Journal of Education and Practice
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.14, No.8, 2023

Utilizing Physics Education Technology (PhET) for Improving Students' Understanding of Energy Conversion and Conservation in a Senior High Technical School

Cynthia Jebuni-Adanu* Victor Antwi Isaac Kwesi Acquah* Desmond Appiah Michael Gyan
Fortune Addo Wuver Issahaku Sontaa Jakalia Bernard Sarkyi
Faculty of Science Education, Department of Physics Education, University of Education, Winneba-Ghana.
*Correspondence authors: Isaac Kwesi Acquah: ikacquah@uew.edu.gh
and Cynthia Jebuni-Adanu: cjadanu@uew.edu.gh

Abstract
This study aims to assess the effectiveness of using Physics Education Technology (PhET) interactive simulations in improving students' understanding of energy conversion and conservation at Tuobodom Senior High and Technical School, with a focus on comparing female and male students. A total of 45 students (male = 29, female = 16) were selected using purposive sampling and taught using both traditional methods and PhET simulations, with their understanding evaluated through pre and post-intervention tests. Data was analyzed using descriptive statistics and t-tests. There was a significant pre-intervention score difference between males (15.88) and females (8.25) with a p-value of 0.00, however post-intervention scores were similar for both groups (males 10.88, females 12.62). The study found that PhET simulations effectively promote gender equity by narrowing the performance gap which is likely to improve student's interest in science, technology, engineering and mathematics (STEM). The findings of the study shows that PhET interactive simulation improves students' conceptual understanding of energy conversion and conservation.
Keywords: Physics Education Technology (PhET), Conceptual, Energy conversion, energy conservation and Interactive visualization, Science Technology engineering and mathematics (STEM).
DOI: 10.7176/JEP/14-8-06
Publication date: March 31st 2023

INTRODUCTION

Physics as a branch of science is a subject perceived by most students, especially senior high students, to be difficult and therefore have profoundly less interest to learn the subject. It is a subject that contains a lot of mathematical equations and abstract concepts. The abstract nature of physics is due to some of its elements being intangible and cannot be visualized. Therefore, teaching students a concept without the relevant visual cues about that concept would cause difficulty in gaining the conceptual understanding of the concept. It was observed that students were having problem in gaining the conceptual understanding of conservation and conservation of energy. Meanwhile, in Ghanaian science syllabus and classrooms, emphasis has been placed on mere definitions, forms of energy and mathematical formulations (Taale and Anderson, 2014). Little attention has been placed on students' ability to relate and transfer the knowledge of conversion and conservation of energy to real life or other situations (Taale and Anderson, 2014). This shows that, there is a gap between what students learn and how they apply the knowledge learnt and this gap is an indication that students lack of conceptual understanding of the concepts. The concept of conversion energy has several real-life applications. Therefore, it is imperative to focus on educating students to gain conceptual understanding of the concept.

In order to teach students a concept to be able to reason in scenarios involving careful applications of the concepts, the teacher should strive to teach the concept with interactive and creative computer-based tools in a form of simulation because, conventional teaching approaches alone have failed to respond to this need in a productive manner (Papadouris and Constantinou, 2011, Teachmint., 2022). Interactive computer simulation provides opportunities for students to analyse problems, make decision, manage real life situations, control projects and experience the consequences of their actions (Bello et al., 2016). The use of computer simulation is one of the best ways to concretise abstract concepts to achieve conceptual understanding. The impact of interactive computer simulations in solving various students' problems in various concepts of physics has been studied by many researchers. For example, Kunnath and Kriek found that students performed well when computer simulation was used to teach photoelectric effect. Kotoka and Kriek showed that students performed well when computer simulation was used to teach electromagnetism and also was effective in enhancing students' conceptual understanding in optics(Kunnath and Kriek, 2018). Computer simulation helps students to visualize abstract concepts (Kotoka and Kriek, 2014). Dega et al showed that the use of computer simulation has enhanced student's conceptual understanding of electricity and magnetism (Dega et al., 2013). PhET interactive simulations are designed to provide students with interactive virtual representations of real-life settings with the aim of developing students' knowledge transfer abilities. PhET interactive simulation is a non-profit open

educational resource developed by University of Colorado Boulder, USA (PhET, 2022). The PhET simulation project was initiated to improve the way science is taught and learned across the globe by using free interactive simulations. PhET simulations are renowned worldwide due to their overwhelming impact on enhancing the teaching and learning of science (Banda and Nzabahimana, 2021).

PhET simulation is active and interactive educational platform that makes learning fun and effective. It directs students' interest towards the learning experience and therefore makes the instruction student-centred. In accordance with that, Adams, 2010 as cited by (Yunzal Jr and Casinillo, 2020) argued that PhET simulation is considerably a powerful tool in achieving the learning of student in science. PhET simulations are vital in developing a platform enriched with scientific and technological resources that enable students to engage in scientific exploration, develop conceptual understanding, make connections to everyday life, view science as accessible and enjoyable, and take ownership of the learning experience (Perkins et al., 2014). Although they can be used as standalone instructional tool, but even the best simulations are not automatically successful. Therefore, they must be used as part of an instructional design to enhance a well-designed curriculum. The animated and game-like nature of PhET interactive simulation enables scientist-life explosion (PhET, 2022).

PhET interactive simulation is innovate and useful in the sense that the simulations are simple and easy to use, they are designed to be engaging, they connect science to everyday life, they can make invisible things virtually visible for example, atoms, electrons, molecules and action of forces. Moreover, they make it possible to adjust variables such as magnitude of frictional force, gravitational force, speed, intensity of light, temperature and many more. They provide immediate visual feedback from every adjustment and action taken in the simulation. These and many other useful features make it easy to use for enhancing conceptual understanding in the concept of study (PhET, 2022).

The aforementioned capabilities of interactive computer simulation, and more specifically PhET simulation, appear to present PhET as an effective teaching tool for promoting conceptual understanding, but few studies such as (Ndihokubwayo et al., 2020, Yunzal Jr and Casinillo, 2020) have examine the impact of PhET simulation on promoting students' conceptual understanding of energy conversion and conservation in Ghana and at Tuobodom Senior High and Technical School. Therefore, this study attempts to solve the problem of lack of conceptual understanding at Tuobodom Senior High School. The variable "conceptual understanding" was chosen because today's society needs people with high innovative abilities, which can be achieved if people have a high level of conceptual understanding of concepts.

The researchers supported the current study with the cognitive theory of multimedia learning formulated by Richard Mayer in 2008. Mayer (2008) asserted three assumptions about how students can effectively and efficiently learn with instructional materials which served as the framework for the theory (Mayer, 2008). These assumptions are: there are two channels (auditory and visual) for processing information, these channels have limited capacity for processing information and lastly, learning is an active process of filtering, selecting, organizing and integrating information based on prior knowledge. According to Mayer and Moreno (2003), learners have different channels in their brain for processing visual and verbal material separately (Mayer and Moreno, 2003). They select relevant words for processing in verbal working memory and relevant images for processing in visual working memory (Toh et al., 2010). Mayer's theory is based on the fact that students' gain conceptual or deeper understanding of a concept from both words and pictures than from words alone. That is, presenting information in both verbal and pictorial form takes advantage of humans' full capacity of processing information. Learners' ability to build mental representations which equips them to construct and transfers knowledge from the classroom to other scenario is the focus of Mayer's cognitive theory of multimedia learning. The core principle of the cognitive theory of multimedia learning is how multimedia work? How does the learner make sense of the instructional material and construct meaningful connections, new knowledge and meaningful learning? (Sorden, 2012). Mayer (2008) mentioned that in order for meaningful and deeper learning to occur, the learners cognitive processing should be able to effectively select, organize, and integrate the visual and verbal information being presented with prior knowledge. Brown et al (2013) stated that instructional multimedia developers are required to balance the use of visual and verbal information to efficiently and effectively engage learners in the learning process (Brown et al., 2013). Additionally, the designer should avoid placing several images on a single slide or frame because this can visually overload the learner. If a video is being used, the designer should not incorporate interactive animations because they could compete for the learner's attention and be distracting. According to the modality principle, multimedia instructional pieces with graphics and narrative are more successful than those with text and graphics on a page. According to the individual difference principle, formal conversational formats should not be used. Instead, the teacher should communicate in a casual manner (Sorden, 2012). A lot of research works has been carried out on the use of PhET in enhancing student learning (Yunzal Jr and Casinillo, 2020, Jufriansah et al., 2022, Susilawati et al., 2022, Salame and Makki, 2021). Ndihokubwayo et al, employed PhET in enhancing the study of optics on secondary school students (Ndihokubwayo et al., 2020). Halim et al., used PhET in evaluating students understanding in Hooke's law (Halim et al., 2020). Till now no work has been done on the use of PhET in enhancing student conceptual

understanding on energy and its conservation. Thereby this present study investigates the effectiveness of PhET on conceptual understanding of conservation energy.

METHODOLOGY

The research study employed is an experimental action research design that utilizes pre-test and post-test design to determine the significant impact of PhET interactive simulation on enhancing students' conceptual understanding of energy conversion and conservation. The study also looked at the effect of PhET simulation on female students' performance.

A purposive sampling method was used to select 45 students for the study. After reviewing their previous examination scripts, it was discovered that students were having challenges in answering questions that demands application of knowledge. Observation of their ability to answer application of knowledge questions orally in class showed that students were having the problem of transferring the abstract concepts learnt to other situations or real-life settings. Pre-test and post-test were administered to confirm the problem and measure the impact of the intervention respectively. Descriptive statistical analysis was used to measure the impact of PhET interactive simulation on students' conceptual understanding of conversion and conservation of energy. Statistical differences between students' performance before and after the study were examined using mean, standard deviation; t-test, mean gain, and effect size. In order to ensure validity of both pre-test and post-test, both tests were given to some experienced colleagues for review to eliminate ambiguous and inappropriate items. To ensure reliability of the tests, the test questions were field pilot-tested at a different senior high school with similar characteristics as the sample of the study.

RESULTS

DESCRIPTIVE STATISTICAL ANALYSIS OF DATA

Table 1: Pre-test and Post-test mean score for the study.

Group	N	Pre-test Mean(M_2)	Post-test Mean(M_1)	Mean Gain
Study	45	7.67	16.38	8.71

Table 1, for a total of 45 students used for the study, the mean scores for the pre-test and the post-test are 7.67 and 16.38 respectively. Obtaining a mean gain of 8.71 was achieved which means that the intervention has had an overwhelming impact on students' achievement.

Table 2: Magnitude of Effect on the Treatment.

Group	Post-test Mean(M_2)	Pre-test Mean(M_1)	Mean Difference(M_2-M_1)	d
Study	7.67	16.38	8.71	3.47

To estimate the extent of difference between the pre-test and post-test administered to the students, an effect size analysis was carried out using Cohen's (d) index to indicate the standardized difference between the two means thus, comparing the mean scores of the two test and dividing them by the standard deviation. The results of Cohen's (d) index are presented in Table 2, the effect size of the study group was calculated to be 3.47. These results show that students' conceptual understanding of energy conversion and conservation has been enhanced using the PhET interactive simulation.

Table 3: Inferential Statistics for Pre-test and Post-test Mean Score Difference.

Test	N	Mean	SD	t-value	p-value
Pre-test	45	7.67	2.89	-18.58	0.00▪
Post-test	45	16.38	2.22		

▪Significant, p<.05

From Table 3 a paired sample test was performed and the results were found that the mean score for the pre-test and post-test was 7.67 and 16.38 and their corresponding standard deviations were found to be 2.89 and 2.22 respectively. Moreover, the t-value and p-value were -18.58 and 0.00 respectively. The results show that there is a significant difference between the post-test scores and the pre-test scores.

Table 4: Inferential Statistics for Male and Female Students.

	Males		Females		
	Mean	SD	Mean	SD	p-value
Pre-test	15.88	4.84	8.25	3.47	0.00
Post-test	10.88	4.84	12.62	4.56	0.24

From Table 4 a paired sample T test was performed and the results were found that the mean score for males was 15.88 and 8.25 for females and their corresponding standard deviations were found to be 4.84 and 3.47 respectively after the pre-test. The p-value for the pre-test was 0.00 which is less than 0.05 and this indicate that there is a significant difference between the performance of the males and females. After the post-test, a

mean of 10.88 and 12.62 and standard deviation of 4.84 and 4.56 for males and females respectively were determined. The p-value for the post-test was 0.24 which is greater than 0.05. This result indicates that, there is a significant difference between the performance of males and females. However, after the post-test, the result shows that there is a no significant difference between the performance of males and females.

DISCUSSION

The study explored the lack of conceptual understanding with the goal to determine the impact of PhET interactive simulation in solving the problem. The analysis showed that students' conceptual understanding of conversion and conservation of energy was enhanced because of their improved performance in the post-test after the PhET intervention lessons. Students' interest in learning physics was enhanced, their misconceptions about physics concepts was cleared and their ability to relate and transfer the concepts learnt in class to real-life was also enhanced. Findings from the studies conducted by (Banda and Nzabahimana, 2021, Kotoka and Kriek, 2014, Ndihokubwayo et al., 2020, Yunzal Jr and Casinillo, 2020) situate PhET interactive simulation as a useful tool in enhancing students' conceptual understanding and facilitating learning of various physics concepts. Also, the use of PhET interactive simulation grabbed students' attention throughout the lesson. Moreover, the result showed that the simulation improved the performance of the female students. They performed as well as the males and this suggest that the use of PhET simulation is an effective tool for promoting gender equity in the classroom. Enhanced students' confidence and collaborative learning skills among students as observed could be attributed to how students were allowed to present and discuss their findings with their colleagues. These virtues are indications of the effectiveness of the PhET interactive simulation.

CONCLUSION

The present study aimed to determine the impact of PhET interactive simulation in enhancing students' conceptual understanding of energy conversion and conservation. The findings suggest that PhET interactive simulation is effective in enhancing students' conceptual understanding of conversion and conservation of energy. Moreover, the findings suggest that PhET simulation is effective to help narrow the gender gap in science, technology, engineering and mathematics (STEM) fields as it improved the performance of female students as well as males.

ETHICAL STATEMENT

Not Applicable

CONSENT STATEMENT

Not Applicable

DATA AVAILABILITY

The data that support the findings of this study are available within the article.

FUNDING STATEMENT

There was no external funding.

REFERENCES

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**,** 023108.

BELLO, S., IBI, M. B. & BUKAR, I. B. 2016. Effect of Simulation Techniques and Lecture Method on Students' Academic Performance in Mafoni Day Secondary School Maiduguri, Borno State, Nigeria. *Journal of Education and Practice,* 7**,** 113-117.

BROWN, G. A., BULL, J. & PENDLEBURY, M. 2013. *Assessing student learning in higher education*, Routledge.

DEGA, B. G., KRIEK, J. & MOGESE, T. F. 2013. Students' conceptual change in electricity and magnetism using simulations: A comparison of cognitive perturbation and cognitive conflict. *Journal of Research in Science Teaching,* 50**,** 677-698.

HALIM, A., SAFITRI, R. & NURFADILLA, E. The development of multi representation practicum modules with PhET in Hooke's law concept. Journal of Physics: Conference Series, 2020. IOP Publishing, 012124.

JUFRIANSAH, A., LERING, L. & DONUATA, P. B. 2022. Utilization of PhET simulation in flipped classroom to improve students' critical thinking skills. *Jurnal Riset dan Kajian Pendidikan Fisika,* 9**,** 17-24.

KOTOKA, J. & KRIEK, J. 2014. The impact of computer simulations as interactive demonstration tools on the performance of Grade 11 learners in electromagnetism. *African Journal of Research in Mathematics,*

Science and Technology Education, 18**,** 100-110.
KUNNATH, B. & KRIEK, J. 2018. Exploring effective pedagogies using computer simulations to improve Grade 12 learners' understanding of the photoelectric effect. *African Journal of Research in Mathematics, Science and Technology Education,* 22**,** 329-339.
MAYER, R. E. 2008. Applying the science of learning: evidence-based principles for the design of multimedia instruction. *American psychologist,* 63**,** 760.
MAYER, R. E. & MORENO, R. 2003. Nine ways to reduce cognitive load in multimedia learning. *Educational psychologist,* 38**,** 43-52.
NDIHOKUBWAYO, K., UWAMAHORO, J. & NDAYAMBAJE, I. 2020. Effectiveness of PhET simulations and YouTube videos to improve the learning of optics in Rwandan secondary schools. *African Journal of Research in Mathematics, Science and Technology Education,* 24**,** 253-265.
PAPADOURIS, N. & CONSTANTINOU, C. P. 2011. A philosophically informed teaching proposal on the topic of energy for students aged 11–14. *Science & Education,* 20**,** 961-979.
PERKINS, K. K., MOORE, E. B. & CHASTEEN, S. V. Examining the use of PhET interactive simulations in US college and high school classrooms. Proceedings of the 2014 Physics Education Research Conference, 2014. 207-210.
PHET. 2022. *Physics Educational Technology (PhET)* [Online]. Available: https://phet.colarado.edu/ [Accessed].
SALAME, I. I. & MAKKI, J. 2021. Examining the use of PhEt simulations on students' attitudes and learning in general chemistry II. *Interdisciplinary Journal of Environmental and Science Education,* 17**,** e2247.
SORDEN, S. D. 2012. The cognitive theory of multimedia learning. *Handbook of educational theories,* 1**,** 1-22.
SUSILAWATI, A., YUSRIZAL, Y., HALIM, A., SYUKRI, M., KHALDUN, I. & SUSANNA, S. 2022. The Effect of Using Physics Education Technology (PhET) Simulation Media to Enhance Students' Motivation and Problem-Solving Skills in Learning Physics. *Jurnal Penelitian Pendidikan IPA,* 8**,** 1166-1170.
TAALE, K. D. & ANDERSON, I. K. 2014. Ghanaian senior high school students' perceptions of energy. *Research on Humanities and Social Sciences,* 4**,** 93-102.
TEACHMINT. 2022. *What is conceptual learning?* [Online]. Available: https://blog.teachmint.com/what-is-conceptual-learning/ [Accessed].
TOH, S. C., MUNASSAR, W. A. S. & YAHAYA, W. Redundancy effect in multimedia learning: A closer look. Proceedings of ascilite, 2010.
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**,** 221-226.