities to provide equivalent knowledge and skills for students (Diwakar et al., 2023; Pearson & Kudzai, 2015; Widyaningrum, 2018).

There have been several previous studies related the application of virtual laboratories in learning activities or the utilization of virtual laboratories to enhanced critical thinking skills. For example, in research conducted it was found that the utilization of virtual laboratories as science laboratory practical simulations could improve high-order learning abilities, critical thinking skills, & cognitive load capabilities (Simon, 2015). Research by previous study in terms of implementing problem-based learning models through virtual laboratories, there is a notable enhancement in critical thinking abilities and educational accomplishments (Serungke et al., 2020). Other study also reported that the utilization of virtual laboratories can increase students' intrinsic motivation and laboratory practical skills (Diwakar et al., 2023). Research findings indicated that the application of the guided inquiry model through a virtual laboratory had a significant impact on science process skills, particularly in hypothesizing, practicum, and communication skills (Gunawan et al., 2019). Research on developing a virtual laboratory to enhanced critical thinking skills was also carried out by other study namely developing a virtual laboratory on the concept of bacteria (Aripin & Suryaningsih, 2020). The research results show that the virtual laboratory developed is valid and effective in improving students' critical thinking skills with an effectiveness of 78%. This research is in accordance with research conducted where virtual laboratories are effective in enhancing students' critical thinking skills (Setya et al., 2021).

This research aims to develop a virtual laboratory in high school class 11 biology subjects on the human digestive system and food testing as well as to determine the effectiveness of the virtual laboratory media developed in improving critical thinking skills. The laboratory that will be developed is novel compared to previously existing media, namely incorporating cultural elements, and traditional Indonesian food, into the virtual laboratory media. The use of ethnoscience in this virtual laboratory is related to one of the characteristics emphasized in the *Profil Pelajar Pancasila* in accordance with Minister of Education and Culture Regulation No. 17 of 2021 in the *Kurikulum Merdeka*, namely global diversity. Students can get to know the culture, explore the culture and cultural identity, and develop a sense of respect for Indonesia's cultural diversity by integrating local culture in virtual laboratories containing ethnoscience. The use of ethnoscience in learning can cause students to care more about the socio-cultural environment and can instill local cultural character values.

2. METHOD

This form of research is categorized as development research. Educational development research is employed to create and verify educational materials and resources. This development research aims to create virtual laboratory learning media to support the utilization of the ADDIE model (which stands for Analyze, Design, Development, Implementation, and Evaluation) is the approach used to facilitate the learning of biology and the improvement of students' critical thinking skills. The philosophy of implementing the ADDIE model focuses on students, with an innovative, inspiring, and authentic approach (Branch, 2009). The first step in the ADDIE model is analysis, which includes performance analysis and needs analysis. The performance analysis aims to identify the conditions of biology learning in schools, finding that experimental-based learning is not carried out due to a lack of laboratories. A needs analysis is carried out to understand the characteristics of students and find a solution, namely using a virtual laboratory. The second stage is design, where media and material concepts are developed. The third stage is initial product development, which is then evaluated by material and media experts. After evaluation, the product is improved based on expert advice. The next stage is implementation, namely to test the effectiveness of the product. After implementation, a summative evaluation is carried out to assess the overall quality of the product that has been developed.The subjects of this research were material experts, media experts, and grade 11 students at Kanisius Harapan Tirtomoyo High School. The research approach employed is a combination of different methods where quantitative methods are used to analyze the outcomes of a product suitability both in terms of the media and the material contained in it and are used to analyze whether the enhancement of students' critical thinking abilities has been observed abilities before and after using virtual laboratory media (Rachmadtullah et al., 2018; Sari et al., 2022). The instruments used for product assessment are in Table 1 and Table 2.

Table 1. Content Assessment Instruments

Aspect	Indicators	Number
Content	Suitability of material with basic competencies	1
	Suitability of the substance of the learning material	2
	Concept truth	3
	Concept clarity	4
Language	Suitability of language to student development	5
	Candor	6
	Ability to motivate	7
Presentation	Serving order	8

Table 2. Media Assesment Instruments

Aspect	Indicators	Number
Media Display	Use of font size, type, and color (typography)	1
	Layout or suitability of layout	2
	Suitability of illustrations, drawings and photos	3
Media application programs	Compatibility	4
	Navigation	5

Base on Table 2 show media and material expert validation is collected from the assessment scores on the assessment sheet that has been created and then converted into a Likert scale with a scale of 1 to 5. Then the resulting assessment scores are averaged and converted into percentages for each question. Using these computations, we can draw a conclusion based on the categories of excellent, satisfactory, poor, and very poor as illustrated in Table 3.

Table 3. Validator Response Conversion Guide

Scale	Interpretation
>76	Very Good
50<X≤75	Good
25<X≤50	Bad
X≤25	Very Bad

From Table 3 it can be concluded that the product can be used if it falls into the good or very good category, while the product cannot be used if it produces bad or very bad results. Qualitative analysis in this research was used on material validator response data and also the media used as considerations in improving the

media being developed (Sofyan et al., 2019). Quantitative analysis is also used to analyze whether Students' critical thinking abilities have shown improvement abilities before and after using virtual laboratory media, namely by using a paired sample t-test using SPSS software. Students' critical thinking abilities are measured using assessments developed and modified derived from criteria assessing critical thinking skills. Critical thinking assessment indicators is show in Table 4.

Table 4. Critical Thinking Assessment Indicators

Aspects of critical thinking abilities	Indicators of Critical Thinking Ability	Number
Basic clarification	Identifying the focus of the problem, question, or conclusion of a topic	1
	Analyzing arguments	2,3
	Clarifying concepts	4
	Understand and use graphs or mathematical calculations	5,6
Basis for decision making	Assessing the credibility of information	7
	Observing and assessing a report (observing and considering the results of observations)	8
Inference	Summarize and consider the results of the deduction	9
	Assess inductive conclusions and arguments	10,11
	Make value judgment decisions	12, 13
Further Clarification	Defining terms and determining definitions	14
	Think assumingly by considering premises, reasons, assumptions, positions, and propositions	15

3. RESULT AND DISCUSSION

Result

Based on development research that has been carried out using the ADDIE model, several results have been obtained. Firstly, at the analysis stage carried out on students, the results of student characteristics were obtained is show in Table 5.

Table 5. Table of Student Characteristics

Criteria	Description
Class	11 (2 Classes)
Number of students	32 students
Use of technology for learning	96,9% of students often use technological assistance such as laptops or smartphones to support learning activities
Students have smartphones	90,6% A portion of students possess smartphones to facilitate their educational tasks.
The importance of practicum	87% of students think it is necessary to do practicums to learn biological concepts
Using virtual laboratories in learning	100% of students said they had never used a virtual laboratory in learning

After analyzing the characteristics of students, the design stage is then carried out. At the design stage, the media concept is designed and the material or content contained in the media is designed. The following are the results of the media concept design in Table 6.

Table 6. Learning Media Design Table

Criteria	Description
Media type	Learning media is a virtual biology laboratory media
Objective	Creating digital learning media in the form of virtual laboratories in biology subjects and containing ethnoscience content to support students' practical activities and enhance critical thinking skills
Format	.apk
Student activities	Students can do virtual practicums using an application on their smartphone
Development tools	Smart Apps Creator, Canva, Ibis Paint, Corel, & Capcut

In designing the material concept, learning objectives for learning content are selected which are adapted to the *Kurikulum Merdeka*. The results of the analysis of learning objectives in Table 7.

Table 7. Table of Learning Objectives and Learning Content

Criteria	Description
Content	Digestive system and food tests
Learning Objectives	1. Students can explain the relationship between the structure and function of the digestive organ system in humans through careful study of the literature 2. Students can explain the mechanisms of the human digestive system through careful literature student 3. Students can gain an understanding of how organ structure and function relate to disorders in the human digestive system by conducting a thorough review of relevant literature. 4. Students can examine the connection between the structure of organs and their functions within the human digestive system by conducting a thorough review of relevant literature. 5. Students can analyze the substance content of food ingredients through careful practicum
Learning Content	1. Structure and function of the digestive organs 2. Digestion mechanism 3. Digestive system disorders 4. Technology to treat digestive disorders 5. Substance content in food

The third stage after the design stage is the development stage. At the development stage, learning media is developed based on designs that have been carried out previously. Development of a virtual laboratory using SAC is show in Figure 1.

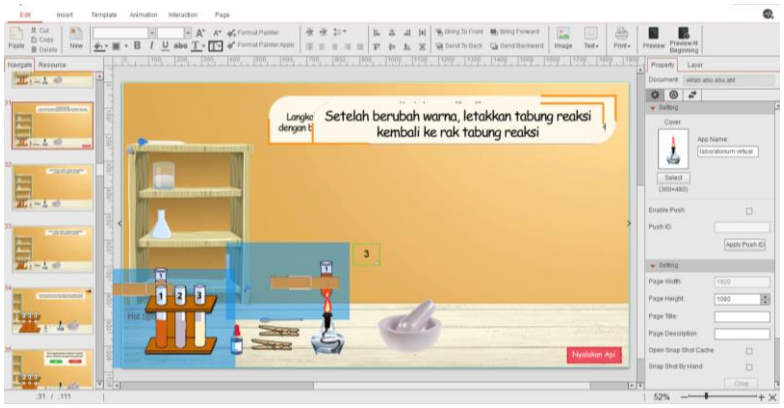

Figure 1. Development of A Virtual Laboratory Using SAC

After product development is carried out, the product is assessed by media and material experts. The following are The outcomes of the media evaluation in Table 8.

Table 8. Table of Assessment Results by Media Experts

Expert	Mean Score	Percentace	Category
Learning Media Expert 1	4.8	96%	Very Good
Learning Media Expert 2	4.4	88%	Very Good
Average	4.6	92%	Very Good

Based on Table 8 the results of the learning media assessment by media experts, an average score of 4.6 or 92% was obtained, which means that the virtual laboratory media was very good. Several improvements need to be made, namely in the design section it should be improved to make it more attractive, in the navigation section the buttons should be given letter descriptions, in the question section feedback should be given from students' answers so that the media is more interactive, and to consider the time spent on quizzes. Apart from validation by

media experts, Validation is conducted by experts in the relevant field regarding the content presented in the virtual laboratory. Here are the results of the validation conducted by material experts as presented in Table 9.

Table 9. Table of Assessment Results by Content Experts

Expert	Mean Score	Percentace	Category
Learning Content Expert 1	4.125	83%	Very Good
Learning Content Expert 2	4.625	93%	Very Good
Average	4.375	88%	Very Good

Based on Table 9 show the results of the assessment by material experts, an average score of 4.375 or 88% was obtained, meaning that the content contained in the virtual laboratory was very good. There are several improvements to the content of the material based on suggestions from material experts, namely the use of scientific names should be italicized, the addition of material on digestive disorders and technology used to treat digestive disorders, the questions used in the quiz should cover all learning objectives and there are questions that are HOTS, the quiz is made interactive, as well as adding explanations about typical foods used in the virtual laboratory to strengthen the ethnoscience content in the media.

After the educational material has been created, assessed by material and media experts, and improvements have been made in accordance with recommendations provided by specialists in the field of materials and media, the next step is the implementation stage or field trial stage. The field trial was carried out in 1 class 11 grade with a total of 32 students. Evaluation of analytical thought abilities is carried out before and after giving the media to find out whether virtual laboratory media is effectively used to enhance critical thinking skills. Normality tests are carried out before hypothesis testing as a test of the analysis requirements. The normality test result is show in Table 10.

Table 10. Normality Test Result

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.121	32	0.200	0.962	32	0.304
Post test	0.131	32	0.175	0.956	32	0.216

Base on Table 10 show the normality test, it is evident that data distribution has been distributed following a normal curve as evidenced by the sig value. 0.304 in pretest and 0.216 in posttest where this value is more than the p-value of 0.05. The result of paired t-test result is show in Table 11.

Table 11. Paired Sample t-test Result

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Post test - Pretest	15.71875	11.11301	1.96452	11.71208	19.72542	8.001	31	**0.000**

Based on Table 11 show the results of the paired sample t-test, it shows a noteworthy distinction exists between students' critical thinking abilities before and after learning using a virtual laboratory. This is proven by the p-value of 0.000, where this value is less than the probability of 0.05. The increase in student scores after using media was 15.71. Therefore, it can be concluded that virtual laboratory learning media containing ethnoscience can improve the critical thinking skills of Kanisius Harapan Tirtomoyo High School students.

The effectiveness of media in improving critical thinking skills can be calculated using the n-gain test, namely by using pretest and post-test data from the experimental class. Based on the results of the N gain test, it can be seen that the effectiveness of learning media in improving critical thinking skills is 47%, which is included in the medium category. Therefore, it can be concluded that virtual laboratory learning media can enhance critical thinking skills and this improvement is included in the moderate category.

Discussion

The capacity for critical thinking is a skill that students should possess. Critical thinking skills are currently also one of the 6 elements of the Pancasila Student Profile contained in the Merdeka Curriculum which

is being implemented in Indonesia (Ibad, 2022; Pardede, 2020). Therefore, learning activities enable students to engage in exercises that promote the development of their critical thinking abilities. Learning activities should use lots of practical activities. Science learning needs to be expanded using practicums to improve students' critical thinking abilities (Bezanilla et al., 2019; Jerrim et al., 2020). One solution to the problem that can be taken is to use a virtual laboratory. Before use, the learning media needs to be tested for validity, namely the validity of the media and the validity of the content or material. The results of the media assessment by expert judgment show that the media is Appropriate for utilization with excellent standards. The results of the material content assessment show that the material contained in the media It is appropriate for use with excellent standards. This indicates that the virtual laboratory is ready to be used in learning activities. However, several improvements were made to the media based on advice from experts to perfect the media before using it in learning.

The findings from the paired sample t-test indicate that virtual laboratory media is effective in improving students' critical thinking skills, as evidenced by the notable variation in test scores before and after using the virtual laboratory in learning. The result show that the effectiveness of learning media in improving critical thinking skills is 47%, which is included in the medium category. This discovery is corroborated by the outcomes of earlier research which shows that the use of virtual laboratories can improve students' critical thinking abilities (Serungke et al., 2020; Simon, 2015). The reason behind this is that in a virtual laboratory, students can carry out experiments similar to those In an actual laboratory setting, by adhering to the provided guidance or the experiment sheet's instructions. The use of virtual laboratories allows students to become familiar with the environment so that they can participate more actively in the learning process (Diwakar et al., 2023; Viitaharju et al., 2021). The use of animation in virtual laboratories also helps increase student motivation and desire to be involved in laboratory activities (Estriegana et al., 2019; Viitaharju et al., 2021).

The use of virtual laboratories can strengthen concepts that have been studied and can develop and prove theories that have been studied. Experimental or practical activities in the laboratory can help students understand science learning effectively because, through practical activities, students gain experience through concrete materials, develop students' work habits, train students in solving problems through experimental activities, and increase students' understanding of practical problems (Falode & Gambari, 2017; Husnaini & Chen, 2019). In the laboratory, students will carry out experiments according to existing work steps, prepare reports, analyze practical data, and explain the data results. Through this activity, it will help students improve their observation abilities and analytical skills (Frolova & Rogach, 2021; Mulyatna et al., 2021). Through this experience, students' knowledge can be built. Activities in virtual laboratories can provide direct experience to students in the form of practical activities in virtual laboratories so that students are expected to be able to manipulate objects, carry out scientific experiments, observe, collect data, and draw conclusions from the experiments carried out (Abdjul & Ntobuo, 2018; Barker et al., 2019). It is hoped that the laboratory media developed can contribute to variations in learning media that are by the Kurikulum Merdeka, namely including elements of critical reasoning and global diversity. Therefore, it is hoped that in the future, similar research will be carried out on different learning materials appropriate to the needs and characteristics of students to enrich scientific contributions in the field of learning media.

The main implication of this research is the potential to increase students' critical thinking skills. If this research is successful, it could provide new insights into how to approach science teaching and technology-based learning. The results of this research can contribute to the further development of virtual laboratories with the integration of ethnoscience elements. This can be useful for curriculum development and science learning methods. However, this study has limitations, the main limitation of the study may lie in the generalization of the results. Because this research can be widely applied in various educational contexts or is only suitable for certain groups, it needs to be explained.

4. CONCLUSION

The problem that has been found is that biology learning does not yet facilitate students with learning activities that can help enhance critical thinking skills. One of the reasons is the absence of laboratories in schools. Therefore, a virtual laboratory was developed which can be used to facilitate practical activities and can assist in enhancing the ability to think critically. Derived from the evaluation conducted by experts in the field of media assessment, it shows that the media is suitable for use with an assessment is included in the very good category. The results of the media assessment by material experts show that the content in the media is suitable for use with an assessment is included in the very excellent category. Field test results indicate that the virtual laboratory effectively enhances students' critical thinking skills. This is substantiated by the paired sample t-test outcomes, which demonstrate a notable disparity in students' critical thinking capabilities before and after their engagement with the virtual laboratory. The effectiveness of learning media in enhancing critical thinking skills is 47%, which is included in the medium category.

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