Kepes
http://scholopress.com/kepes-journal
2023 Volume 21 Issue 3 pp. 244-253

Enhancing Junior High School Students' Learning Outcomes through a Hybrid Approach of Virtual and Real Experimental Methods on Static Electric Material

Dens E. S. I. Asbanu [1], **Kostan D. F. Mataubenu** [1], **Angreni B. Liunokas** [2]

[1]Physics Education Department in Institut Pendidikan SoE, Badak Street No. 5A, SoE, 85519, Indonesia
[2]Primary Teacher Education Department in Institut Pendidikan SoE, Badak Street No. 5A, SoE, 85519, Indonesia

Abstract

The virtual experimental method is not a substitute for real experiments in the laboratory, however, the two methods complement each other to facilitate the learning of physics in the classroom. Unfortunately, in Indonesia, there has not yet been found any research in terms of analyzing the effectiveness of the combination of these two methods. The purpose of this study was to analyze the effectiveness of the combination of virtual and real experimental methods on improving the learning outcomes of class IX students at junior high school. The research method used is one group pre-test post-test design. The research sample was 52 students consisting of 3 classes with 14 students in each class. The sampling technique used is random simple sampling. The research instruments are lesson plans, worksheets, and test instruments. The research instrument was declared valid and reliable before being used. The data analysis techniques used were the non-parametric Wilcoxon Signed Rank Test, n-gain, and Kruskal Wallis test because the prerequisite tests for normality and homogeneity of variance were not met. The findings of this study are that there is a significant increase in student learning outcomes in the moderate category before and after learning, and there is no difference in student learning outcomes in the 3 classes after the application of the learning method. Thus, the combination of virtual and real experimental methods is effective in improving the learning outcomes of class IX students.

Keywords: Learning outcome, Virtual laboratory, Real laboratory, Static electricity, Physics learning

1. Introduction

Natural science (IPA) including physics is a systematic way to understand nature, and master knowledge, facts, concepts, principles, and laws through the scientific method (Religia & Achmadi, 2017). Science is not only mastering knowledge in the form of facts, concepts, and principles but also the process of discovery. Mastery and understanding of scientific concepts cannot be separated from laboratory experiments (Zulkifli et al., 2022).

Physics learning aims to train critical thinking, creative and problem-solving skills. Teachers are required to design creative learning models and methods that can be applied in the classroom (Siswadi et al., 2018). Physics learning in the classroom to teach physics as a product in the form of facts, concepts, principles, theories, and laws can be conducted through experimental-based learning with scientific steps.

Experimental-based physics learning provides opportunities for students as active thinkers, to formulate

*Corresponding author
DOI https://doi.org/10.5281/zenodo.7936583#88

and solve problems like scientists, thereby increasing mastery of scientific concepts (Zulkifli et al., 2022). Experimental learning activities can enhance students' learning motivation and active learning, improve skills, scientific attitudes, and learning outcomes (Azhar et al., 2021).

The application of experimental methods in learning physics is combined with various approaches, models, and learning methods. For example, problem-based learning (Aziz et al., 2015), quantum learning model (Arifin et al., 2016), cooperative learning model (Juraini et al., 2017), inquiry learning model (Wahyuni et al., 2017), and contextual learning model (Wati et al., 2021); (Huda & Hikmawati, 2019). However, teachers still encounter problems in their application, namely the lack of experimental tools and limited time to prepare experiments (Taibu & Mataka, 2021).

Current technological advance provides various virtual experimental innovations such as physics education technology (PhET) as a solution for teacher problem. The application of a virtual PhET simulation laboratory is effective in increasing the ability of prospective physics teacher students to solve problems on direct current material (Yuliati et al., 2018), junior high school students' science process skills on temperature & heat material (Haryadi & Pujiastuti, 2020), conceptual understanding, motivation and creativity of junior high school students on the material of the solar system (Prima et al., 2018) (Astutik & Prahani, 2018) (Yunzal, Jr. & Casinillo, 2020), and students science process skills (Taibu & Mataka, 2021). According to Evangelou and Kotsis (Evangelou & Kotsis, 2019), the combination of PhET simulation virtual experiments and real experiments is more effective in improving student learning outcomes than only using the one of them.

PhET simulation has good accuracy in presenting models and principles of physics (Finkelstein et al., 2005). The use of PhET simulation through experimental-based learning supports students' creativity to be actively involved in learning and understanding physics concepts (Perkins et al., 2006). The PhET simulation virtual laboratory is easy to use and accessible anywhere at any time.

The use of virtual laboratories in physics experiments does not eliminate real laboratories but complements the shortcomings of real laboratories. Experiments using virtual laboratories are able to simulate conditions that are not visible to the eye, presenting forms of macroscopic, microscopic, and graphic representations of abstract physics concepts so that they are easy to be understood (Yuliati et al., 2018)(Ceberio et al., 2016). Unfortunately, research that examines the effectiveness of the combination of a virtual laboratory simulation of PhET and a real laboratory in physics learning has not yet been widely carried out.

Static electricity is a basic concept used to understand more complex electromagnetic concepts. Mastery of student learning on static electricity material determines the success of students in understanding more complex electromagnetic material. However, students have difficulties on understanding the concepts of charge and electric circuits (Stefanidou et al., 2019). Students have difficulty connecting abstract physics concepts with real phenomena that occur in everyday life. As a result, student learning outcomes are low.

Student learning outcomes in physics subjects that are still low are the attention of teachers and the world of education today (Putranta & Jumadi, 2019). There are external and internal factors that determine student learning outcomes (Al-Darmaki, 2004). Factors from outside the students are for example the learning media used by the teacher (Sahronih et al., 2019). Meanwhile, from within students, for example, motivation, emotional intelligence, intellectual intelligence (Wayan Jati Adnyana, Ketut Suma, 2017), parental involvement, and student social attitudes (Saraswati et al., 2019).

The results of observations of physics learning in class IX students of SMP Negeri Liman are students who have difficulty understanding physics concepts, low learning outcomes, students are less active during learning and the highest is 50% of students who complete learning at each meeting. Thus, it is necessary for the creativity of teachers to facilitate students in learning in order to improve their learning outcomes.

The effectiveness of the combination of virtual and real laboratory experimental methods is measured by the significant difference in student learning outcomes before and after learning at the significance level α= 5%, the average increase in student learning outcomes in the medium category is based on normalized n-gain calculations and there is no significant difference in average learning outcomes between treatment classes. This research aims to analyzing the effectiveness of the hybrid approach of virtual and real experimental laboratory and real laboratory in improving learning outcomes in the topic of static electricity.

2. Methods

The research method used is a quantitative method, one group pretest-posttest.

Table 1 One group pretest-posttest design

Pretest	Treatment	Post-test
O1	X	O2

O1: Pre-test

O2: Posttest

X: Combination of virtual and real experimental methods

Pretest is given before the implementation of learning through a combination of virtual and real laboratory experimental methods. The time allocation for pretest and post-test was the same, namely 90 minutes. The learning outcomes test instrument used questions about physics concepts developed by Hewit (2008).

The population of this study was grade IX students of SMP Negeri Liman (junior high school) in East Nusa Tenggara Indonesia, consisting of 3 classes. Students in all classes have the same academic ability. The research sample was selected by random sampling technique. The population consists of 3 classes, namely Class IXA, Class IXB and Class IXC with 14 students in each class. So, the total sample is 42 students.

This research begins with the development of learning tools such as lesson plans, student worksheets and learning outcomes test instruments. The learning outcomes test instrument used 4 number essay questions. The learning outcomes test instrument was adapted from the comprehension questions developed by Hewit (2008). In the following table, the validity and reliability of the instrument are presented.

Table 2 Validity and reliability of lesson plans, teaching materials and learning outcomes test instruments

Learning Media	Validity	Category	Reliability	Category
Lesson Plan	3.8	valid	86.5%	reliable
Student Worksheet	3.7	valid	85.0%	reliable
Test instrument	3.8	valid	88.0%	reliable

Table 2 shows the validity and reliability of all research instruments. The results of the validity and reliability test of the instrument showed that the RPS, LKS, and test instruments were valid with a maximum score of 4 and reliable at a maximum score of 100%. Thus, the RPS, LKS and learning outcomes test instruments are feasible to use. The stages of implementing learning with a combination of virtual and real experimental methods are: 1) apperception, 2) formulating questions, 3) students are divided into groups, 4) experiments using PhET and real simulations, 5) discussions and compiling reports, 6) presentations, 7) conclusion. The pretest was carried out at the beginning of the meeting and the post-test was carried out at the end of the last meeting. The pre-test and post-test questions used are the same.

The data analysis technique of student learning outcomes used paired sample t-test or non-parametric analysis of the Wilcoxon Signed Rank Test. Paired sample t-test was carried out if the pre-test and post-test score normality assumptions were met. On the other hand, if the assumption of normality is not met, non-parametric analysis will be used. The n-gain test equation (Hake, 2009) is used to determine the increase in student learning outcomes as follows:

$$n - gain = \frac{\text{Sposttest} - \text{Spretest}}{\text{Ideal score} - \text{Spretest}}$$

Table 3 Interpretation of n-gain

n-gain value	Category	Conclusion
n-gain ≥0.70	Tall	Very effective
0.3 < n-gain < 0.70	Currently	effective
n-gain ≤0.3	low	Less effective

One-way ANOVA test was used to determine the significant difference in the average results in group 1, group 2 and group 3. The ANOVA test was used if the normality and homogeneity assumptions were met. On the other hand, if not, then the non-parametric Kruskal Wallis test will be continued. Analysis of this data used IBM SPSS statistical software 25.

3. Results

Table 4 shows that the average learning outcomes of students in grades IXA, IXB and IXC before the implementation of combined virtual and real laboratory experimental methods, namely 30.33, 30.36, 33.93 respectively in low category and after learning the average of student learning outcomes increased with an average post-tests are 66.07, 66.97 and 71.43, in the range of values 0-100.

Table 4 Descriptive statistics

Group	N	mean	Std. Deviation
Pre-test Class IXA	14	30.33	17,482
Pre-test Class IXB	14	30.36	22,315
Pre-test Class IXC	14	33.93	18,624
Post-test Class IXA	14	66.07	18,624
Post-test Class IXB	14	66.97	15,833
Post-test Class IXC	14	71.43	13,363

Table 5 describes the results of the normality test with Kolmogorov-Smirnov shows the significance value of the pre-test and post-test for classes IXA, IXB, and IXC < 0.05. It means that the pre-test and post-test data for classes IXA, IXB and IXC are not normally distributed. Thus, the statistical test of increasing learning outcomes for each class was followed by a non-parametric test, namely the Wilcoxon Signed Rank Test. Table 6 presents the results of the Wilcoxon Signed Rank Test.

Table 5 Normality test

	Class	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
		Statistics	df	Sig.	Statistics	df	Sig.
Learning outcomes	Pretest Class IXA	.263	14	.009	.806	14	.006
	Posttest Class IXA	.306	14	.001	.773	14	.002
	Pretest Class IXB	.238	14	.031	.889	14	.079
	Posttest Class IXB	.285	14	.003	.771	14	.002
	Pretest Class IXC	.306	14	.001	.773	14	.002
	Posttest Class IXC	.391	14	.000	.713	14	.001

a. Lilliefors Significance Correction

Table 6 shows that: the negative rank or the difference (negative) between the average student learning outcomes for the pre-test and post-test in classes IXA, IXB, IXC is 0, both in the value of N, mean rank, and sum rank. This 0 value indicates no decrease (reduction) from the pre-test to post-test scores.

Table 6 Wilcoxon Signed Rank Test

		N	Mean Rank	Sum of Ranks
Posttest Class IXA - Pretest Class IXA	Negative Ranks	0 [a]	.00	.00
	Positive Ranks	14 [b]	7.50	105.00
	Ties	0 [c]		
	Total	**14**		
Post Class IXB - Pretest Class IXB	Negative Ranks	0 [d]	.00	.00
	Positive Ranks	14 [e]	7.50	105.00
	Ties	0 [f]		
	Total	**14**		
Posttest Class IXC - Pretest Class IXC	Negative Ranks	0 [g]	.00	.00
	Positive Ranks	14 [h]	7.50	105.00
	Ties	0 [i]		
	Total	**14**		

Positive rank or difference (positive) between the average student learning outcomes for pre-test and post-test in class IXA, IXB, IXC. From the table, we ca see that N for classes IXA, IXB, and IXC are all 14, meaning that 14 students in each class were experienced an increase in learning outcomes. The mean rank or the average increase is 7.50, while the number of positive ranks is 105. Ties are the similarity of pre-test and post-test scores. In table 3 the value of ties is 0, so it is said that the pre-test and post-test are not the same value.

Table 7 Statistical test

	Posttest Class A - Pretest Class A	Posttest Class B - Pretest Class B	Posttest Class C - Pretest Class C
Z	-3,440 [b]	-3,440 [b]	-3,384 [b]
asymp. Sig. (2-tailed)	.001	.001	.001

Hypothesis I

Table 7 shows the value of Asym.Sig (2-tailed) post-test – pretest of class A namely 0.01 < 0.05, therefore H_{01} is rejected. This means that there is a positive and significant increase in student learning outcomes for class IXA at α= 5%.

Hypothesis II

Table 7 shows the value of Asym.Sig (2-tailed) post-test – pretest of class B namely 0.001 < 0.05, therefore H_{02} is rejected. This means that there is a positive and significant increase in student learning outcomes for class IXB at α= 5%.

Hypothesis III

Table 7 shows the value of Asym.Sig (2-tailed) post-test – pretest of class C namely 0.001 < 0.05, then H_{03} is rejected. This means that there is a positive and significant increase in student learning outcomes for class IXC at α= 5%.

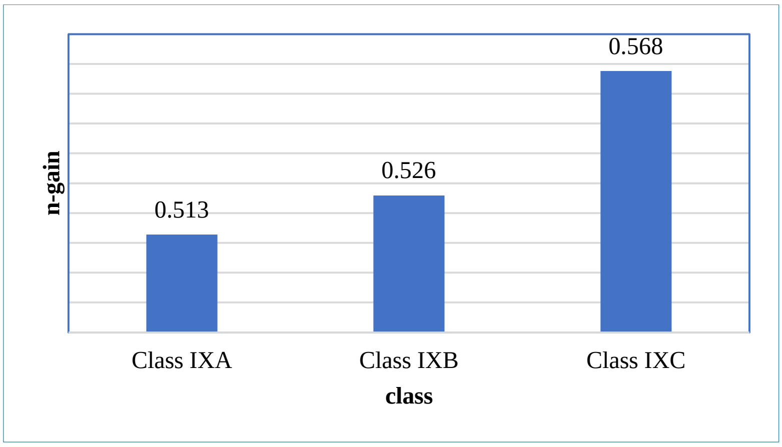

Fig. 1 N-gain Class IXA, IXB, and IXC

Fig. 1 shows the number of n-gain of students learning outcomes in grades IXA, IXB and IXC namely 0.513, 0.526, and 0.568 respectively. These values indicate that there is an increase in student learning outcomes for each class in the medium category.

Table 8 Normality Test

		Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	class	Statistics	df	Sig.	Statistics	df	Sig.
Posttest	Class IXA	.388	14	.000	.684	14	.000
	ClassIXB	.389	14	.000	.688	14	.000
	Class IXC	.369	14	.000	.639	14	.000

Based on table 7 about the Shapiro-Wilk normality test, it is shown that the obtained sig value of post-test class IXA, IXB, and IXC namely 0.000 < 0.05 indicate that the data is not normally distributed.

Table 9 Test of Homogeneity of Variances

		Levene Statistics	df_1	df_2	Sig.
Learning Outcomes	Based on Mean	2,548	2	39	.091
	Based on Median	2.186	2	39	.126
	Based on Median and with adjusted df	2.186	2	36,268	.127
	Based on trimmed mean	2,472	2	39	.098

Based on Table 9, the homogeneity test shown that the value of sig. is 0.091 > 0.05 therefore it can be concluded that the data is homogeneous. The results of the normality assumption test are not satisfied, on the other hand the homogeneity test is satisfied. Thus, the requirements of the parametric statistical test were not also satisfied, therefore the non-parametric Kruskall Wallis test was applied in the next step. The results of the Kruskal Wallis test are presented in Table 10.

Table 10 Kruskal Wallis test

	Post-test
Kruskal-Wallis H	.045
df	2
asymp. Sig.	.978

a. Kruskal Wallis Test

b. Grouping Variable: Class

Table 10 shows the value of Asymp. Sig is 0.978 > 0.05 so that Ho is accepted. This means that there is no significant difference in student learning outcomes between class IXA, class IXB and class IXC at α= 5%.

4. Discussion

Analysis of the research data showed that there was a positive increase in student learning outcomes from pre-test to post-test at α= 5%, with an average n-gain increase in 3 classes, namely 0.513, 0.526, and 0.568 in the medium category, and there was no difference in significant average learning outcomes between classes at α= 5%. Thus, the application of the experimental method of combining virtual and real laboratories effectively improves the learning outcomes of class IX students. There is a lack of research investigating the effects of using a combination of virtual and real laboratories on students' conceptual understanding. However, the results of several comparative studies between the two types of laboratories suggest that students' conceptual understanding tends to be higher and significantly different when they learn using virtual laboratories compared to real laboratories.

Nevertheless, there is a significant improvement in student's conceptual understanding (learning outcomes) of the material on direct current electricity among the groups that use both virtual and real laboratories, as revealed in the study by Faour et al. (Faour et al., 2018). This finding differs from the conclusion of Zulkifli et al. (Zulkifli et al., 2022) who found no significant difference in student's conceptual understanding (learning outcomes) between virtual and real laboratories in learning Hooke's law. Therefore, teachers should consider the characteristics of the material when selecting a suitable laboratory method, whether it be virtual, real, or a combination of both.

Based on the analysis of research data, it shows that the combination of virtual experimental methods is effective in improving student learning outcomes from pre-test to post-test. These results support the findings of Jaakkola et,al (2011)(Jaakkola et al., 2011) (Jaakkola et al., 2011)that students who are given learning using a combination of virtual and real experimental methods have a higher level of understanding than the virtual experimental method or the real experimental method only. Another study states that the combination of virtual and real experimental methods provides high support for students' conceptual understanding, and is effective in promoting the strengthening of physics concepts than the experimental method or the experimental method alone (Chini et al., 2012; Zacharia et al., 2008; Zacharia & de Jong, 2014; Wang & Tseng, 2018).

The improvement of student learning outcomes due to the combination of virtual and real laboratory experimental methods bridges the gap between concepts and theories. The use of virtual laboratories facilitates students observing the microscopic phenomena of charge transfer in static electricity and turns abstract phenomena into concrete ones (Wang & Tseng, 2018) . A good understanding of microscopic phenomena makes it easier for students to abstract the concepts that underlie real phenomena (Jaakkola et al., 2011; Zacharia & Jong, n.d.). The use of virtual experimental methods provides understanding and experience of the topics that students learn about (Yuliati et al., 2018), creates a pleasant learning environment (Aljuhani et al., 2018), and makes students active in learning (Özcan et al., 2020). The experimental method of combining virtual and real laboratories can be applied to students and teachers as a solution to improve student learning outcomes.

The sample used in this study was grade IX junior high school students, in contrast to the research from Jaakola, et al. (2011) who were using a sample of elementary school students (Jaakkola et al., 2011), meanwhile, Zacharia and Jong using a research sample of university students (Zacharia & Jong, n.d.). Further research that can be carried out is by expanding the research sample, learning materials and experimental methods involving the control class.

5. Conclusions

The finding of this study indicates that the application of the experimental method of combining virtual and real laboratories effectively improves the learning outcomes of grade IX students. The average of n-gain increases at the medium category namely 0.513, 0.526 and 0.568 in three classes respectively. However, there was no significant difference in average learning outcomes among the classes. The study highlights the need for further research on the effects of using a combination of virtual and real laboratories on student's learning outcomes. The results of the study support previous research that showed a higher level of understanding among students who learn using a combination of virtual and real experimental methods. The combination of virtual and real experimental methods provides high support for students' learning outcomes and promotes the strengthening of physics concepts. The improvement of student learning outcomes due to the combination of virtual and real laboratory experimental methods bridges the gap between concepts and theories. The use of virtual laboratories facilitates students in observing microscopic phenomena and turning abstract concepts into concrete ones. The experimental method of combining virtual and real laboratories can be an effective solution to improve students learning outcomes. Further research can be carried out by expanding the research sample, learning materials and experimental methods involving the control class.

Funding Information

The authors did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Conflict

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Al-Darmaki, F. R. (2004). Counselor training, anxiety, and counseling self-efficacy: Implications for training psychology students from the United Arab Emirates University. *Social Behavior and Personality*, *32*(5), 429–440. https://doi.org/10.2224/sbp.2004.32.5.429
2. Aljuhani, K., Sonbul, M., Althabiti, M., & Meccawy, M. (2018). Creating a Virtual Science Lab (VSL): the adoption of virtual labs in Saudi schools. *Smart Learning Environments*, *5*(1). https://doi.org/10.1186/s40561-018-0067-9
3. Arifin, Z., Sudarti, S., & Lesmono, A. D. (2016). Pengaruh Model Quantum Learning Disertai Metode Eksperimen Terhadap Hasil Belajar Fisika Siswa Di Sma Negeri Kalisat. *Jurnal Pembelajaran Fisika*, *4*(4), 365-370–370.
4. Astutik, S., & Prahani, B. K. (2018). The practicality and effectiveness of Collaborative Creativity Learning (CCL) model by using PhET simulation to increase students' scientific creativity. *International Journal of Instruction*, *11*(4), 409–424. https://doi.org/10.12973/iji.2018.11426a
5. Azhar, Herfana, P., Nasir, M., Irawan, D., & Islami, N. (2021). Development of 3D physics learning media using augmented reality for first-year Junior high school students. *Journal of Physics: Conference Series*, *2049*(1). https://doi.org/10.1088/1742-6596/2049/1/012036
6. Aziz, A., Rokhmat, J., & Kosim. (2015). "Pengaruh Model Pembelajaran Berbasis Masalah Dengan Metode Eksperimen Terhadap Hasil Belajar Fisika Siswa Kelas X SMAN 1 Gunungsari ". *Jurnal Pendidikan Fisika Dan Teknologi*, *I*(3), 201–204.
7. Ceberio, M., Almudí, J. M., & Franco, Á. (2016). Design and Application of Interactive Simulations in Problem-Solving in University-Level Physics Education. *Journal of Science Education and Technology*, *25*(4), 590–609. https://doi.org/10.1007/s10956-016-9615-7
8. Chini, J. J., Madsen, A., Gire, E., Rebello, N. S., & Puntambekar, S. (2012). Exploration of factors that affect the comparative effectiveness of physical and virtual manipulatives in an undergraduate laboratory. *Physical Review Special Topics - Physics Education Research*, *8*(1), 1–12. https://doi.org/10.1103/PhysRevSTPER.8.010113

9. Evangelou, F., & Kotsis, K. (2019). Real vs virtual physics experiments: comparison of learning outcomes among fifth grade primary school students. A case on the concept of frictional force. *International Journal of Science Education*, *41*(3), 330–348. https://doi.org/10.1080/09500693.2018.1549760
10. Faour, M. A., Ayoubi, Z., & Faour, Malak Abou; Ayoubi, Z. (2018). The Effect of Using Virtual Laboratory on Grade 10 Students' Conceptual Understanding and their Attitudes towards Physics. *Journal of Education in Science, Environment and Health*, *4*(1), 54–68. https://doi.org/10.21891/jeseh.387482
11. Finkelstein, N. D., Adams, W. K., Keller, C. J., Kohl, P. B., Perkins, K. K., Podolefsky, N. S., Reid, S., & Lemaster, R. (2005). When learning about the real world is better done virtually: A study of substituting computer simulations for laboratory equipment. *Physical Review Special Topics - Physics Education Research*, *1*(1), 1–8. https://doi.org/10.1103/PhysRevSTPER.1.010103
12. Hake, R. R. (2009). *Analyzing Change/Gain Scores*. *1*(1), 1–4. https://doi.org/10.24036/ekj.v1.i1.a10
13. Haryadi, R., & Pujiastuti, H. (2020). PhET simulation software-based learning to improve science process skills. *Journal of Physics: Conference Series*, *1521*(2). https://doi.org/10.1088/1742-6596/1521/2/022017
14. Huda, N., & Hikmawati, K. (2019). PENGARUH PENDEKATAN KONTEKSTUAL BERBANTUAN ALAT PERAGA TERHADAP PENGUASAAN KONSEP DAN KEMAMPUAN PEMECAHAN MASALAH FISIKA. *J. Pijar MIPA*, *14*(1), 62–72. https://doi.org/10.29303/jpm.v14i1.958
15. Jaakkola, T., Nurmi, S., & Veermans, K. (2011). A comparison of students' conceptual understanding of electric circuits in simulation only and simulation-laboratory contexts. *Journal of Research in Science Teaching*, *48*(1), 71–93. https://doi.org/10.1002/tea.20386
16. Juraini, J., Taufik, M., & Gunada, I. W. (2017). Pengaruh Model Pembelajaran Kooperatif Tipe STAD (Student Team Achievement Division) dengan Metode Eksperimen Terhadap Keterampilan Proses Sains dan Hasil Belajar Fisika pada Siswa SMA Negeri 1 Labuapi Tahun Pelajaran 2015/2016. *Jurnal Pendidikan Fisika Dan Teknologi*, *2*(2), 80. https://doi.org/10.29303/jpft.v2i2.293
17. Özcan, H., Çetin, G., & Koştur, H. İ. (2020). The Effect of PhET Simulation-based Instruction on 6th Grade Students' Achievement Regarding the Concept of Greenhouse Gas. *Science Education International*, *31*(4), 348–355. https://doi.org/10.33828/sei.v31.i4.3
18. Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., & LeMaster, R. (2006). PhET: Interactive Simulations for Teaching and Learning Physics. *The Physics Teacher*, *44*(1), 18–23. https://doi.org/10.1119/1.2150754
19. Prima, E. C., Putri, A. R., & Rustaman, N. (2018). Learning solar system using PhET simulation to improve students' understanding and motivation. *Journal of Science Learning*, *1*(2), 60. https://doi.org/10.17509/jsl.v1i2.10239
20. Putranta, H., & Jumadi. (2019). Physics teacher efforts of Islamic high school in Yogyakarta to minimize students' anxiety when facing the assessment of physics learning outcomes. *Journal for the Education of Gifted Young Scientists*, *7*(2), 119–136. https://doi.org/10.17478/JEGYS.552091
21. Religia, R., & Achmadi, H. R. (2017). Pengembangan KIT Sederhana Stirling Engine pada Materi Termodinamika sebagai Media Pembelajaran Fisika SMA Racy Religia, Hainur Rasyid Achmadi. *Jurnal Inovasi Pendidikan Fisika (JIPF)*, *06*(03), 113–119.
22. Sahronih, S., Purwanto, A., & Sumantri, M. S. (2019). The effect of interactive learning media on students' science learning outcomes. *ACM International Conference Proceeding Series*, *Part F1483*, 20–24. https://doi.org/10.1145/3323771.3323797
23. Saraswati, Suwindra, & Mardana. (2019). Hubungan Keterlibatan Orang Tua Dan Sikap Sosial Siswa Dengan Prestasi Belajar Fisika Sma Negeri. *Jppf*, *9*(1), 43–54. https://ejournal.undiksha.ac.id/index.php/JJPF/article/view/20648
24. Siswadi, S., Susilawati, S., & Hikmawati, H. (2018). Pengaruh Pendekatan Vak (Visualization, Auditory, Kinestetic) Terhadap Hasil Belajar Fisika Siswa Smpn 10 Mataram. *Jurnal Penelitian Pendidikan IPA*, *4*(1). https://doi.org/10.29303/jppipa.v4i1.100
25. Stefanidou, C. G., Tsalapati, K. D., Ferentinou, A. M., & Skordoulis, C. D. (2019). Conceptual difficulties pre-service primary teachers have with static electricity. *Journal of Baltic Science Education*, *18*(2), 300–313. https://doi.org/10.33225/jbse/19.18.300

26. Taibu, R., & Mataka, L. (2021). *CUNY Academic Works Using PhET Simulations to Improve Scientific Skills and Attitudes of Community College Students How does access to this work benefit you ? Let us know ! Using PhET Simulations to Improve Scientific Skills and Attitudes of*.
27. Taibu, R., Mataka, L., & Shekoyan, V. (2021). Using PhET simulations to improve scientific skills and attitudes of community college students. *International Journal of Education in Mathematics, Science and Technology*, *9*(3), 353–370. https://doi.org/10.46328/IJEMST.1214
28. Wahyuni, R., Hikmawati, H., & Taufik, M. (2017). Pengaruh Model Pembelajaran Inkuiri Terbimbing dengan Metode Eksperimen terhadap Hasil Belajar Fisika Siswa Kelas XI IPA SMAN 2 Mataram Tahun Pelajaran 2016/2017. *Jurnal Pendidikan Fisika Dan Teknologi*, *2*(4), 164. https://doi.org/10.29303/jpft.v2i4.308
29. Wang, T. L., & Tseng, Y. K. (2018). The Comparative Effectiveness of Physical, Virtual, and Virtual-Physical Manipulatives on Third-Grade Students' Science Achievement and Conceptual Understanding of Evaporation and Condensation. *International Journal of Science and Mathematics Education*, *16*(2), 203–219. https://doi.org/10.1007/s10763-016-9774-2
30. Wati, R. Y., Ningrat, H. K., & Didik, L. A. (2021). Pembelajaran fisika berbasis CTL melalui metode eksperimen untuk meningkatkan motivasi dan hasil belajar materi tata surya. *Edu Sains Jurnal Pendidikan Sains & Matematika*, *9*(1), 40–49. https://doi.org/10.23971/eds.v9i1.2103
31. Wayan Jati Adnyana, Ketut Suma, I. S. (2017). Kontribusi Motivasi Belajar, Kecerdasan Emosional, dan Kecerdasan Intelektual Terhadap Prestasi Belajar Fisika. *Jurnal Pendidikan Fisika Undiksha*, *7*(2), 42–52.
32. Yuliati, L., Riantoni, C., & Mufti, N. (2018). Problem solving skills on direct current electricity through inquiry-based learning with PhET simulations. *International Journal of Instruction*, *11*(4), 123–138. https://doi.org/10.12973/iji.2018.1149a
33. Yunzal, Jr., A. N., & Casinillo, L. F. (2020). Effect of Physics Education Technology (PhET) Simulations: Evidence from STEM Students' Performance. *Journal of Education Research and Evaluation*, *4*(3), 221. https://doi.org/10.23887/jere.v4i3.27450
34. Zacharia, & Jong, T. de. (n.d.). The Effects on Students' Conceptual Understanding of Electric Circuits of Introducing Virtual Manipulatives Within a Physical Manipulatives-Oriented Curriculum. *Cognition and Instruction*, *32*(2), 101–158.
35. Zacharia, Z. C., & de Jong, T. (2014). The Effects on Students' Conceptual Understanding of Electric Circuits of Introducing Virtual Manipulatives Within a Physical Manipulatives-Oriented Curriculum. *Cognition and Instruction*, *32*(2), 101–158. https://doi.org/10.1080/07370008.2014.887083
36. Zacharia, Z. C., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching*, *45*(9), 1021–1035. https://doi.org/10.1002/tea.20260
37. Zulkifli, Z., Azhar, A., & Syaflita, D. (2022). Application Effect of PhET Virtual Laboratory and Real Laboratory on the Learning Outcomes of Class XI Students on Elasticity and Hooke's Law. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 401–407. https://doi.org/10.29303/jppipa.v8i1.1274