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Virtual Experiments of DNA Isolation and Hybridoma Techniques to Improve Students' Critical Thinking Ability

Erna Noor Savitri[1*], Andin Vita Amalia[1], Prasetyo Listiaji[1] & Rifa Atunnisa[1], Fidia Fibriana[1,2]

[1]Department of Integrated Science, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia
[2]Laboratory of Molecular Biotechnology, Faculty of Agro-Industry, Prince of Songkla University Thailand

[*]Corresponding Author: ernanoors@mail.unnes.ac.id

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Abstract. Virtual learning during the Covid-19 pandemic always requires innovation from educators to present effective and interesting learning. The case method is an alternative learning method that can be used to increase awareness responses to problems contextually. This study aims to determine the effectiveness of implementing the use of virtual DNA isolation experiments and hybridoma techniques on students' critical thinking skills. The research was conducted on students majoring in Integrated Science, Semarang State University in the 2021-2022 academic year. Samples from the population are divided into experimental class and control class. The research instrument used to measure critical thinking skills uses a test. The results of the assessment of critical thinking skills were analyzed using quantitative analysis. The results showed that the experimental class obtained an average critical thinking ability of 87.86 and the control class obtained an average critical thinking ability of 73.86. The results of the posttest difference test analysis between the experimental class and the control class obtained a sig. (2-tailed) 0.000 less than the t table significance value of 0.05. Based on these results it can be concluded that the implementation of the use of virtual DNA isolation experiments and hinridoma techniques is effective in increasing students' critical thinking skills. The novelty of the results is virtual experiments of DNA Isolation and Hibridoma can be an alternative to virtual practice for schools with incomplete laboratory facilities.

Key words: Case Method, Virtual Experiment, DNA Isolation, Hibridoma.

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INTRODUCTION

The Covid-19 pandemic learning is identical to distance learning to avoid face-to-face meetings that may trigger crowds. Since March 2020, to be precise, after the Covid-19 outbreak, all education units in Indonesia have implemented the Distance Learning (*Pembelajaran Jarak Jauh*/PJJ) (Bahasoan *et al.,* 2020). The UNESCO on March 4, 2020, advised the use of distance learning and opened up educational platforms that schools and teachers can use to reach learners remotely as well as limit educational disruptions. Distance learning maintains the scientific literacy learning process in different ways and levels (Sharon & Baram, 2020).

The widespread of Covid-19 has forced the government to temporarily stop learning activities in schools and encourage distance learning at home. Various initiatives have been carried out to ensure the continuity of learning activities even though there are no face-to-face sessions (Ferri *et al.*, 2020). Learning can be done in class or remotely due to clamant conditions (Gacs *et al.*, 2020). Distance learning is carried out online by relying on the internet network connection using computers or gadgets interconnecting between students-teachers and students-lecturers.

The use of information technology and communication in the pandemic learning era is not optional but has become a necessity (Mishra *et al.*, 2020). It is a solution for learning to run well. For that reason, educators are required to design online-based learning media as innovations (Dewi *et al.*, 2021). There have been various applications used for teaching and learning activities by educators and students for synchronous learning activities, for example, Zoom, Google Meet, Microsoft Teams, and others.

Distance learning demands educators to be creative in delivering materials via remote online media (Al-Karaki *et al.,* 2021). Teacher skills play a huge role in achieving quality learning. Moreover, teacher creativity in dealing with learning during the pandemic is very much needed so that distance learning continues to run smoothly

and is fun as well as meaningful for children (Omar *et al.,* 2020). The positive mindset of educators can help students in selecting and utilizing the proper online learning media, resulting in quality learning outcomes.

The TIMSS (Trends in International Mathematics and Science Study) is an international study examining the skills and knowledge of mathematics and science (Suhendar & Wahyuni, 2019), and in 2015, TIMSS reported that Indonesia ranked 44 of 49 nations. According to Suwarma & Apriyani (2022), one of the science skills measured in the TIMSS is the higher-order thinking skills (HOTS). As stated by Widana *et al.* (2020), there are five skills in HOTS that cover problem-solving, decision-making, critical thinking, and creative thinking. This is parallel with Lin *et al.* (2021) who defined critical thinking as an attitude to think about issues profoundly beyond a person's experience. Lin *et al.* (2021) also conveyed that critical thinking is a skill to apply inspection methods and logical reasoning. It is pivotal to be mastered for the students to creatively construct arguments, investigate credibility of sources, or make decisions.

The success of education could not be detached from the selection of learning methods. The learning method is a way to implement established plans to achieve the learning goals (Hidayati *et al.*, 2019). One of the methods to improve critical thinking skills is the case method, a participative-based activity to solve cases (Mahdi *et al.*, 2020; Saputra *et al.*, 2019).

Research that refers to the use of ICT-based virtual experiments has been carried out before. Firmayanto *et al.* (2021) have used a virtual laboratory in basic physics courses to measure students' science process skills. Admoko *et al.* (2019) have also used a virtual laboratory with the Discovery Learning method. Ismail *et al.* (2016), have also used STEM-based virtual laboratories. These studies still focus on learning outcomes only. In its development, researchers adopted the importance of critical thinking and communication skills in facing the Industrial Revolution 4.0, especially during the current co-19 pandemic. The results of the research which took the theme of critical thinking and communication skills have been carried out by several researchers, including research on improving critical thinking skills and communication which was carried out using Problem Based Learning (PBL) assisted by information and communication technology to improve students' critical thinking skills (Yennita & Zukmadini, 2021). In addition, there is also research that uses a problem-based learning model based on socio-scientific issues to develop students' critical thinking and communication skills (Lubis *et al.*, 2022). The application of the discussion-presentation method combined with critical analysis of articles through lesson study can also be used to improve conceptual understanding, critical thinking skills, and communication (Nugraheni *et al*., 2022). The basic research that will be carried out also measures critical thinking and communication skills, but by using a case method based on virtual experiments (Gunawan *et al.,* 2017). Malik & Ubaidillah (2021) says that the Multiple Skill Laboratory Activity Model (MSLAM) improves students' collaboration skills better than communication skills. The result of Widodo *et al.* (2017) *explain that* the virtual laboratory promotes a constructivist learning environment slightly better than the real laboratory, while virtual laboratory activities showed improvement, real laboratory activities did not.

Based on the discussed issues upfront, there needs a solution to overcome the shortcomings of distant learning. Interesting learning always requires innovation of methods and media. On the other hand, the case method is identical to a case-solving method which gives chances to students to comprehend problems directly and try to solve the problems independently. The critical thinking skills must be possessed by students to facilitate them in entering the social world later on (Sutiani, 2021). This research intended to examine the effectiveness of the virtual experiment-based case method to improve students' critical thinking skills. The meant 'effectiveness' refers to the difference between the average scores of the experimental and control class.

The purposes to be achieved in this study are to analyze the effectiveness of the virtual experiment-based case method on students' critical thinking skills. Based on the purposes, the research is expected to bring theoretical and practical benefits. The expected theoretical benefits are that the results of this research can be used as input for the implementation of learning that supports the development of students' abilities related to critical thinking skills. In addition, the results of this study can be used as a reference for similar research more broadly and in depth. Practical benefits in research are that it can be used as input or alternative material for lecturers to vary the implementation of learning in class. In addition, learning using the case method assisted

by a virtual lab can be an alternative learning model to improve students' critical thinking skills.

METHODS

This study adopted the experimental method-a method that intends to examine the connection between variables influencing a particular treatment in a controlled condition (Sugiyono, 2022; Creswell, 2015). Research using this method has two randomly-picked classes as the sample. This study owned two examined classes including the experimental class, which applied the problem-based learning supported by the virtual experiment-based case method, and the control class as a comparison which implemented the inquiry-based learning assisted by virtual animation media.

The virtual experiment-based case method learning was carried out in several stages consisting of: (1) orientation; (2) practice, in which each class implemented the intended methods; (3) experiment, in which the experimental class used the virtual experiment, and the control class used the discovery; and (4) evaluation through online tests.

The observed aspects during learning were critical thinking skills which examined through tests. The test items were made based on the assessment indicators of critical thinking stated by Ennis in Sutiani (2021) involving (1) conveying modest explanations; (2) creating basic competencies; (3) drawing conclusions; (4) creating advanced explanations; and (5) applying strategies and tactics.

This research employed the True Experimental Design with the Pretest-Posttest Control Group Design type. According to Sugiyono (2022), there are two groups selected randomly in this type of research design, then given a pretest to determine the initial state of students' abilities between the experimental and control class.

R_1	**O_1**	**X**	**O_2**
R_2	**O_3**	**X**	**O_4**

Figure 1. The Illustration of Experimental Design

Information :
R1 : Experimental Class
R2 : Control Class
O1 : Pretest Score of Experimental Class
O2 : Posttest Score of Experimental Class
O3 : Pretest Score of Control Class
O4 : Posttest Score of Control Class

The research subject consisted of students of the Science Education Study Program, Integrated Science Department, UNNES who took the Basic Biology II course. The research sample was selected using simple random sampling, a technique of picking a sample by neglecting the existing strata in the population (Sugiyono, 2010; Datey & Kuthe, 2015). Sample data were taken by 139 students who were divided into a control class and an experimental class.

The data taken consisted of aspects of critical thinking skills. The data collection technique included: (1) initial survey on the population to decide the sample for both classes; (b) observation of learning activities using the virtual experiment-based case method; (c) data collection by gathering critical thinking skill scores using tests that meet the criteria for measuring critical thinking skills. The instruments used in this study have gone through a validation process by experts, namely material validation and media validation consisting of lecturers and teachers. The results obtained are the research instruments used are valid and reliable

Before analyzing the critical thinking skills, a normality test was done on the pre-and post-test data to examine the statistical test to be used. The normality test revealed that both tests in both classes were normally distributed; thus, a statistical parametric test in the form of a normalized gain (g) analysis was performed to study the influence of case method on critical thinking skills, and a comparative t-test to investigate the effectiveness of the virtual experiment-based case method in improving critical thinking skills.

The scoring data from both the experimental and control class were known through a homogeneity test aiming at knowing the variances of research data. The homogeneity test results were examined on SPSS 23 software as displayed in the following Table 2.

Table 2. The Homogeneity Test Results by SPSS

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.150	1	42	.290

The homogeneity test outcomes revealed that the value of Sig. Levene's Statistics was 0.290 > 0.05; hence, the variance of the learning outcomes data in the control and experimental classes were homogeneous. This means that the research sample had the same conditions or variance. The

pretest and posttest scores in the experimental and control class were then tested for normality, to ensure that the data distribution in both classes was normally distributed. The normality test was carried out with SPSS software and the results are written in Table 3.

Table 3. The Normality Test Results by SPSS

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		22
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	4.44688948
Most Extreme Differences	Absolute	.217
	Positive	.106
	Negative	-.217
Test Statistic		.217
Asymp. Sig. (2-tailed)		.090

Based on the table, the data were normally distributed, therefore, it required an N-gain test to unveil the difference of score between the control and experimental class.

RESULTS AND DISCUSSION

Critical thinking is an ability that students need to have in the 21st century, even several developed countries have included it in the curriculum as a learning goal (Bahasoan *et al.*, 2019). Referring to Bean & Mezler (2021), critical thinking is the ability of a person's thought process to evaluate or investigate evidence, assumptions, and logic underlying the ideas of others. This statement is supported by Facione (2011) elucidating that critical thinking is self-regulation in deciding something that results in interpretation, analysis, evaluation, and inference, as well as exposure using evidence, concepts, methodologies, criteria, or contextual considerations that form the basis of decision-making.

The case method is one of the most suitable models for developing critical thinking skills in lectures as it can train students to debate, dialogue, express opinions, accept other people's opinions, make decisions, and take actions related to the problems at hand (Al-Husban, 2020). The ability to think critically has a close relationship with observation activities on cases and finding solutions.

The measurement of students' critical thinking skills referred to the indicator items which are translated into material indicators. The relationship between critical thinking skills and learning materials for students is shown in Table 1.

Table 1. The Relationship between Critical Thinking Indicators and Learning Materials

No	Critical Thinking Indicators	Material Indicators
1	Conveying Modest Explanations	a) Studying the structure of chromosomes b) Examine the meaning of genetic engineering c) Examine the nitrogenous bases involved in protein synthesis events
2	Creating Basic Competencies	a) Comparing the difference between DNA and RNA b) Differentiating types of genetic engineering c) Detecting the possibility of false protein synthesis
3	Drawing Conclusions	a) Concluding the function of DNA related to bodywork b) Concluding the benefits of genetic engineering c) Concluding the goals of protein synthesis
4	Constructing Advanced Explanations	a) Analyzing DNA's component structures b) Analyzing possible issues due to genetic engineering c) Connecting the protein synthesis process with gene expression
5	Applying Strategies And Tactics	a) Reconstructing DNA isolation techniques and chromosome preparation using virtual experiment b) Designing process/way of genetic engineering c) Reconstructing protein synthesis events

Table 1 informs the relationship between the materials and indicators of critical thinking. The students' abilities were measured through written tests developed based on the indicators. Critical thinking skills in science learning must be honed for the sake of the students' ability in facing science problems in daily life; moreover, such skills serve as the basis of analysis, information gathering, and evaluation. This is in line with Mehmet (2018) who claimed that students could think critically in the contextual learning process instead of rote learning.

The student's critical thinking skills were measured through two tests in each class; the

pretest and posttest. The obtained data were then tested for normality, and the results indicated that the data were normally distributed. Then, to get to know the mean difference of the two classes, the N-gain was carried out.

Table 4. The Results of N-gain's Pretest and Posttest

Class	Mean		Gain Score	Criteria
	Pretest	*Posttest*		
Experiment	63.77	87.86	0.65	Medium
Control	63.54	73.18	0.25	Low

Based on Table 4, the experimental class' N-gain was 0.65 (medium) and the control class' was 0.43 (medium). The experimental class' higher improvement happened due to the use of the virtual experiment-based case method. This reversed the control class which employed animation learning video.

The significance of the difference between the two classes was revealed through an Independent Sample Test which intends to know the significance discrepancy. The Independent Sample Test results of the experimental and control class' posttest were displayed in Table 5.

Tabel 5. The Independent Sample Test Results of the Experimental and Control Class' posttest

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	1.834	.183	-12.725	42	.000	-14.000	1.100	-16.220	-11.780
	Equal variances not assumed			-12.725	40.648	.000	-14.000	1.100	-16.222	-11.778

The table shows that the value of Sig. Levene's Test for Equality of Variances was 0.183, greater than 0.05 (0.183> 0.05); thus, both classes were declared homogeneous that the interpretation of independent sample test outputs referred to the scoring guidelines contained in the table of equal variances assumed.

Based on the table of the posttest test results between the experimental and the control class, it is known that the value of Sig. Levene's Test for Equality of Variances was 0.183 which had a value greater than 0.05 (0.183> 0.05); therefore, both classes were homogeneous so that the interpretation of the independent sample test output table used the guidelines on the values contained in the equal variances assumed table. It has been identified that the value of Sig. (2-tailed) was 0.000 < 0.05, thus referring to the basis for decision making in the independent sample t-test, it concluded that there was a significant difference between the posttest mean scores in the experimental and the control class.

In this study, the increase in the experimental class was higher than in the control class. The use of case methods based on virtual labs provided students with experience using virtual labs, furthermore, they were trained to be able to analyze problems and provide solutions to the given problems. Analytical skills were also honed in learning activities for the students to provide simple explanations of the observations. Simple concepts formed through experiences will then be able to build basic skills that students must have. In the subject matter taught, students could compare the differences between DNA and RNA, differentiate types of genetic engineering, and detect possible errors in protein synthesis. Once the students have been able to build these basic skills, they will be able to conclude and make further explanations about the subject.

According to Nirmala & Darmawati (2021) in their research results, learning with virtual laboratory-made learning activities more interesting, students' interest is in line with their increase in learning enthusiasm and participation, so that it could help understand the concepts being taught. Moreover, in their research, Estriegana *et al.* (2019) argued that learning with virtual laboratories has a positive impact on increasing teaching efficiency. Further, students also experience an increase and showed greater endurance in remembering information.

The virtual laboratory-based case method learnings have been proven to increase student curiosity through virtual practicum activities on computers/laptops. It presented the process of DNA isolation taken from cells in living things. Presenting problems at the beginning of learning

can build student interest in learning further, also, to find solutions to the given problems.

Student lively participation could be seen when students carried out activities according to the instructions written in the application. The stages of experimental activities contained in virtual applications are similar to actual experiments in the laboratory. One of the advantages of using a virtual lab is the flexibility to perform anywhere and anytime and economics as it does not require large costs to purchase tools and materials yet provides a real experience.

CONCLUSION

Based on the results obtained, the researchers concluded that the implementation of the virtual experiment-based case method is worthwhile in improving future science teachers' critical thinking skills. The implication of the research is that learning using the virtual lab-assisted case method can be an alternative learning model to improve critical thinking skills. However, the use of the virtual lab must be supported by a strong internet signal, so it is expected that an internet connection is prepared before conducting research using the virtual lab

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