JoISE 1 (2) (2024): 1 - 7

Journal of Integrated Science Education

https://www.e-journal.umc.ac.id/index.php/JoI

THE EFFECT OF DIFFERENTIATION LEARNING USING THE PHET VIRTUAL LABORATORY ON STUDENTS' CRITICAL THINKING SKILLS

Fuzna Laela[1]*, Norma Bastian[2], Rinto[3]
[1,2,3] Department of Science Education, Universitas Muhammadiyah Cirebon, Indonesia
*Corresponding Author: fuznalaela45@gmail.com

DOI: https://doi.org/10.32534/joise.v1i2

Accepted: 04 August 2024 Approved: 18 August 2024 Published: 10 September 2024

Abstract

This research aims to determine the effect of differentiated learning using the PhET virtual laboratory on students' critical thinking skills in vibration and waves. This research uses quantitative experimental research methods with a non-equivalent control group design. This research used two classes with a sample size of 40, consisting of 20 experimental class students and 20 control class students. The instruments used for differentiated learning are diagnostic assessments and formative assessments. Meanwhile, the critical thinking skills test instrument consists of 20 pretest and posttest questions. Data were processed statistically non-parametrically using the Wicoxon Test and N-Gain Test. The results of the research show that there is an influence of differentiated learning using the PhET virtual laboratory on students' critical thinking skills in vibration and waves as evidenced by the Asmp value. Sig 0.000. No students experienced a decrease in learning outcomes and experienced an increase of 30%. The effectiveness of differentiated learning that is applied has an effect of 61% in the "quite effective" category.

Keyword: Differentiated learning, PhET, critical thingking skills, vibration and waves.

INTRODUCTION

Science learning requires students to think critically and connect it to everyday phenomena. According to Ilhamdi et al. (2020), however, critical thinking skills among students in Indonesia have not been maximally cultivated, which impacts their critical thinking ability. Based on data from the Programme for International Student Assessment (PISA) in 2018, Indonesia ranked 66th out of 81 countries in Science ability, with an average score of only 383 compared to the PISA average score of 500. This means that Indonesia is among the bottom 15 countries worldwide, compared to other Asian countries such as Thailand and Malaysia (PISA, 2022).

Based on several previous studies, the critical thinking skills of students, especially junior high school students, are still relatively low due to several factors: (1) Teaching is still teacher-centered with less varied methods, causing students to be less interested in studying Integrated Science (Anggareni et al., 2013; Kartika et al., 2020; Rahmatika, 2016; Ramdani et al., 2020; Trimawati, 2020), (2) learning instruments are oriented only towards memorization and concepts (Lissa, 2020; Jamaluddin et al., 2020), and (3) even though media is used, it has not significantly developed students' critical thinking skills (Rahayu et al., 2015). The aforementioned problems align with what the researchers found when conducting observations at SMP Negeri 1 Karangsembung. Based on field observations, interviews with the 8th-grade science teacher, and interviews with 10 8th-grade students, a conclusion can be drawn regarding the low critical thinking skills.

The teacher is still the main source of information and tends to shape students who are passive in exploration. This means that students have not yet actively discovered the true meaning

of learning Science. Science is still merely a subject to be memorized, not applied. From the teacher's perspective, most teachers are concerned about students' attitudes during learning due to low human resources and diversity. If students' abilities vary but teaching is standardized, it is possible that students with low comprehension will fall behind, while students with high comprehension will run out of activities (Al-Shehri, 2020).

tudents need a space that can meet their learning needs. Teachers need to collaborate on ideas to organize learning that not only accommodates student grades but also provides meaningful learning. One student-centered learning model that can be applied currently is differentiated learning integrated with PhET simulation media. The book "Kajian Akademik Kurikulum Merdeka" by the Ministry of Education and Culture (2024) mentions the principle of student-centered learning, which emphasizes that learning should cater to the needs of learners, including varying learning achievements and speeds. Therefore, learning should also be designed to accommodate this diversity (Dinn Wahyudin et al., 2024). Differentiated learning is a method that can accommodate learning needs (Wahyuni and Ganesha, 2022). Differentiated learning is both a philosophical foundation and an organizational structure or framework that describes the learning process aimed at providing the best opportunities for all students (Mumpuniarti and Aini Mahabatti, 2023). In the implementation of differentiated learning, suitable learning media are needed to ensure the learning process meets expectations. One possible learning medium is the PhET virtual laboratory. The use of PhET simulation media aims to connect everyday life phenomena with science lessons through engaging animations, thereby supporting the learning process (Rohmawati et al., 2023). PhET simulations are developed to help students understand physics concepts visually (Rizaldi et al., 2020). PhET can be used as a virtual laboratory with experiments presented in animations, offering ease of use and the ability to connect science learning with natural phenomena (Rizkiana and Apriani, 2020). This will facilitate students in learning science concepts.

Learning that does not merely demand students to master the material but opens their minds to understand and apply it in everyday life. Especially in science learning, which is rich in application contexts. The diversity of students in terms of abilities, interests, and learning styles can be considered in organizing an impactful learning process. Thus, students feel they have contributed in their own way. Differentiated learning can also enhance critical thinking skills (Al-Shehri, 2020).

The subject chosen for this study is Vibrations and Waves. This subject is considered difficult because it involves theories, formulas, and calculations. In reality, the topic of Vibrations and Waves is closely related to daily activities. Therefore, to change this mindset, it is hoped that through differentiated learning, students will be able to connect everyday issues with the topic of Vibrations and Waves. When students can analyze and relate everyday phenomena to the topic of Vibrations and Waves, they can develop their critical thinking skills.

METHODE

The research uses a quantitative experimental research method with a non-equivalent control group design. According to Sugiono (2021), the experimental research method is an approach that involves experimentation and is used to measure the impact of the independent variable (treatment) on the dependent variable (outcome) in a controlled situation.

Tabel 1. Research Design Nonequivalent Control Group Design

Group	Pre Test	Teatment	Post test
Experiment	O_1	X_1	O_2
Control	O_3	X_2	O_4

Explanation:
O1: Experimental class before treatment

ISSN 3031-4518 (online)

O2: Experimental class after treatment
O3: Control class before treatment
O4: Control class after treatment
X1: Differentiated learning using the PhET virtual laboratory
X2: Conventional learning

The research was conducted at SMPN 1 Karangsembung from March 18 to April 1, 2024. The sample consisted of 40 students, comprising 20 students from class 8F as the experimental group (given differentiated learning) and 20 students from class 8G as the control group (given conventional learning). The instruments used included diagnostic assessments, formative assessments, LKPD (Student Worksheets) and pretest-posttest instruments consisting of 15 multiple-choice questions. Pre-test and post-test instruments were first validated by expert validators and senior students. Then, the validity and appropriateness of the test items were further verified using the ANATES application before being distributed to the research sample.

The research stages began with conducting a diagnostic assessment before implementing differentiated learning, in order to assess students' learning profiles, interests, and readiness. A pretest was also conducted to evaluate the students' initial abilities in the topic of vibrations and waves. Next stage is to group students based on their learning styles, which include visual, auditory, and kinesthetic groups. Then, students are provided with instruction through differentiated learning using the PhET virtual laboratory, with 2 brief meetings. The final stage of the research is to conduct formative assessments to understand students' responses to differentiated learning using the PhET virtual laboratory, and a post-test to assess the level of students' critical thinking skills, after being treated. For the control class, only pre-tests and post-tests were used, and conventional teaching methods were applied, with students randomly grouped.

This study employs inferential data analysis techniques using SPSS 25 to test the research hypotheses, including prerequisite tests such as normality and homogeneity tests. Additionally, hypothesis testing is conducted using the non-parametric Wilcoxon Signed-Rank Test because the data is not normally distributed, and the N-Gain test is used to measure the effectiveness of differentiated learning using the PhET virtual laboratory.

RESULT AND DISCUSSION

1. Result

a. Comparison of the Average Pre-Test and Post-Test Scores of the Experimental and Control Class

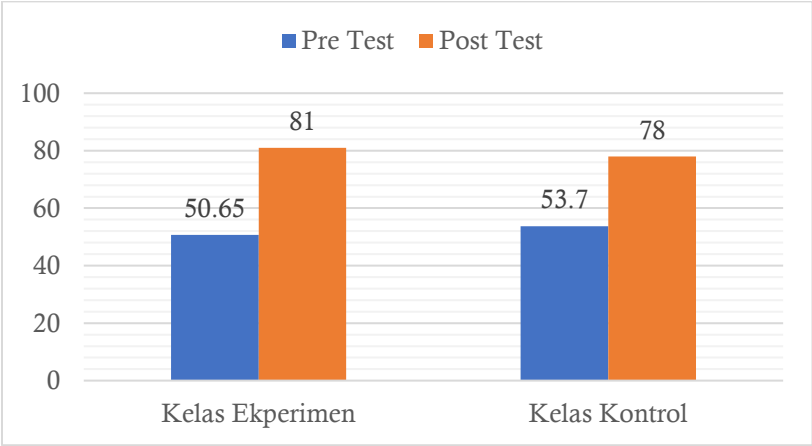

Figure 1. Comparison of the Average Pre-Test and Post-Test Scores of the Experimental and Control Class

b. Prerequisite Tests

ISSN 3031-4518 (online)

1) Normality Test

Table 2. Normality Test Results

Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Pre Test Experiment	,218	20	,014	,883	20	,020
Post Test Experiment	,237	20	,005	,898	20	,038
Pre Test Control	,223	20	,010	,809	20	,001
Post Test Control	,219	20	,013	,885	20	,022

Based on the Shapiro-Wilk decision criteria, data is considered normally distributed if the significance value is ≥0.05. It can be seen from the table that the data obtained is not normal in the pre-test and post-test results of both the experimental and control classes. Therefore, the requirements for parametric analysis cannot be met. As an alternative to the paired sample t-test, the researcher uses non-parametric analysis before further testing with the Wilcoxon test.

2) Homogeneity Test

Table 3. Homogeneity Test Output

	Levene Statistic	df1	df2	Sig.
Based on Mean	,428	3	76	,734
Based on Median	,226	3	76	,878
Based on Median and with adjusted df	,226	3	74,031	,878
Based on trimmed mean	,378	3	76	,769

Based on the homogeneity test, the significance value based on mean for the pre-test and post-test of the experimental and control classes is 0.734. According to the decision criteria for the homogeneity test, if the significance value based on the mean is ≥ 0.05, the populations in the experimental and control classes are said to have the same or homogeneous variance. Therefore, with a result of 0.734, it can be said that the populations in the experimental and control classes have the same or homogeneous variance.

c. Data Analysis Result

1) Wilcoxon Signed Rank Test

Table 4. Wicoxon Test Output

		N	Mean Rank	Sum of Ranks
Post Test – Pre Test Experiment Class	Negative Ranks	0[a]	,00	,00
	Positive Ranks	20[b]	10,50	210,00
	Ties	0[c]		
	Total	20		
Post Test – Pre Test Control Class	Negative Ranks	0[d]	,00	,00
	Positive Ranks	20[e]	10,50	210,00
	Ties	0[f]		
	Total	20		

Based on the Wilcoxon test for the experimental and control classes, negative ranks are interpreted as negative differences between the pre-test and post-test scores of students. In the data above, the values for N, mean rank, and sum of ranks are all 0. This indicates that no students in the experimental and control classes experienced a

ISSN 3031-4518 (online)

decrease in their pre-test and post-test scores. On the other hand, positive ranks indicate an increase between the pre-test and post-test scores in both the experimental and control classes. The value of N represents the number of students in the experimental and control classes, which is 20 students. The mean rank is 10.50 in both the experimental and control classes, and the sum of positive ranks is 210.00 in each class. Ties represent instances where the pre-test and post-test scores are the same. In the table above, the value for ties is 0, meaning there are no equal scores between the pre-test and post-test.

Table 5. Results Wilcoxon *Signed-Rank Test*

	Post Test– Pre Test Experiment Class	Post Test – Pre Test Control Class
Z	-3,933[b]	-3,948[b]
Asymp. Sig. (2-tailed)	,000	,000

The decision criterion for the Wilcoxon hypothesis test is as follows: if Asymp. Sig (2-tailed) < 0.005, then H_0 is rejected and H_a is accepted. Conversely, if Asymp. Sig (2-tailed) > 0.005, then H_0 is the hypothesis indicating no effect in learning.

Based on the table above, the value of Asymp. Sig (2-tailed) is 0.000. Since 0.000 < 0.005, it can be concluded that H_a is accepted. This means there is a significant difference between the pre-test and post-test results, indicating that differentiated learning using the PhET virtual laboratory, as conducted in this study, has an impact on students' critical thinking skills.

2) N-Gain Test

Table 6. N-Gain Test Output

	Class		Statistic	Std. Error
NGain_Percent	Experiment	Mean	61,1879	2,75868
	Control	Mean	52,4723	2,81678

Based on the calculation of the N-Gain score, the average N-Gain score for the experimental class (differentiated) is 61.1879 or 61%. Referring to the interpretation of N-Gain effectiveness discussed earlier, a mean gain score between 56 and 75 falls into the "moderately effective" category. This means that differentiated learning using the PhET virtual laboratory in the experimental class is fairly effective in improving students' critical thinking skills on the topic of Vibrations and Waves. However, with an N-Gain value of 61.1879 or 0.61, it falls into the "moderate" category, indicating that differentiated learning has a moderate effect on students' critical thinking skills on the topic of Vibrations and Waves.

On the other hand, the average N-Gain score for the control class is 52.4723 or 52%, which is categorized as "less effective." This means that conventional teaching methods used in the control class are less effective in enhancing students' critical thinking skills on the topic of Vibrations and Waves. Nevertheless, with an N-Gain value of 52.4723 or 0.52, it falls into the "moderate" category, indicating that conventional teaching also has a moderate effect on students' critical thinking skills on the same topic.

2. Discussion

Differentiated learning becomes an alternative to accommodate student diversity. Differentiated learning is a strategy to address student diversity in the classroom by meeting

ISSN 3031-4518 (online)

learning needs, aiming to align with students' learning styles, interests, and abilities Tomlinson (2013).

In the implementation of differentiated learning, appropriate learning media is necessary to ensure that the learning process aligns with expectations. One such media that can be utilized is the PhET virtual laboratory. The use of PhET simulations aims to connect everyday phenomena with IPAS learning through interactive simulations, thereby supporting the learning process Rohmawati et al (2023). The simulations on PhET are developed to assist students in understanding concepts visually Rizaldi et al (2020). This allows students to hone their critical thinking skills and effectively solve problems in challenging situations (Rahardhian, 2022).

The research findings indicate that differentiated learning using the PhET virtual laboratory has an impact on students' critical thinking skills. The improvement in students' critical thinking skills is supported by learning that is packaged with a differentiated approach that considers students' learning styles, allowing all students to be facilitated according to their characteristics and enhancing their critical thinking skills more effectively compared to students who receive traditional learning Putri et al (2023). Additionally, the improvement in critical thinking skills is supported by media presented through simulations on PhET, which are developed to help students understand physics concepts visually (Rizaldi et al., 2020).

Table 6 shows that the use of differentiated learning with the PhET virtual laboratory is also considered quite effective in improving students' critical thinking skills. This is achieved through the use of instructional materials developed differently based on learning styles. These materials present content in various ways tailored to students' needs. The varied presentation facilitates learners with different learning styles, and thus, three series of instructional materials have been developed to help students with visual, auditory, and kinesthetic learning styles achieve their learning objectives (Maulida et al., 2024).

Differentiated learning using PhET-based virtual simulations in the experimental class has an impact on improving students' critical thinking skills. This is because the learning approach focuses on student diversity with a differentiated learning process through various worksheets tailored to students' interests and innovative practices that have not been previously implemented. These findings can serve as a reference for future research.

CONCLUSION

Differentiated learning using the PhET virtual laboratory has an impact on improving students' critical thinking skills in the topic of Vibrations and Waves. This is evidenced by the hypothesis test results using the non-parametric Wilcoxon Signed-Rank Test, which yielded an Asymp. Sig (2-tailed) value of 0.000 with a significance level of < 0.005, leading to the rejection of H_0 and acceptance of H_a. This means that differentiated learning using the PhET virtual laboratory has a significant impact on enhancing students' critical thinking skills. The effectiveness of differentiated learning using the PhET virtual laboratory in improving students' critical thinking skills, based on the N-Gain results, shows a mean statistic of 61.1879 or 61%, which falls into the "moderately effective" category. Differentiated learning using the PhET virtual laboratory, conducted according to procedure over 2 sessions, received the highest positive response from students. Approximately 64.16% of students agreed that the implemented learning met their needs, increased their motivation, and encouraged them to think critically.

However, differentiated learning needs to be re-evaluated concerning preparation and the learning process so that the results can improve to an effective category. Thus, this study can serve as a reference for future research.

REFERENCES

Al-shehri, M. S. (2020). *Effect of Differentiated Instruction on the Achievement and Development of Critical Thinking Skills among Sixth-Grade Science Students*. *19*(10), 77–99.

Anggareni, N. W., Ristiati, N. P., Widiyanti, N. L. P. M., Studi, P., Sains, P., Pascasarjana, P., & Ganesha, U. P. (2013). *Kemampuan Berpikir Kritis dan Pemaaman Konsep IPA*. *3*.

Dinn Wahyudin, Edy Subkhan, Abdul Malik, Moh. Abdul Hakim, Elih Sudiapermana,

ISSN 3031-4518 (online)

LeliAlhapip, Maisura, Nur Rofika Ayu Shinta Amalia, Lukman Solihin, Nur Berlian Venus Ali, F. N. K. (2024). Kajian Akademik Kurikulum Merdeka. *Kemendikbud*, 1–143.

Filsafat, M., & Mada, U. G. (2020). *Merdeka Belajar dalam Pandangan Ki Hadjar Dewantara dan Relevansinya bagi Pengembangan Pendidikan Karakter*. *3*(3), 95–101.

Hardani Ahyar, Helmina Andriani, D. J. S. (2020). Buku *Metode Penelitian Kualitatif & Kuantitatif* (H. Abadi (ed); Issue March). CV. Pustaka Ilmu.

Indarta, Y., Jalinus, N., Samala, A. D., Riyanda, A. R., & Adi, N. H. (2022). *Edukatif : Jurnal Ilmu Pendidikan Relevansi Kurikulum Merdeka Belajar dengan Model Pembelajaran Abad 21 dalam Perkembangan Era Society 5 . 0*. *4*(2), 3011–3024.

Maulida, F., Fitriani, A. D., & Darmayanti, M. (2024). Development of Teaching Materials Based on Differentiated Learning to Improve Critical Thinking Dimensions of The Pancasila Learner Profile. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, *10*(1), 125. https://doi.org/10.33394/jk.v10i1.10420

Mumpuniarti, Aini Mahabatti, R. R. H. (2023). Diferensiasi Pembelajaran (PengeloLaan Pembelajaran untuk Siswa yang Beragam). In *UNY Press*. http://repo.iain-tulungagung.ac.id/5510/5/BAB 2.pdf

Putri, A. P., Rachmadiarti, F., & Kuntjoro, S. (2023). Implementation of Project Based Learning (PjBL) Model with Differentiation Approach to Improve Critical Thinking Ability. *International Journal of Current Educational Research*, *2*(2), 140–149. https://doi.org/10.53621/ijocer.v2i2.250

Rahardhian, A. (2022). Kajian Kemampuan Berpikir Kritis (Critical Thinking Skill) Dari Sudut Pandang Filsafat. *Jurnal Filsafat Indonesia*, *5*(2), 87–94. https://doi.org/10.23887/jfi.v5i2.42092

Rizaldi, D. R., Jufri, A. W., & Jamaluddin, J. (2020). PhET: Simulasi Interaktif dalam Proses Pembelajaran Fisika. *Jurnal Ilmiah Profesi Pendidikan*, *5*(1), 10–14. https://doi.org/10.29303/jipp.v5i1.103

Rohmawati, L., Wulandari, R., & Wulandari, F. E. (2023). Pengaruh Model Pembelajaran Berbasis Masalah Terintegrasi Media Simulasi Phet Terhadap Keterampilan Berpikir Kritis Peserta Didik Pada Materi Pesawat Sederhana. *Quantum: Jurnal Inovasi Pendidikan Sains*, *14*(1), 1. https://doi.org/10.20527/quantum.v14i1.14458

Sugiyono, P. D. (2021). *Metode Penelitian Pendekatan Kuantitatif, Kualitatif*, Dan R&D (M. Dr. Ir. Sutopo, S.Pd. (ed); 2nd ed). Alfabeta.

Terpadu, J. I. P. A., Matematika, F., & Alam, P. (2015). *Pengaruh Model Pemebelajaran Proces Oriented Guided Learning*. *4*(3).

Tomlinson, C. A., & Moon, T. R. (2013). A*ssessment and Student Success in a Differentiated Classroom*. Alexandria, VA: Association for Supervision and Curiculum Development.

Wahyuni, A. S., & Ganesha, U. P. (2022). *Jurnal Pendidikan MIPA*. *12*, 118–126.

ISSN 3031-4518 (online)