PERJ
Physics Education Research Journal
ISSN 2685 - 6190 (p)
ISSN 2714 - 7746 (e)
Department of Physics Education
Faculty of Science and Technology
UIN Walisongo Semarang-Indonesia

Gender Influence of PhET Simulation on Students' Score Level

Abdul-Hafiz Abolade Alabi*, Ridwan Enuwa Mohammed, Aishat A Yusuf

Department of Science Education, University of Ilorin, Nigeria

ARTICLE INFO

Article history:
Submitted : December 22nd, 2022
Revised : March, 17th, 2023
Accepted : June 29th, 2023

Keywords:
Achievements; Conceptual Understanding; Gender; Performance; Retention; Score Levels; Simulation.

ABSTRACT

Students' performances are often compared and evaluated based on their score levels. Poor performance across each score level can be linked to the general perception of physics as a complex subject due to its abstract and calculative nature. Hence, to help improve students' performance across each score level, this study investigated the influence of innovative simulations on students' performance and retention based on their score levels and gender. This study adopted a quasi-experimental non-randomized 2×2×3×2 factorial design. A purposive sampling technique was used to choose two schools with 55 students in Ilorin, Kwara state. The research instruments include a Physics Education Technology (PhET) simulation developed by the University of Colorado Boulder, a Physics Performance Test (PPT), and a Physics Retention Test (PRT). The reliability of the performance and retention test was determined using KR-21 with indices values of 0.855 and 0.769 correspondingly. The findings revealed that the use of computer simulation had a positive effect on the performance and retention in terms of the score levels and had a significant impact on the student's performance and retention with a t-value (-3.13);$p<0.005$ and t-value (-3.69); p-value< 0.005 respectively. Also, it established that the female students performed better than the male students across different score levels. It was concluded that computer simulation affected the students' performance and retention based on score levels and gender. Therefore, it is recommended that computer simulation be used in the teaching and learning process for better conceptual understanding of the students at different score levels.

Introduction

The main objective of the teaching and learning process is to change the three domains of learning: cognitive, psychomotor, and affective, which are directly related to the student's skills, abilities, and achievements. To determine if these changes have occurred, tests are usually given regularly to the students to evaluate their skills, abilities, and achievements by categorizing them based on their scores. The students' score level is divided into three: high scorer, medium scorer, and lower scorer. Usually, it is considered that high achievers are highly competent, medium scorers are students at average, and low scorers are below average. In contrast, the low scorers are students below average (Ali et al., 2021). High-achieving students are usually characterized by their in-depth comprehension compared to their peers and can apply their knowledge and skills to more challenging situations. However, teachers often believe higher-order thinking is appropriate only for high-achieving students. In contrast, medium and low-achieving students who need more basis are appropriate for such tasks (Vrapi et al., 2021). Therefore, to bridge the gap between these groups of different competencies, the teacher's teaching methodology needs to shift from mere reproduction of the conventional chalkboard method to a more sophisticated and relevant pedagogical approach, such as using technological tools that promote the acquisition of 21st-century skills.

*Correspondence email: afeezabolade01@gmail.com
doi: 10.21580/perj.2023.5.2.14141

In our era, the effective use of Information and Communication Technology (ICT) has become essential for educational advancement. Information and Communication Technological (ICT) tools can be regarded as an innovative way to impart knowledge to students and help meet the needs of the contemporary and ever-evolving world (Lasisi, 2021). The National Policy on Education (Federal Republic of Nigeria, 2013) recognized the importance of ICT in the Nigerian educational system, stating that the "government must provide facilities and required infrastructures for the position of ICT and e-learning." However, the introduction of Information and Communication Technology (ICT) led to the creation of Virtual Learning Environments in the teaching and learning process, such as computer simulations, artificial intelligence, and the propagation of classes through an online learning platform.

The topic of the kinetic theory of gas and gas laws is a topic that is often riddled with several misconceptions because it portrays the two aspects of physics: macroscopic and microscopic. The macroscopic concept is based on experimental theories, which can easily be explained in the classroom with the help of instructional materials and applications of the physics formula. The microscopic concept is based on explanatory theories that include the element of visibility, which can only be measured imaginatively. Many concepts unseen in the discussion of the kinetic theory of gases, such as the behavior of gas particles associated with microscopic and macroscopic quantities, are usually the cause of misconceptions in this topic. Misconceptions posed mainly by the need for more understanding of the topic, and it has been reported severally by the Waec chief Examiner (2009, 2013-2015) that there needs to be a better performance of students in the Kinetic theory of gas and gas. However, to fulfill the WASSCE curriculum (2021), students must comprehend the idea of gas, the kinetic theory of gas, and gas laws (Boyle's law, Charles's law, and Gay-Lussac's law) and define the characteristics of the gas in the enclosed space. Therefore, there is a need to create a learning environment to help solve the students' misconceptions.

As a result, a medium that allows for the existence of the kinetic theory of gas simulation on microscopic phenomena is required so that students may understand it (Gusmida & Islami, 2017). Numerous concepts regarding microscopic phenomena in the kinetic theory of gas are only possible to observe indirectly (Niaz, 2000). Therefore, understanding the microscopic aspect of the kinetic theory of gas and gas laws when taught using conventional methods will only increase the misconceptions of the subject matter as the student will try to understand the concept through their imagination. In this scenario, computer-based media can give experimental simulation and microscopic viewing of gas, which could be a viable alternative to virtual experiments. With computer simulation, the student's misconceptions will be solved due to the computer simulation's ability to simulate the problem's real-life model. Focusing on the finer points, the topics explained using Virtual Learning Environments (VLE), particularly computer simulations, enable students to benefit from computer-based material to learn better the concepts of gas law and kinetic gas theory (Pratidhina et al., 2019).

Computer simulation is founded on the constructivism principle, which emphasizes the importance of pupils learning through scientific experimentation. Constructivism emphasizes the ideas of collaborative learning, which state that when a group of learners works together to solve a problem and is given enough information and cognitive tools to help them, they will collectively generate meaning via their interactions with one another and with the tools (Mitchell & Forer, 2010). Using computer simulation creates a learning environment that stresses acquiring knowledge, emphasizing that knowledge is learned by active interaction between learners and their learning environments rather than being gathered or absorbed. Operating on the constructivist learning theory, the following are the characteristics of computer simulation:

1) Multiple representations of reality are available in constructivist learning contexts.
2) Unlike typically planned teaching sequences, virtual learning environments create real-life scenarios or case-based studies.
3) Rather than abstract instruction from the instructor, the learning settings encourage learners to actively participate authentically in the activities allocated to them in a relevant context.
4) Unlike typically planned teaching sequences, the learning environments create real-life scenarios or case-based studies.
5) The learning environments "provide for the production of knowledge based on context and content."

Science educators have expressed several concerns over the performance of physics students in internal and external examinations. Several reviewed literature have revealed that physics students must perform better in internal and external examinations. This poor performance can be linked to the general perception of physics as challenging due to its abstract and

calculative nature and the teacher's teaching methodology (Waec et al., 2019). Also, different studies have been carried out to investigate the effect of innovative computer simulation on students' academic achievement, and it has been that the use of computer simulation has favorable effects on student's performance (Lasisi (2021), Birgin & Uzun Yazc (2021) and Lownes-Jackson (2015)). Although some research studies have covered the topic of the effects of PhET interactive computer simulations on students' performance, to the researchers' knowledge, insufficient studies have been carried out to investigate the effects of the PhET interactive computer simulations on the students' retention level. Therefore, this study aims to investigate the effects of computer simulation on students' performance and retention in the kinetic theory of gas and gas laws based on their score levels and gender.

Methods

The research type employed was a quasi-experimental type of Pretest, posttest, non-randomized 2×2×3×2 factorial design. It represented two groups of instructional strategies (computer simulation instructions and conventional instruction), students' gender (male and female), three categories of score levels (low, medium, and high), and two research variables (performance and retention), respectively. The computer served as the independent variable, the student's performance and retention were the dependent variables, and the moderating variables were students' gender and score levels. The groups were given a pretest to establish equivalence in the ability of the groups. The posttest was administered after the treatment, and the post-posttest was administered two weeks after the posttest was administered to measure the students' retention ability.

During this study, the Kinetic theory of gas and gas laws was selected because of their inclusion in the syllabus for SSS II students according to the 2021 WAEC curriculum. The sample population was Senior Secondary School II (SS2) physics students from two (2) selected schools in Ilorin, Kwara state. This study employed a purposive sampling technique in choosing the school because a co-educational school is needed to answer the research questions based on gender. One of the selected schools was used as the experimental group and was exposed to the treatment, and the other school was used as a control group. Forty (55) students were sampled: 25 for the experimental group and 30 for the control group.

The research instruments for this study were the Physics Education Technology (PHET) simulation for the kinetic theory of gas and gas laws developed by the University of Colorado, the Physics Performance Test (PPT), and the Physics Retention Test (PRT) in the kinetic theory of gas and gas laws. The Physics Performance Test (PPT) and Physics Retention Test (PRT) includes twenty (20) and ten (10) objective questions, respectively, on the kinetic theory of gas and gas laws, which were selected from WAEC, NECO, and JAMB past questions and physics textbooks.

The PhET simulation was validated by an expert at the Department of Educational Technology at the University of Ilorin using the evaluator's guide checklist. Also, the PPT and PRT were subjected to content validation. They were validated by two science educators at the Department of Science Education at the University of Ilorin and two secondary school physics teachers. PPT and PRT's reliability was tested using the Kuder-Richardson (KR-21) reliability test. The reliability indices were 0.855 and 0.769, respectively.

This study covered four weeks. A pretest was administered to both groups to establish equivalence in the ability of the groups. Their scores from the Pretest were classified into three levels: High scorers, Medium Scorers. And Low scorers. During the first week of the study, the experimental group was taught the kinetic theory of gas and gas laws using the Physics Education Technology (PhET) simulation as the instructional package. A video projector connected to the researcher's computer was used in parallel to support and guide the students in their knowledge construction. The students were allowed to explore the simulations to have hands-on skills on how to use simulation. The control group was taught using the conventional method of teaching (chalkboard method). After teaching both groups, a Physics Performance Test (PPT) was administered to collect data on their performance. After two weeks, a Physics Retention Test (PRT) was administered to both groups to collect data on their retention level.

The statistical package for social science (SPSS) was used for analysis. The data collected was analyzed using descriptive and inferential statistics. The mean score and standard deviation were used to answer all the research questions, and the research hypotheses were answered using t-test statistics and analysis of covariance (ANCOVA).

Result and Discussions

As shown in Table 1, inferential statistics of mean and standard deviation were used to compare the means of both the experimental and control groups. Data

presented in Table 1 shows that the experimental group had a mean pretest score of 35.60 and a mean posttest score of 75.20, while the control group had a mean pretest score of 35.60 and a mean posttest score of 58.83. It was further revealed that the mean gain score of the experimental group (39.60) was higher than the mean gain score of the control group (23.33). This result means that the group taught with the PhET simulation performed better than those taught without computer simulation.

Table 1
Mean and Standard Deviation of Pretest and Posttest Scores of Both Experimental Group and Control Group

Group	N	Pretest		Post-test		Mean gain
		Mean	*Sd*	*Mean*	*Sd*	
Experimental	25	35.60	11.84	75.20	18.51	39.6
Control	30	35.50	16.15	58.83	19.89	23.33

The result presented in Table 2 used t-test statistical analysis to compare the mean of the two groups to determine if the difference in the two groups' means was significant. The result shows a significant difference in the performance of students taught the kinetic theory of gas and gas laws using the PhET simulation and those taught without it. It was indicated by the calculated t-value (-3.13); $p<0.005$, and since the p-value was less than the significance value (0.05). Therefore, hypothesis one was rejected. It means that the performance of students who taught the kinetic theory of gas and gas laws using the PhET was significantly better than those taught without it.

Table 2
T-Test Analysis of the Experimental and Control Group's Posttest Mean Score

Variable	Group	N	Mean	Sd	df	t-value	p-value	Remark
Performance	Experimental	25	75.20	18.51	53	-3.13	0.003	H_{o1} rejected
	Control	30	58.83	19.89				

The results are presented in Table 2. The PhET simulation positively affected the student's performance in the kinetic theory of gas and gas laws and favored the students in the experimental group. These findings can, therefore, be attributed to the fact that the experimental group was exposed to the treatment, PhET Simulation, which is capable of visualizing and explaining abstract concepts and promoting better conceptual understanding. These findings agree with that of Ben Ouahi et al. (2021), who researched the effects of PhET simulation on students' performance in teaching and learning Ohm's law. Their results showed that the experimental group performed better than the control group. Though students in the experimental group performed better than those in the control group, as shown in Table 2, the findings disagreed with that of Ben Ouahi et al. (2021) regarding significant differences in the performance of the experimental and control groups. Their findings found no significant difference between the experimental and control groups' performance.

Table 3 shows a t-test analysis of the retention levels of those taught with the PhET simulation and those taught without it. The Table shows a t-value (-3.69) and a p-value< 0.005. Since the P-value is lesser than the significance value of 0.005, it implies that the students taught with the PhET simulation performed significantly better than those taught without it. Table 4 indicated a significant difference in the retention level of the students taught with the PhET simulation and those taught without it.

Table 3
Mean, Standard Deviation, and t-test Analysis of the Retention Score Level

Variable	Group	N	Mean	SD	df	t-value	p-value	Remark
Retention	Experimental	25	58.40	28.84	53	-3.69	0.001	H_{o2} rejected
	Control	30	39.00	14.82				

The results presented in Table 3 show that the students taught the kinetic theory of gas with the computer simulation had better retention ability than those taught without it. This ability of the students to recall information can be attributed to the use of modern scientific instructional material (computer simulation), which contains multimedia that helps to stimulate reality and help students understand physical terms, which makes learning enjoyable and relatable. Also, the multimedia characteristics of the instructional material are used to give the students an indelible experience and knowledge delivered in the form of words, pictures, or sounds, which stimulates and improves student retention. These findings align with that of Birgin and Uzun Yazc (2021), who conducted a study investigating the influence of the dynamic geometry program GeoGebra on pupils' conceptual grasp and recall of linear equations and slopes. They found that compared to textbook-based direct instruction, GeoGebra software-supported training for learning linear equations and slope significantly improved their conceptual understanding and recall of information. Also, Table 4 indicates that there was a significant difference between the retention level of students in the experimental group and the control group. This result agrees with that of Nkok (2021), and he found a significant difference in the retention level of the groups.

Table 4 shows the mean score of the students exposed to the PhET simulation treatment based on their scores. As shown in Table 5, the means and standard deviation of the students were compared based on their score levels. It was revealed that the high-level scorer had a mean score of (49.0), the medium-level scorer had a mean score of 81.75, and the low-level scorer had no mean score. This shows that the high-level scorer benefitted the most from the treatment compared to the medium-level scorer.

Table 4

Mean Score and Standard Deviation of Students Taught with PhET Simulation Based on Score Levels

Score Levels	N	Mean	SD
High scorer	20	49.00	4.18
Medium scorer	5	81.75	14.26

Table 5

Summary of ANCOVA of Posttest Score Based On Gender and Score Level

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5082.814[a]	3	1694.271	16.164	.000
Intercept	21.899	1	21.899	.209	.652
Gender	2.325	1	2.325	.022	.883
Score level	4020.866	1	4020.866	38.360	.000
gender * score level	49.094	1	49.094	.468	.501
Error	2201.186	21	104.818		
Total	110325.000	25			
Corrected Total	7284.000	24			
a. R Squared = .698 (Adjusted R Squared = .655)					

The null hypothesis 3, which states that there is no significant difference in the interaction effects of gender and score levels on the student's performance when taught Kinetic Theory of Gas and Gas Laws using computer simulation, was tested using Analysis of Covariance to determine the interactive effect of the PhET simulation on the student's gender and score level. As indicated in Table 5, F-value= 0.468, p-value = 0.501; p>0.05. Since the p-value is greater than the significance value of 0.005, it can be implied that gender and score level had no significant effects on the students' performance taught the kinetic theory of gas and gas laws. Hence, the null hypothesis of no significant difference in the interaction effects of gender and score levels on the student's performance was accepted when taught the Kinetic Theory of Gas and Gas Laws using computer simulation.

Table 6 shows the performance of both males and females based on their score levels. The Table revealed that the high-level scoring female students had a mean score of 84.00 while the male students had a mean score of 79.50. Also, the Table indicated that the female students of the medium level scorer had a mean score of 50.00 while the male students had a mean score of 48.00. Thus, female students in both score levels performed better than male students. Therefore, it can be concluded that gender impacted the student's performance in both groups.

Table 6

Mean and Standard Deviation of the Students Exposed to the Treatment Based on Gender and Score Level

Score Levels	Gender	N	Mean	SD
High scorer	Male	10	79.50	12.79
	Female	10	84.00	15.95
Medium scorer	Male	3	48.33	2.89
	Female	2	50.00	7.07

Conclusions

Based on the findings from the analyzed data, it was concluded that computer simulation positively affected students' performance in the kinetic theory of gas and gas laws, and the effect on their performance was significant. This implies that computer simulation could improve students' performance in physics. The computer simulation positively impacted the student's retention level, and the impact was significant. This could be due to the ability of computer simulation to create a long-lasting experience. Therefore, computer simulation could promote students' retention of physics. The usage of computer simulation favors the high-level scorer compared to the medium-level scorer, and there was a significant difference in the performance of the two score levels. Therefore, computer simulation helps improve the students' performance by improving their scores. The female students performed better than the male students in both score levels (i.e., medium, level, and high-level scorers). Therefore, it can be concluded that gender impacted students' performance in both score levels. At the end of this research, it is evident that simulation positively impacted the students' performance and enabled them to overcome difficulties in learning the kinetic theory of gas and gas laws. Therefore, this study recommends that computer simulation be used in the teaching and learning process for a better conceptual understanding of the students with different score levels. Also, it helps solve the students' misconceptions and beliefs that physics is complex due to its abstract and calculative nature.

References

Adolphus, T. (2019). Why Students in Secondary Schools Choose not to do Physics? Implications for Policy and Practice in Developing Countries. European Scientific Journal ESJ, 15(34). https://doi.org/10.19044/esj.2019.v15n34p103

Ali Khan, W., & Saeed s. (2021). Relationship between Secondary School Students' Physics Academic Achievement Scores and their Conceptual Knowledge. Bulletin of Education and Research, 43(2), 1–16. https://files.eric.ed.gov/fulltext/EJ1338293.pdf

Ben Ouahi, M., Ait Hou, M., Bliya, A., Hassouni, T., & Al Ibrahmi, E. M. (2021). The Effect of Using Computer Simulation on Students' Performance in Teaching and Learning Physics: Are There Any Gender and Area Gaps? Education Research International, 2021, 1–10. https://doi.org/10.1155/2021/6646017

Birgin, O., & Uzun Yazıcı, K. (2021). The effect of GeoGebra software–supported mathematics instruction on eighth-grade students' conceptual understanding and retention. Journal of Computer Assisted Learning, 37(4), 925–939. https://doi.org/10.1111/jcal.12532

Gusmida, R., & Islami, N. (2017). The Development of Learning Media for the Kinetic Theory of Gases Using the ADDIE Model with Augmented Reality. JOURNAL OF EDUCATIONAL SCIENCES, 1(1), 1. https://doi.org/10.31258/jes.1.1.p.1-10

Guy, R., & Lownes-Jackson, M. (2015). The Use of Computer Simulation to Compare Student performance in Traditional versus Distance Learning Environments. Issues in Informing Science and Information Technology, 12, 095–109. https://doi.org/10.28945/2254

Ibitomi, O. O., Oyelekan, O. S., & Olorundare, A. S. (2022). The Effect of Computer Simulation on Student Performance in High School Chemistry Learning on Chemical Equations. Indonesian Journal of Science and Mathematics Education, 5(3), 341–358. https://doi.org/10.24042/ijsme.v5i3.12071

Lasisi, A. R. (2021, March 8). The Effect of Innovative Computer Simulation Instruction on Studentsâ™ Academic performance in Abstract Concepts in Science. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3799962

Mitchell, P., & Forer, P. (2010). Blended Learning: The Perceptions of First-year Geography Students. Journal of Geography in Higher Education, 34(1), 77–89. https://doi.org/10.1080/03098260902982484

Nkok, E. M. (2021). Effect of Computer Simulation on Students' Achievement and Retention In Sexual Reproduction In Plants In Niger State, Nigeria. International Journal of Innovative Social & Science Education Research, 9(3), 10–18. https://seahipaj.org/journals-ci/sept-2021/IJISSER/full/IJISSER-S-2-2021.pdf

NPE. (2013). National-policy-on-education. Https://education.gov.ng/wp-content/uploads/2020/06/national-policy-on-education.pdf. https://education.gov.ng/wp-content/uploads/2020/06/national-policy-on-education.pdf

Pratidhina, E., Pujianto, P., & Sumardi, Y. (2019). Developing Computer Program as a Learning Resource on Gas Law Topics for High School Students. International Journal of Instruction, 12(2), 133–146. https://doi.org/10.29333/iji.2019.1229a

Vrapi, R., Alia, A., & Brese, F. (2021). Characteristics of High- and Low-Performing Students. IEA Research for Education, 191–212. https://doi.org/10.1007/978-3-030-85802-5_9

WAEC Chief examiner report 2019. (2019). waeconline.org.ng. Retrieved December 27, 2021, from https://www.waeconline.org.ng/e-learning/Physics/Phys228mw.html