Tekno-Pedagogi 14 (2) (2024)
ISSN: 2088-205X | E-ISSN: 2715-7415
Tekno-Pedagogi : Jurnal Teknologi Pendidikan
https://online-journal.unja.ac.id/pedagogi
DOI: 10.22437/teknopedagogi.v14i2.37487

Comparison of the Effect of Using Virtual Laboratory Based on PhET Simulation and Real Laboratory in Improving Mastery of Electronic Concepts of Physics Education Students

Annisa Fitriani[1]
[1]UIN Alauddin Makassar, Makassar, Indonesia
Corresponding author email: anisafit@gmail.com

Info Article
Received: 21 Aug 2024
Revised: 22 Sep 2024
Accepted: 7 Oct 2024
OnlineVersion: 7 Oct 2024

Abstract
This study aimed to compare the mastery of electronic concepts among physics education students using a constructivist virtual laboratory (PhET Simulation) and a real constructivist laboratory. The importance of this research lies in the potential of virtual laboratories as an alternative to physical ones, especially when resources are limited. The research employed a quasi-experimental design with a matching-only posttest-only control group. The sample consisted of 68 physics education students from UIN Alauddin Makassar, divided into two groups: one using PhET Simulation (34 students) and the other using real laboratories (34 students). Data were collected through multiple-choice tests designed to measure concept mastery, analyzed using descriptive statistics and inferential tests such as t-tests. The results showed no significant difference in concept mastery between students using PhET Simulation and those using real laboratories ($t = -0.167$, $p = 0.868$). Both methods were equally effective in enhancing students' understanding of electronics. The novelty of this study lies in directly comparing the two laboratory approaches within a constructivist framework. This finding suggests that virtual laboratories can serve as a viable alternative to real laboratories in supporting concept mastery, offering flexibility and resource efficiency. The implications of the study are particularly relevant for educational institutions with limited access to physical laboratories, as PhET Simulation provides a cost-effective solution without compromising learning outcomes.

Keywords: Concept Mastery; Constructivist Laboratory; Electronic; PhET Simulation; Physics Education

INTRODUCTION

The laboratory is a vital facility in science education, especially physics. The laboratory allows students to conduct various experiments, trials, and tests that can strengthen the theories learned in class (Altmeyer et al., 2020; Yusuf & Widyaningsih, 2020). A laboratory is a place to conduct experiments, research, or investigations related to physics, chemistry, and so on (Coccia, 2020; Kamid et al., 2023; Kolil et al., 2020). In a laboratory environment, students can practice skills, introduce themselves to the tools and components of the practicum, and gain new knowledge through scientific experiments.

Practicums provide hands-on experience that enhances students' understanding of scientific concepts. In laboratory activities, students not only understand the theory but also develop psychomotor skills such as data analysis and teamwork. In addition, practicums encourage students to think critically and creatively in facing scientific challenges (Kulgemeyer et al., 2020; Noorjanah et al., 2023; Sjøen, 2023). Previous studies have shown that practicums play an important role in improving students' cognitive, affective, and psychomotor aspects (Adiningsih et al., 2020; Eralita, 2023; Fitriani et al., 2021).

With the development of technology, virtual laboratories such as PhET Simulation have become an efficient alternative to overcome the limitations of physical laboratories. PhET Simulation is interactive software that allows students to simulate physics experiments visually (Banda & Nzabahimana, 2021; Sarwoto et al., 2020; Uwamahoro et al., 2021). This program helps students understand abstract concepts such as electric current and the movement of electrons in electronic circuits, which are difficult to see in physical laboratories (Alfiyanti et al., 2020; Ruwiyah et al., 2021; Serevina & Kirana, 2021). The use of virtual laboratories also minimizes the risk of equipment damage and facilitates experiments without equipment limitations.

Mastery of concepts is an important aspect in physics education, especially in electronics courses that study the movement of electric current in circuits. Students often have difficulty understanding the movement of electric current theoretically and practically (Assem et al., 2023; Chen et al., 2013). With the use of constructivist laboratories, both virtual and real, it is hoped that students can master electronic concepts in more depth (Sinaga & Setiawan, 2022). PhET Simulation provides advantages in visualizing invisible current flows, while physical laboratories allow students to assemble components in real terms (Ouahi et al., 2022; Sarwoto et al., 2020).

Previous studies have shown that the use of virtual and real constructivist laboratories has its own advantages and disadvantages. Research by Liana et al. (2023) showed that PhET Simulation was able to increase students' creativity and conceptual mastery. However, there have not been many studies that specifically compare the effectiveness of conceptual mastery between the use of virtual and real constructivist laboratories in the context of electronics learning for physics education students.

Along with the development of technology and challenges in physics learning, innovation is needed in more effective and efficient learning methods. Physical laboratories often face obstacles such as limited equipment and maintenance costs, while virtual laboratories offer greater flexibility. Therefore, this study is very important to evaluate which method is more effective in improving students' mastery of electronics concepts. This study aims to compare the mastery of electronics concepts of physics education students between those who use virtual constructivist laboratories with PhET Simulation and real constructivist laboratories. This study is expected to contribute to the development of better learning methods in the context of physics education, as well as offer practical solutions for educational institutions that have limited physical laboratories.

RESEARCH METHODS

Research Design

This study used a quasi-experimental design with a matching-only posttest-only control group design. This study involved two groups, namely the experimental group and the control group. In this design, the experimental group was given treatment in the form of using a virtual constructivist laboratory (PhET Simulation), while the control group used a real constructivist laboratory. After the treatment, both groups were given a posttest to evaluate students' mastery of electronics concepts.

Research Target/Subject

The subjects of this study were students majoring in Physics Education class of 2022 at UIN Alauddin Makassar. The research sample consisted of 68 students, who were divided into two groups: 34 students in the experimental class and 34 students in the control class. The sampling technique used was convenience sampling combined with matching techniques, which ensured that both groups had balanced characteristics.

Research Procedure

The research procedure began by dividing the sample into two groups. The experimental class used PhET Simulation to conduct virtual experiments, while the control class conducted direct experiments in a real laboratory. After the learning and practicum period was completed, both groups were given the same posttest to measure their mastery of electronics concepts. This posttest is the main instrument in this study to assess student learning outcomes.

Instruments, and Data Collection Techniques

The research procedure begins by dividing the sample into two groups. The experimental class uses PhET Simulation to conduct virtual experiments, while the control class conducts direct experiments in a real laboratory. After the training period, the instrument used in this study is an electronics concept mastery test in the form of a multiple-choice test. This test includes 20 questions arranged based on Bloom's taxonomy at levels C1 to C4, namely from remembering to analyzing. The score for each correct answer is 1, while the wrong answer gets a score of 0. In addition, the practical module is also used as an instrument that distinguishes between virtual and real laboratory modules that are arranged specifically for each group. After the lesson and practice are completed, both groups are given the same posttest to measure mastery of electronics concepts. This posttest is the main instrument in this study to assess student learning outcomes..

Data analysis technique

The collected data were analyzed using descriptive analysis and inferential analysis. Descriptive analysis was used to describe the frequency distribution, mean value, standard deviation, and variance of the posttest results. In addition, a normality test was conducted to determine whether the data was normally distributed using the Kolmogorov-Smirnov method. If the data was normally distributed, then it was continued with an independent t-sample test to compare the mastery of concepts between the two groups. A homogeneity test was also conducted to ensure that the two groups had the same variance.

RESULTS AND DISCUSSION

The following are the research results presented in table form for each section:

Table 1. Descriptive Mastery of Electronics Concepts

Description	Experimental Class (PhET Simulation)	Control Class (Real Laboratory)
Mean	71.35	71.71
Maximum Value	86	87
Minimum Value	60	40
STANDAV	6,884	10,259

This table presents descriptive statistics on the posttest results of students' mastery of electronics concepts. The experimental class, which used the PhET Simulation virtual laboratory, had an average score of 71.35, with a maximum score of 86 and a minimum score of 60. The control class, which used a real laboratory, had a slightly higher average of 71.71, with a maximum score of 87 and a minimum score of 40. In terms of standard deviation, the experimental class showed a lower score (6.884) than the control class (10.259), indicating that the distribution of scores in the experimental class was more homogeneous or consistent than in the control class. In general, both groups showed comparable results in mastery of electronics concepts.

Table 2. Category of Concept Mastery

Category	Experimental Class (PhET Simulation)	Control Class (Real Laboratory)
Very Good (≥ 80)	4 students (11.77%)	7 students (20.59%)

Good (60-79)	30 students (88.23%)	24 students (70.58%)
Fair (40-59)	0 students (0%)	3 students (8.83%)

This table categorizes students' conceptual mastery into three categories: very good (≥ 80), good (60-79), and sufficient (40-59). In the experimental class (PhET Simulation), 4 students (11.77%) were in the very good category, while 30 students (88.23%) were in the good category. No students were in the sufficient category. In the control class (real laboratory), 7 students (20.59%) were in the very good category, 24 students (70.58%) were in the good category, and 3 students (8.83%) were in the sufficient category. From this table, it can be seen that more students from the control class achieved the very good category, but overall, the majority of students from both groups were in the good category.

Table 3. Results of Normality and Homogeneity Tests

Test	Results
Normality Test	Data is normally distributed
Homogeneity Test	Significance = 0.287 (homogeneous)

This table shows the results of the normality and homogeneity tests to ensure that the data used meet the statistical assumptions for the t-test. The results of the normality test indicate that the data from both groups are normally distributed, meaning there is no violation of the normality assumption. The homogeneity test shows a significance value of 0.287, which is greater than 0.05, so it can be concluded that the variance between the experimental and control groups is homogeneous. This indicates that the variability of scores in the two groups is not significantly different, which is an important requirement in the t-test analysis.

Table 4. Hypothesis Test Results

Test	Value
t-count	-0.167
Sig. (2-tailed)	0.868
Conclusion	No significant difference

This table presents the results of the independent sample t-test used to compare the mastery of electronics concepts between the experimental and control groups. The results show that the t-test is -0.167 and the sig. (2-tailed) value is 0.868, which is greater than 0.05. Thus, there is no significant difference in concept mastery between students who use the PhET Simulation virtual constructivist laboratory and those who use the real laboratory. Therefore, H0 is accepted, which means that both laboratory methods are equally effective in improving students' mastery of electronics concepts.Overall, the results of this study indicate that both the use of virtual laboratories and real laboratories provide comparable results in concept mastery for physics education students.

The results of this study indicate that there is no significant difference between students' mastery of electronics concepts using the PhET Simulation-based virtual laboratory and the real laboratory. The practical implication of this finding is that educational institutions can be more flexible in choosing laboratory methods without sacrificing the quality of learning (Müller, ClauMüller & Mildenberger, 2021; Triani et al., 2023; Valtonen et al., 2021). Virtual laboratories can be an effective alternative, especially for educational institutions that have limited physical laboratory facilities or budgets (Orobor & Orobor, 2020). In addition, the use of PhET Simulation can also increase accessibility, allowing students to conduct experiments outside the physical laboratory space and without time constraints, while maintaining learning effectiveness (Pela et al., 2023; Samijo & Romadona, 2023). The uniqueness (novelty) of this study lies in the direct comparison between two constructivism-based laboratory approaches—virtual and real—in the context of mastering electronics concepts, which is rarely done in previous studies. Many previous studies have focused more on the effectiveness of one method, but this study provides a new contribution by evaluating the equivalence of conceptual mastery results between the two methods in physics learning. In addition, this study provides insight that virtual laboratories are not only an alternative, but can play an equal role with physical laboratories in developing students' conceptual mastery, especially in the field of electronics.

CONCLUSION

Based on the results of the study, it can be concluded that the mastery of electronic concepts of students who use virtual constructivist laboratories based on PhET Simulation shows results that are equivalent to students who use real constructivist laboratories. There was no significant difference in concept mastery between the two groups, which means that both laboratory methods are equally effective in helping students master electronic concepts. These results indicate that the virtual laboratory approach can be relied on as a learning method that is equivalent to a real laboratory in improving students' conceptual understanding. In addition, virtual laboratories based on PhET Simulation provide advantages in terms of flexibility and accessibility, allowing students to conduct experiments at any time without relying on the availability of physical equipment. However, real laboratories still provide important practical experience in developing students' psychomotor skills. Thus, educational institutions can consider the use of virtual laboratories as an alternative that is equivalent to physical laboratories, especially in environments with limited facilities, without reducing the effectiveness of learning.

REFERENCES

Adiningsih, M. D., Karyasa, I. W., & Muderawan, I. W. (2020). Profile of Students Science Process Skills in Acid Base Titration Practicum at Class XI MIPA 3 SMA Negeri 1 Singaraja Bali. *IOP Conference Series: Materials Science and Engineering*, *1503*(012037), 1–7. https://doi.org/10.1088/1742-6596/1503/1/012037

Alfiyanti, I. F., Jatmiko, B., & Wasis. (2020). The Effectiveness of Predict Observe Explain (POE) Model with PhET to Improve Critical Thinking Skills of Senior High School Students. *Studies in Learning and Teaching*, *1*(2), 76–85. https://doi.org/10.46627/silet.v1i2.34

Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brunken, R. (2020). The use of augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses Theoretical background and empirical results. *British Journal of Educational Technology*, *51*(3), 611–628. https://doi.org/10.1111/bjet.12900

Assem, H. D., Nartey, L., Appiah, E., & Aidoo, J. K. (2023). A Review of Students Academic Performance in Physics: Attitude , Instructional Methods , Misconceptions and Teachers Qualification. *European Journal of Education and Pedagogy*, *4*(1), 84–92. https://doi.org/10.24018/ejedu.2023.4.1.551

Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students’ conceptual understanding in physics: A review of literature. *Physical Review Physics Education Research*, *17*(2), 23108. https://doi.org/10.1103/PhysRevPhysEducRes.17.023108

Chen, Y.L., Pan, P.-R., Sung, Y.T., & Chang, K.E. (2013). Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model. *Educational Technology and Society*, *16*(2), 212–227.

Coccia, M. (2020). The evolution of scientific disciplines in applied sciences: dynamics and empirical properties of experimental physics. In *Scientometrics* (Vol. 124, Issue 1). Springer International Publishing. https://doi.org/10.1007/s11192-020-03464-y

Eralita, N. (2023). Analisis Keterampilan Proses Sains dalam Praktikum Kimia Fisika. *Orbital: Jurnal Pendidikan Kimia*, *7*(2), 187–196. https://doi.org/10.19109/ojpk.v7i2.19402

Fitriani, R., Maryani, S., Chen, D., Aldila, F. T., Br.Ginting, A. A., Sehab, N. H., & Wulandari, M. (2021). Mendeskripsikan Keterampilan Proses Sains Siswa melalui Kegiatan Praktikum Viskositas di SMAN 1 Muaro Jambi. *PENDIPA Journal of Science Education*, *5*(2), 173–179. https://doi.org/10.33369/pendipa.5.2.173-179

Kamid, Kurniawan, D. A., Perdana, R., Widodi, B., Triani, E., Yathasya, D., & Fadillah, P. (2023). The Persistence Character and Math Processing Skills of Elementary School Students in Thematic Learning. *Jurnal Ilmiah Sekolah Dasar*, *7*(2), 363–373. https://doi.org/10.23887/jisd.v7i2.55094

Kolil, V. K., Muthupalani, S., & Achuthan, K. (2020). Virtual experimental platforms in chemistry laboratory education and its impact on experimental self-efficacy. *International Journal of Educational Technology in Higher Education*, *17*(1), 30.

Kulgemeyer, C., Borowski, A., Buschhuter, D., Enkrott, P., Kempin, M., Reinhold, P., Riese, J., Schecker, H., Schröder, J., & Vogelsang, C. (2020). Professional knowledge affects action-related skills: The development of preservice physics teachers' explaining skills during a field experience. *Journal of Research in Science Teaching*, *57*(10), 1554–1582. https://doi.org/10.1002/tea.21632

Liana, L., Kosim, K., & Taufik, M. (2023). The Influence of the Problem-Based Learning Model Assisted by PhET Simulations on Students' Problem-Solving Abilities and Mastery of Physics Concepts. *AMPLITUDO: Journal of Science and Technology Innovation*, *2*(2), 101–107.

Muller, ClauMuller, C., & Mildenberger, T. (2021). Facilitating flexible learning by replacing classroom time with an online learning environment: A systematic review of blended learning in higher education. *Educational Research Review*, *34*, 100394.

Noorjanah, A. D., Astuti, R., & Sa'diyah, H. (2023). Profil Laboratorium Ipa Di SMP Negeri 2 Karangdowo Tahun Ajaran 2021/2022. *Journal of Educational Learning and Innovation (ELIa)*, *3*(1), 01–15. https://doi.org/10.46229/elia.v3i1.473

Orobor, I. A., & Orobor, E. H. (2020). A review of virtual laboratory and justification for adoption in Nigeria tertiary educational institutions. *International Journal of Open Information Technologies*, *8*(2), 47–53.

Ouahi, M. Ben, Lamri, D., Hassouni, T., & Al Ibrahmi, E. M. (2022). Science teachers' views on the use and effectiveness of interactive simulations in science teaching and learning. *International Journal of Instruction*, *15*(1), 277–292. https://doi.org/10.29333/iji.2022.15116a

Pela, S. O., Le, N. N., Kaboro, P. G., & Nurjamil, A. (2023). Innovation of physics e-module: Utilizing local wisdom of Lampung' s handwritten batik in teaching heat and temperature material to foster students' scientific attitude. *Schrodinger:Journal of Physics Education*, *4*(4), 132–138. https://doi.org/10.37251/sjpe.v4i4.924

Ruwiyah, S., Rahman, N. F. A., Rahim, A. R. A., Yusof, M. Y., & Umar, S. H. (2021). Cultivating science process skills among physics students using PhET simulation in teaching. *Journal of Physics: Conference Series*, *2126*(1). https://doi.org/10.1088/1742-6596/2126/1/012007

Samijo, & Romadona, D. D. (2023). A Study of Science Process Skills on Simple Pendulum Materials. *Schrodinger:Journal of Physics Education*, *4*(1). https://doi.org/10.37251/sjpe.v4i1.494

Sarwoto, T. A., Budi Jatmiko, & Elok Sudibyo. (2020). Development of Online Science Teaching Instrument Based on Scientific Approach Using PhET Simulation to Improve Learning Outcomes at Elementary School. *IJORER: International Journal of Recent Educational Research*, *1*(2), 90–107. https://doi.org/10.46245/ijorer.v1i2.40

Serevina, V., & Kirana, D. (2021). The development of virtual laboratory assisted by flash and PhET to support distance learning. *Journal of Physics: Conference Series*, *2019* (1). https://doi.org/10.1088/1742-6596/2019/1/012030

Sinaga, P., & Setiawan, W. (2022). The impact of electronic interactive teaching materials (EITMs) in e-learning on junior high school students' critical thinking skills. *Thinking Skills and Creativity*, *46*, 101066.

Sjoen, M. M. (2023). From Global Competition to Intercultural Competence: What Teacher Training Students with Cross Cultural Teaching Experience Should be Learning. *Scandinavian Journal of Educational Research*, *67*(1), 140–153. https://doi.org/10.1080/00313831.2021.1990121

Triani, E., Darmaji, & Astalini. (2023). Identiifikasi Keterampilan Proses Sains dan Kemampuan Berargumentasi. *Jurnal Pendidikan Dan Pembelajaran IPA Indonesia*, *13*(1), 9–16. https://doi.org/10.23887/jppii.v13i1.56996

Uwamahoro, J., Ndihokubwayo, K., Ralph, M., & Ndayambaje, I. (2021). Physics Students' Conceptual Understanding of Geometric Optics: Revisited Analysis. *Journal of Science Education and Technology*, *30*(5), 706–718. https://doi.org/10.1007/s10956-021-09913-4

Valtonen, T., Leppänen, U., Hyypiä, M., Kokko, A., Manninen, J., Vartiainen, H., Sointu, E., & Hirsto, L. (2021). Learning environments preferred by university students: a shift toward informal and flexible learning environments. *Learning Environments Research*, *24*, 371–388.

Yusuf, I., & Widyaningsih, S. W. (2020). Implementing E-Learning-Based Virtual Laboratory Media to Students' Metacognitive Skills. *International Journal of Emerging Technologies in Learning*, *15*(5).