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The Effect of the Virtual Laboratory Method on the Conceptual Understanding of Thermal Physics among Undergraduates

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ABSTRACT

Access to adequate resources in the form of physical laboratory facilities and consumables has continually been a major challenge to the success of students in physics, especially in developing countries This study was carried out to investigate the effect of the virtual laboratory on the conceptual understanding of thermal physics among undergraduates. To achieve this, three research questions and one hypothesis were raised. The quasi-experimental design using the pretest-posttest control group design was employed in the study. The sample size for this study was made up of 120 first-year undergraduate students selected based on a multistage sampling technique from students in the faculties of education, science, and engineering, who registered for the thermal physics (Phy 104) course in Nigeria. The Thermal Concept Questionnaire (TCQ) was adopted as the research instrument for the study. The data were analyzed using the SPSS package. Findings emanating from the study showed that the mean scores of students taught with virtual laboratory were higher than those taught with the conventional laboratory method. However, there was no significant difference in the mean scores. The virtual laboratory method could be recommended as a suitable alternative to the conventional laboratory method.

Keywords:
Conceptual understanding; thermal physics; virtual laboratory; conventional laboratory

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1. Introduction

With the unprecedented increase in the level of scientific and technological development [1], the need to prepare future-ready graduates who will man the future workplace continues to be strong for universities and other tertiary institutions [2]. Science and engineering education provide the foundation for achieving this [3], hence, the increased focus on STEM learning at the pre-tertiary level and sound science and engineering education at the tertiary level. Physics is one of the main science subjects required for understanding the complexities of modern technology [4], it also forms the foundation for the understanding of many practical applications and ideas in other areas of science, hence the need for students of science and engineering to be well-grounded in physics. Undergraduate introductory physics is thus a prerequisite for all courses within sciences, applied

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sciences, and engineering in the university to provide a solid foundation for the understanding of more complex related concepts.

Despite the importance of physics, research continually shows that student performance remains unimpressive, and pre-tertiary and tertiary physics education continues to show high rates of dropout and low enrolment [3,5]. Among the reasons put forward to explain this, are poor pedagogy, especially traditional, teacher-centered approaches to instruction, the challenge of understanding abstract concepts, and making the connection between theory and practical [3]. This results in poor conceptual understanding among learners, leading to poor performance. Because conceptual understanding is directly linked to instructional strategy [6], a direct link can be established between instructional strategy and students' conceptual understanding of physics.

The implementation of active learning environments across science, technology, engineering, and mathematics (STEM) fields has garnered attention from education researchers across the globe [7,8]. These studies have revealed the greater advantages of active learning strategies over traditional, lecture-based pedagogies. In the arena of science and physics education, a variety of active learning approaches have led to the reformation of introductory physics courses in colleges and universities [9]. One such innovation is the use of a virtual laboratory in the teaching of physics practical.

According to Kodavasal, *et al*., [10], virtual practicals are computer simulations that contain several instructions and procedures, data analysis, and presentations where students can carry out several activities as in real laboratories. Gunawan *et al*., [11] described a virtual laboratory as a form of interactive multimedia object to simulate laboratory experiments on a computer. They provide simulated versions of traditional laboratories and support learner-centered learning approaches in which the learner is provided with objects that are virtual representations of real objects used in traditional laboratories [12]. Virtual laboratories may contribute to teaching and learning processes by allowing students to learn by doing, providing them with intriguing and enjoyable activities, urging them to discover, and guaranteeing an active classroom interaction utilizing discussions and debates [13,14].

The field of thermal physics is one that the students interact with daily. Thermal physics deals with concepts relating to heat and temperature, which are directly related to the physical environment of a living organism [15]. It is prevalent in the science curriculum from elementary to graduate education [16] and it is one area in which students' poor conceptual understanding has been noted. Heat and temperature are not directly observable quantities, hence, concepts developed by students originate from the interpretation of ideas gained from everyday experiences [17].

Related previous studies have established a direct link between instructional strategy and learners’ conceptual understanding [6,18]. However, there are insufficient studies reporting university students’ level of conceptual understanding, particularly in the field of thermal physics [17,18] and especially in developing nations like Nigeria. Though several instructors and schools are already taking advantage of these virtual tools, it is not clear how effective these virtual laboratories (VLs) are in supporting conceptual understanding of physics at the university level when compared with traditional laboratory learning environments. There is a scarcity of evidence-based reports and empirical data related to measured student learning outcomes or achievement [19] concerning this. Therefore, this study aims to investigate the comparative effects of virtual laboratories and traditional laboratories on the conceptual understanding of undergraduate students in thermal physics.

1.2 Research Question

Specifically, this research aims to answer the following research questions:

i) What is the level of conceptual understanding of thermal physics of undergraduate students when taught in the traditional laboratory?
ii) What is the level of conceptual understanding of thermal physics of undergraduate students when taught in the virtual laboratory?
iii) Is there a significant difference in the level of conceptual understanding of thermal physics of undergraduate students between traditional laboratory and virtual laboratory?

1.3 Research Hypothesis

The research hypothesis is as follow:

> "There is no significant difference in the level of conceptual understanding (CU) between undergraduate students taught thermal physics using virtual laboratory (VL) and the ones taught using traditional laboratory (TL)."

2. Methodology

The quasi-experimental design using the pretest-posttest control group design is employed in this study. The population of this study consists of all the 2020/2021 session intake students of the University of Abuja who take the introductory practical physics (Physics 104) course. The choice of first-year undergraduate students is based on the fact that it is the foundation year for all students across the sciences, mathematics, engineering, and applied sciences who are required to register for the introductory Practical Physics (Phy 104) Course. The sample size for this study was 120 first-year students selected based on a multistage sampling technique from students in the faculties of education, science, and engineering, who registered for the thermal physics (Phy 104) course.

This study involved two different groups of participants; half (60 participants) in the traditional laboratory group and the other half in the virtual laboratory group. Based on several factors, including space for traditional laboratory activities in line with COVID-19 social distancing recommendations, management of learners by the instructor-researcher, and availability of sufficient laboratory equipment, 30 students at a time can be accommodated within the laboratory. This wiase matched by the same number in the virtual lab sessions. For data collection, each group of 30 participants underwent 3 laboratory sessions over the 5 weeks of the study.

The main instrument for obtaining data in this study was the Thermal Concept Questionnaire (TCQ) developed by [20]. It features 20 multiple-choice questions (MCQ) items aimed at exploring students' understanding of basic concepts of thermal physics. The items of the TCQ were adapted from the Thermal Concept Evaluation instrument [21]. The TCQ has 15 items and respondents' sum scores were analyzed. As the data was an interval scale and the assumption was made for defining properties for the population, the data is considered parametric data [22].

The study data were analyzed by descriptive and inferential analyses. Descriptive analysis was used to analyze the data of improvement in the level of conceptual understanding. The inferential analysis was used to analyze any improvement in students' conceptual understanding as a whole. Before the data analysis was done, a test of the analysis prerequisite needed to be done. The purpose of doing the analysis prerequisite test was to get information on whether the data would be analyzed by using parametric or non-parametric statistics. The analysis prerequisite test done to the sample data was the Kolmogorov-Smirnov normality test.

The data resulting from the normality test were then analyzed to know the conclusion related to the increase/improvement of students' conceptual understanding of thermal physics. The inferential analysis used for this study was the paired t-test because the data were normally distributed.

3. Results and Discussion

Table 1 shows the mean scores of the students' CU before and after the use of TL and the standard deviation. The mean score increased from 47.02 to 57.73 which indicated an improvement of 10.71. This implies that TL has a positive impact on the learning of thermal physics.

Table 1
Mean difference in CU before and after the use of TL

Test	N	Mean	Std. Deviation
Ctr_PreTest	60	47.02	7.414
Ctr_Postest	60	57.73	7.220
Gain	60	10.71	

Similarly, Table 2 also shows the descriptive statistical level of the mean score in conceptual understanding of students taught physics through the virtual laboratory. The average mean value of the pre-test score was 47.13 while the post-test was 60.12. this means there is a gain of an average of 12.99%. this implies that there is a positive relationship in the level of conceptual understanding of thermal physics among undergraduate students learning through virtual laboratory.

Table 2
Descriptive statistics of difference in the level of CU using VL

Test	N	Mean	Std. Deviation
Exp_PreTest	60	47.13	8.035
ExP_Postest	60	60.12	7.533
Valid N (listwise)	60	12.99	

From Table 3, on average, the score of CU from VL (M=60.12, SD=7.53) performed better than that of TL (M=57.73, SD=7.22). The difference (2.39) (95%) is statistically not significant at t (118)=1.769, p >0.05 as shown in Table 4. Hence, the null hypothesis is accepted, i.e There is no significant difference in the level of CU of the undergraduate students in learning thermal physics between TL and VL.

Table 3
Samples statistics on the level of difference in CU between VL and TL

	Group	N	Mean	Std. Deviation	Std. Error Mean
CU	TL	60	57.7333	7.22019	.93212
	VL	60	60.1167	7.53318	.97253

Table 4
Independent Samples t-Test of the difference in CU between VL and TL

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	T	Df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Interval Confidence of the Difference

									Lower	Upper
CU	Equal variances assumed	.284	.595	-1.769	118	.079	-2.38333	1.34710	-5.05095	.28428
	Equal variances not assumed			-1.769	117.788	.079	-2.38333	1.34710	-5.05100	.28433

4. Discussion

The finding of this study revealed that the traditional laboratory improves students' conceptual understanding of thermal physics. This is in line with some researchers who argue that working with real equipment in traditional laboratories supports more information, such as more cues based on perspectives from the theories of presence and media richness [23-25.

Findings also revealed that the use of virtual laboratories impacts positively the level of students' conceptual understanding, this is in line with Muliyati *et al*., [26] who showed that the results of students' conceptual understanding with virtual laboratories were better than with real experiments. He explained that the higher conceptual understanding in the experimental group compared to the control group was due to the ability of the virtual laboratory to provide simple explanations related to the material and to bridge learning by showing simulations and animations related to the material so that students found it easier to understand.

The study also revealed that there was no significant difference in the mean scores of students taught through Virtual laboratories and those taught through the traditional laboratory. This is in agreement with Tsihouridis *et al*., [27]. Their findings led to the conclusion that a combination of the two approaches to teaching would decisively help students develop an investigative attitude related to anything science, their cooperative abilities, and their ability to clearly and accurately articulate essential queries.

5. Recommendations

Based on the findings and conclusion, several recommendations were made for future studies:

1. Combining Teaching Approaches: Future research could explore the integration of both traditional and virtual laboratory methods to capitalize on their respective strengths in improving students' understanding of thermal physics concepts.

2. Deeper Investigation: Researchers might consider conducting in-depth inquiries into the specific aspects of traditional and virtual labs that contribute to students' comprehension. Utilizing qualitative research methods could yield richer insights from educators and students.

3. Educator Training: Providing educators with pedagogical training to effectively utilize both traditional and virtual lab resources could enhance their teaching practices. Workshops or professional development programs focused on incorporating technology into science education could be beneficial.

4. Enhancing Virtual Labs: Continued refinement of virtual lab platforms should prioritize intuitive interfaces, clear explanations, and interactive simulations to optimize students' learning experiences.

5. Long-Term Studies: Longitudinal research efforts could be undertaken to assess the lasting impacts of traditional and virtual lab experiences on students' knowledge retention and attitudes towards science.
6. Cross-Topic Comparisons: Future studies could compare the effectiveness of traditional and virtual labs across different physics topics and other scientific disciplines to ascertain if the findings are consistent across various subjects.

7. Inclusive Research: Ensuring the inclusion of diverse student populations in future studies would enable a more comprehensive evaluation of the effectiveness of traditional and virtual labs for students with varied backgrounds and learning preferences.

Addressing these suggestions in future studies can contribute significantly to our understanding of how traditional and virtual labs can be optimally utilized to enhance students' understanding of thermal physics and other scientific concepts.

6. Conclusion

Based on the discussion of findings, it can be concluded that both traditional laboratory and virtual laboratory approaches positively impact students' conceptual understanding of thermal physics. While traditional laboratories provide more cues and sensory experiences, virtual laboratories offer simplicity in explanations and facilitate learning through simulations and animations. However, the study found no significant difference in mean scores between students taught via virtual laboratories and those taught via traditional laboratories. Therefore, a combination of both approaches could enhance students' investigative attitude, cooperative abilities, and their ability to articulate essential queries in science education.

References

[1] Pande, S., M. Ertsen, and M. Sivapalan. "Endogenous technological and population change under increasing water scarcity." *Hydrology and Earth System Sciences* 18, no. 8 (2014): 3239-3258. https://doi.org/10.5194/hess-18-3239-2014
[2] Hu, Ridong, Yi-Yong Wu, and Chich-Jen Shieh. "Effects of virtual reality integrated creative thinking instruction on students' creative thinking abilities." *Eurasia journal of mathematics, science and technology education* 12, no. 3 (2016): 477-486. https://doi.org/10.12973/eurasia.2016.1226a
[3] Karacop, Ataman. "The Effects of Using Jigsaw Method Based on Cooperative Learning Model in the Undergraduate Science Laboratory Practices." *Universal Journal of Educational Research* 5, no. 3 (2017): 420-434. https://doi.org/10.13189/ujer.2017.050314
[4] Erinosho, Stella Y. "How do students perceive the difficulty of physics in secondary school? An exploratory study in Nigeria." *International Journal for Cross-Disciplinary Subjects in Education* 3, no. 3 (2013): 1510-1515. https://doi.org/10.20533/ijcdse.2042.6364.2013.0212
[5] Ryan, P., & Guido, M. D. (2013). Attitude and Motivation towards Learning Physics. 2(11), 2087–2094.
[6] Bradforth, Stephen E., Emily R. Miller, William R. Dichtel, Adam K. Leibovich, Andrew L. Feig, James D. Martin, Karen S. Bjorkman, Zachary D. Schultz, and Tobin L. Smith. "University learning: Improve undergraduate science education." *Nature* 523, no. 7560 (2015): 282-284.
[7] Chini, Jacquelyn J., Carrie L. Straub, and Kevin H. Thomas. "Learning from avatars: Learning assistants practice physics pedagogy in a classroom simulator." *Physical review Physics education research* 12, no. 1 (2016): 010117.https://doi.org/10.1103/PhysRevPhysEducRes.12.010117
[8] Dou, Remy, Eric Brewe, Justyna P. Zwolak, Geoff Potvin, Eric A. Williams, and Laird H. Kramer. "Beyond performance metrics: Examining a decrease in students' physics self-efficacy through a social networks lens." *Physical Review Physics Education Research* 12, no. 2 (2016): 020124. https://doi.org/10.1103/PhysRevPhysEducRes.12.020124

[9] Asencios-Trujillo, Lucía, Lida Asencios-Trujillo, Carlos LaRosa-Longobardi, Djamila Gallegos-Espinoza, Livia Piñas-Rivera, and Rosa Perez-Siguas. "Virtual Assistance System for Teaching Physics Experiments in University Students." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 40, no. 1 (2024): 109-117.

[10] Kodavasal, Janardhan, Matthew J. McNenly, Aristotelis Babajimopoulos, Salvador M. Aceves, Dennis N. Assanis, Mark A. Havstad, and Daniel L. Flowers. "An accelerated multi-zone model for engine cycle simulation of homogeneous charge compression ignition combustion." *International Journal of Engine Research* 14, no. 5 (2013): 416-433.https://doi.org/10.1177/1468087413482480

[11] Gunawan, Gunawan, Ahmad Harjono, Hermansyah Hermansyah, and Lovy Herayanti. "GUIDED INQUIRY MODEL THROUGH VIRTUAL LABORATORY TO ENHANCE STUDENTS'SCIENCE PROCESS SKILLS ON HEAT CONCEPT." *Jurnal Cakrawala Pendidikan* 38, no. 2 (2019): 259-268. https://doi.org/10.21831/cp.v38i2.23345

[12] Ayoubi, Z. "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, no. 1 (2018): 54-68. https://doi.org/10.21891/jeseh.387482

[13] Edwards, Bosede Iyiade, Nurbiha A. Shukor, and Adrian David Cheok, eds. *Emerging Technologies for Next Generation Learning Spaces*. Springer, 2021.

[14] Oidov, L., Tortogtokh, U., & Purevdagva, E. (2012). Virtual laboratory for physics teaching. 2012 International Conference on Management and Education Innovation, 37, 319–323. Retrieved from http://www.ipedr.com/vol37/062-ICMEI2012-E10015.pdf

[15] Winarti, Cari, Suparmi, Sunarno, W., & Istiyono, E. (2016). International Conference on Recent Trends in Physics 2016 (ICRTP2016). Journal of Physics: Conference Series, 755, 011001. https://doi.org/10.1088/1742-6596/755/1/011001

[16] Supurwoko, Supurwoko, C. Cari, Sarwanto Sarwanto, Sukarmin Sukarmin, Rini Budiharti, and Tiarasita Summa Dewi. "Virtual lab experiment: physics educational technology (PhET) photo electric effect for senior high school." In *International Journal of Science and Applied Science: Conference Series*, vol. 2, no. 1, p. 381. 2017. https://doi.org/10.20961/ijsascs.v2i1.16750

[17] Suprapto, Nadi, T-S. Chang, and C-H. Ku. "Conception of learning physics and self-efficacy among indonesian university students." *Journal of Baltic Science Education* 16, no. 1 (2017): 7.

[18] Fernandez, Flavian Brian. "Action research in the physics classroom: the impact of authentic, inquiry based learning or instruction on the learning of thermal physics." *Asia-Pacific Science Education* 3, no. 1 (2017): 1-20. https://doi.org/10.1186/s41029-017-0014-z

[19] Brinson, James R. "The Effects of Virtual Versus Physical Lab Manipulatives on Inquiry Skill Acquisition and Conceptual Understanding of Density." PhD diss., Indiana State University, 2017.

[20] Hadžibegović, Zalkida, and Suada Sulejmanović. "Fundamental thermal concepts understanding: the first-year chemistry student questionnaire results." *Bulletin of the Chemists and Technologists of Bosnia and Herzegovina* 42 (2014): 21-30. Retrieved from http://www.pmf.unsa.ba/hemija/glasnik/files/Issue

[21] Yeo, Shelley, and Marjan Zadnik. "Introductory thermal concept evaluation: Assessing students' understanding." *The Physics Teacher* 39, no. 8 (2001): 496-504. https://doi.org/10.1119/1.1424603

[22] Rittle-Johnson, Bethany, and Michael Schneider. "Developing conceptual and procedural knowledge of mathematics." (2014). https://doi.org/10.1093/oxfordhb/9780199642342.013.014

[23] Kuyath, S. J., & Winter, S. J. (2019). Distance Education Communications: The Social Presence and Media Richness of Instant Messaging. Online Learning, 10(4). https://doi.org/10.24059/olj.v10i4.1751

[24] Oregon, Evie, Lauren McCoy, and Lacee Carmon-Johnson. "Case analysis: exploring the application of using rich media technologies and social presence to decrease attrition in an online graduate program." *Journal of Educators Online* 15, no. 2 (2018): n2. https://doi.org/10.9743/jeo.2018.15.2.7

[25] Zhao, Yiming, Afeng Wang, and Yongqiang Sun. "Technological environment, virtual experience, and MOOC continuance: A stimulus–organism–response perspective." *Computers & Education* 144 (2020): 103721. https://doi.org/10.1016/j.compedu.2019.103721

[26] Muliyati, Dewi, Dadan Sumardani, Siswoyo Siswoyo, Fauzi Bakri, Handjoko Permana, Erfan Handoko, and Ni Larasati Kartika Sari. "Development and evaluation of granular simulation for integrating computational thinking into computational physics courses." *Education and Information Technologies* 27, no. 2 (2022): 2585-2612. https://doi.org/10.1007/s10639-021-10724-8

[27] Tsihouridis, Charilaos, Denis Vavougios, and George S. Ioannidis. "Evaluation of educational software regarding its suitability to assist the laboratory teaching of electrical circuits." In *Conference ICL2007, September 26-28, 2007*, pp. 15-pages. Kassel University Press, 2007.