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Effect of a Physics Educational Technology on Students' Conceptual Understanding in Physics: A Case a Secondary School in Ngoma District, Rwanda

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Abstract: This study sought to establish the effect of a Physics Educational Technology (PhET) on students' conceptual understanding in Physics. The study employed the experimental research design, using pre-test and post-test procedures with experimental and control groups. The study sampled one secondary school in Ngoma District, Rwanda. The school was sampled because it had a conducive computer laboratory, electricity and high internet connection to support the study. The study involved 40 students in the experimental group and 45 students in the control group of students who took physics. The researchers used a self-designed instrument with fifteen multiple-choice items. During the pre-test and post-test sessions, the students were requested to choose correct answers of their choice. The information gathered was analyzed through t-test, focusing on mean scores and standard deviations to determine the differences between the results. Based on the findings, the study concluded that teaching physics concepts with technological simulations enhances the students' conceptual understanding levels. Based on the conclusions, the study recommends that physics teachers be creative in teaching various concepts by the use of modern technologies to enhance the students' achievements in secondary schools.

Keywords: Students; PhET; simulations; teaching; learning; Projectile motion.

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Introduction

Physics is a crucial subject in addressing events that occur in the cosmos and around it. Physical laws and principles regulate everything around us. Projectile motion is among the physics concepts that are more theoretical in general. Students fail to capture the physical concepts that are more theoretical as they do if the concepts are practical(Lestari & Mansyur, 2021). Therefore, physics should be taught in a constructivist style since the concepts are understood better when students apply hands on activities and use ICT simulations (Kabalisa et al., 2019). Physics is essential for knowing the world in which we live, the world within us and the world beyond us. While it is the most essential and foundational science, physics is also one of the most difficult courses in schools (Dantic & Fluraon, 2022).

In teaching using the board and chalk model, the teacher spends most of the time explaining, speaking, and demonstrating as well as assigning tasks and managing the teaching and learning process. In such kind of learning atmosphere, the teacher is ahead of the class because he is the only one who knows the session's agenda. The knowledge to be taught, according to this model, travels via the teacher and is altered according to a typology of personal didactics transference before being assimilated by the learners. Using this practice, the students do not participate in the creation of knowledge, which has a detrimental impact on their understanding (Mrani et al., 2020). In response, since the adoption of the competency-based approach by Rwanda's educational system in 2015, the learner has been placed at the center of the teaching-learning process (REB, 2015). As a result, traditional pedagogical tools that place the instructor or learning content at the center of the teaching-learning process must be reconsidered.

The integration of information and communication technology tools into the educational process has led to the emergence of a new paradigm that transforms the dynamics within the well-known didactic triangle. In this evolving model, the traditional approach is increasingly challenged, as learners, now equipped with abundant digital resources, often adopt a more active role rather than remaining passive participants in their education (Adams et al., 2008). The usage of computer simulations helps students learn concepts better. Computer simulations further enhance the learners' experimental opportunities, playing an important role in conceptual understanding of the domains of Science, Technology, Engineering, and Mathematics (STEM) (Banda & Nzabahimana, 2023).

Among others, the Physics Educational Technology (PhET) is an ICT platform that supports competency-based curriculum implementation. PhET was developed by Colorado University to enhance the modern teaching of science and mathematics (Wieman et al., 2010).

Motivation

Motivation determines how a person is enthusiastic to complete the intended task. Educators have struggled to determine what stimulates students' interest in learning. Many factors influence one's willingness to put effort into learning. Key factors in learning motivation includes student's personality and talents, characteristics of learning activities, the environment, rewards and behavior of the instructor (Kafyulilo et al., 2013).

Most of the active teaching strategies increase students' motivation. Learners in different groups could discuss physical phenomenon, each student providing his/her view and as a group, they end up having a constructive conclusion about physical events (Kori et al., 2016). The PhET simulation enables students to get a better conceptual understanding of the physical phenomena (Dantic & Fluraon, 2022).

Technology and Physics Education

Building knowledgeable communities with ICT experiences is one of the 21st century's learning challenges. Yet the incorporation of ICT in the teaching and learning process shapes the characteristics of the 21st century society (Haryadi & Pujiastuti, 2020). Physics is one of 21st-century learning disciplines that requires the ICT intervention through the PhET software. PhET is a simulation developed by the University of Colorado to support physics, biology and chemistry learning through simulation (McKagan et al., 2008). The use of the PhET simulation yields better outcomes when it is accompanied by careful planning.

When employed as part of inquiry-based teaching and learning methods, well-designed computer simulations support students' scientific comprehension, thinking abilities, scientific arguments, conceptual evolution and active participation (Bell & Binns, 2005). The use of technology makes the learning more interesting (Kumar et al., 2008).

The use of PhET simulation involves the following stages: (1) Preparation in the Classroom, (2) Activity Sheet, (3) Pre-Post Assessment (Optional), (4) Topic Introduction and Motivation, (5) Sim Play Time, (6) Sim Activities, and (7) Reflections(Banda & Nzabahimana, 2023). Simulation media is essentially one of the learning media that attempts to create a more concrete learning experience through supporting visual limitations in real-world experiences. Therefore, this study sought to establish the role of the Physics Educational Technology in enhancing conceptual understanding of physics concepts among secondary schools in Ngoma District, Rwanda.

Methodology

This section presents the methodology that guided this study. It includes such aspects as design, population and sampling, instruments, treatment of data and ethical considerations.

Design

This study employed the experimental research design, using pre-test and post-test procedures to experimental and control groups.

Population and sampling.

The researchers selected one secondary school from Ngoma District in Rwanda. The school was purposely chosen because it had a computer laboratory, electricity and high connection to facilitate to support the study. The study involved 40 form four students in the experimental group and 45 form four students in the control group, who took physics.

Statistical Treatment of Data

The control group was taught using traditional methodologies while the experimental group was taught using some instructional technology. The researchers used a self-designed instrument, called Projectile Motion Conceptual Assessment consisting of fifteen multiple-choice questions. During the pre-test and post-test periods, the students were requested to choose the correct answer of their choice. The information gathered from both the pretest and posttest sessions was analyzed through t-test, focusing on mean scores and standard deviations to determine the differences between the results.

Before the Intervention

Both experimental and control groups were given the Projectile Motion Conceptual Assessment as a pre-test. The Pre-test scores provided the researchers necessary information about the pre-existing knowledge held by the students. This information enabled the researchers to prepare the lessons taking into consideration the students' background. Secondly, these scores were subjected to a statistical test to determine the comparability of the two groups before the intervention.

Intervention

During the intervention, the control class was taught using the normal instruction method. The teacher demonstrated the concepts of projectile motion. The teacher demonstrated formulae such as the maximum height of the projectile, time to reach the maximum height of the projectile, horizontal range, and time of flight. The teacher discussed with the students the effect of air resistance on the body launched at a given angle to the horizontal. He gave mathematical examples to solve using the demonstrated formulae.

The experimental group, on the other hand, was taught using a Physics Educational Technology. The teacher first divided the students into ten sub-groups, each of the groups consisting of about four students. Each sub-group sat on the table around the computer. The teacher demonstrated formulae on board and by setting initial conditions, such as initial velocity and angle θ, students demonstrated the PhET simulations in groups and in whole class presentations. Students used the PhET simulations to demonstrate the effect of air resistance, mass of the projectile and diameter of the projectile. After the intervention for seven periods, both groups sat for the posttest assessment.

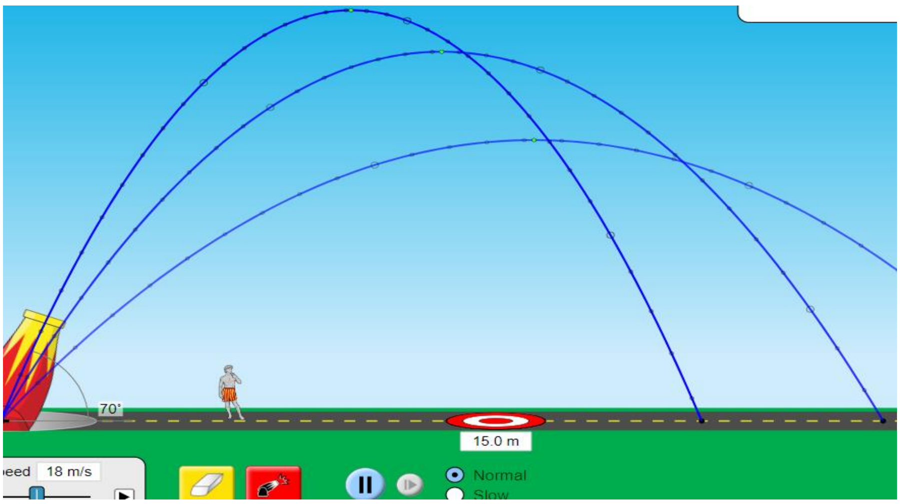

Figure 1: Intervention Activity

Figure 1 indicates different analyses of projectile at different angles of inclination. This analysis indicates that when initial velocity is maintained at a constant value, the height of the projectile is directly proportional to the angle of inclination. This means that when increasing the angle at which the projectile is launched, the higher it will move upwards but the shorter it will move horizontally. PhET simulations helped students to capture these concepts since the students learned via gaming, involving multiple senses, including hearing and seeing.

Ethical Considerations

The researchers discussed with the participants about the purpose of the study, explaining to them that the results would not affect their current academic study. Participants asked some questions and the researcher answered them. The participants agreed to participate and signed consent forms. The respondents were given freedom to participate and withdraw at any time of the data collection period. Anonymity and confidentiality were maintained to safeguard the rights of the respondents.

Findings and Discussion

This section presents the study's findings and discussions through literature.

Demographic Characteristics

This section shows the demographic characteristics of the respondents, of which 60 (70.5%) were males and 25 (29.5%) were females. On the other side, 50 (58.8%) of the respondents were between the ages of 14 and 17 while 35 (41.2%) were between the ages of 18 and 20.

Pre-Test Results

To determine the students' initial conceptual understanding of the projectile motion, the researchers gave the pretest assessment to the students as it appears in Table 1 and 2.

Table 1: Group Statistics for Pre-Test Assessment

	Group	N	Mean	Std. Deviation	Std. Error Mean
Score	Control group	45	43.2444	6.42494	.95777
	Experimental group	40	42.9750	5.44665	.86119

Table 2: Independent sample t-test for pre-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	.452	.503	.207	83	.836	.26944	1.30063	-2.31745	2.85634
	Equal variances not assumed			.209	82.827	.835	.26944	1.28801	-2.29244	2.83133

In Table 1, the mean score for the control group was 43.2444 with the standard deviation of 6.42494 while the experimental group's mean score was 42.9750 with the standard deviation of 5.44665. Table 2 shows that the paired sample test has the Sig. of 0.836, which is greater than the critical threshold (0.05). This suggests that the mean score between the control and the experimental groups was comparable at the initial stage.

Post-Test Results

Before the post-test session, the researchers did the intervention with the experimental group. For one week (seven periods), the experimental and control groups were taught about the projectile motion. During the teaching process, the experimental group was taught using the PhET simulations. The learners in the experimental group played the simulations and the teacher demonstrated the concepts using some formulae, then students, guided by the teacher, verified the results using simulations. The control group was taught the same concepts, using the traditional instruction methods. The teacher demonstrated the formulae and gave mathematical examples. After the intervention period, both students sat for the post-test.

From Table 3, the mean score for the control group was 51.00 with the standard deviation of 11.81678. For the experimental group, the mean score was 60.02 with the standard deviation of 7.98231.

Table 3: Group Statistics for Post-Test Assessment

	Group	N	Mean	Std. Deviation	Std. Error Mean
Score	Control group	45	51.0000	11.81678	1.76154
	Experimental group	40	60.0250	7.98231	1.26211

Table 4: Independent Samples T-test for post-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	6.011	.016	-3.171	83	.002	-7.02500	2.21571	-11.43197	-2.61803
	Equal variances not assumed			-3.242	77.676	.002	-7.02500	2.16702	-11.33948	-2.71052

The independent samples test in table 4 indicates the Sig. of .002, which is lesser than the critical value (p=0.05). This implies that the mean difference between the control and the experimental groups was significantly different. The experimental group, which used the PhET simulations in the teaching and learning periods performed better than the control group, which used the conventional methods. Therefore, PhET is a powerful teaching strategy in enhancing the students' conceptual understanding. The results confirmed that ICT interventions are effective in enhancing the conceptual understanding in physics. Therefore, the second null hypothesis was rejected. The findings align those by Lestari and Mansyur in (2021) that direct instruction with PhET simulations boost the students' conceptual grasping powers. The findings are similar to those by Kapelle et al. (2019), whose study showed that students who were given interactive interventions significantly outperformed their counterparts who learned through traditional methods.

Conclusions and Recommendations

The study concludes that teaching physics concepts with technological simulations enhances the students' conceptual understanding levels. Therefore, the Physics Educational Technology program is an effective tool that enhances the achievement of students in physical concepts. Based on the conclusions, the study recommends that physics teachers be creative by the use of modern technologies to enhance the students' achievements in secondary schools.

References

Adams, W. K., Reid, S., Lemaster, R., McKagan, S. B., Perkins, K. K., Dubson, M. and Wieman, C. E. (2008). A study of educational simulations Part 1 - Engagement and learning. Journal of Interactive Learning Research, 19(3), 397–419.

Banda, H. J. and Nzabahimana, J. (2023). The Impact of Physics Education Technology (PhET) Interactive Simulation-Based Learning on Motivation and Academic Achievement Among Malawian Physics Students. Journal of Science Education and Technology, 32(1), 127–141. https://doi.org/10.1007/s10956-022-10010-3.

Bell, R. L., & Binns, I. C. (2005). Simplifying inquiry instruction Understanding Technology and Technology in Education View project. January 2005. https://www.researchgate.net/publication/228665515

Dantic, M. J. P. and Fluraon, A. (2022). PhET interactive simulation approach in teaching electricity and magnetism among science teacher education students. Journal of Science and Education (JSE), 2(2), 88–98. https://doi.org/10.56003/jse.v2i2.101.

Haryadi, R. and Pujiastuti, H. (2020). PhET simulation software-based learning to improve science process skills. Journal of Physics: Conference Series, 1521(2). https://doi.org/10.1088/1742-6596/1521/2/022 017.

Kabalisa, J., Gapfizi, P., Uwamahoro, J. and Uwayezu, C. J. (2019). Effect of Real-life Application-based Classroom Activities on Engineering Students' Conceptual Understanding of Electromagnetism: A

Case of Rwanda Polytechnic, Huye Campus. Journal of Research Innovation and Implications in Education, 7, 6–8. https://doi.org/10.59765/wsbd2974.

Kafyulilo, A., Rugambuka, I. and Moses, I. (2013). Implementation of Competency Based Teaching in Morogoro Teachers' Training College, Tanzania. Makerere Journal of Higher Education, 4(2), 311–326. https://doi.org/10.4314/majohe.v4i2.13.

Kapelle, N. R., Jatmiko, B., Munasir, M. and Wenno, I. H. (2019). Development of PhET-Aid-Based Inquiry Learning Devices to Improve Student Critical Thinking Skills. International Journal of Multicultural and Multireligious Understanding, 6(5), 980. https://doi.org/10.18415/ijmmu.v6i5.1149.

Kori, K., Pedaste, M., Leijen, Ä., & Tõnisson, E. (2016). The Role of Programming Experience in ICT Students' Learning Motivation and Academic Achievement. International Journal of Information and Education Technology, 6(5), 331–337. https://doi.org/10.7763/ijiet.2016.v6.709.

Kumar, N., Rose, R. C., & D'Silva, J. L. (2008). Teachers' readiness to use technology in the classroom: An empirical study. European Journal of Scientific Research, 21(4), 603–616.

Lestari, P. D. and Mansyur, J. (2021). The influence of the online PhET simulation-assisted using direct instruction on student's conceptual understanding of parabolic motion. Journal of Physics: Conference Series, 2126(1). https://doi.org/10.1088/1742-6596/2126/1/012013.

McKagan, S. B., Perkins, K. K., Dubson, M., Malley, C., Reid, S., LeMaster, R. and Wieman, C. E. (2008). Developing and researching PhET simulations for teaching quantum mechanics. American Journal of Physics, 76(4), 406–417. https://doi.org/10.1119/1.2885199.

Mrani, C. A., El Hajjami, A. and El Khattabi, K. (2020). Effects of the integration of PhET simulations in the teaching and learning of the physical sciences of common core (Morocco). Universal Journal of Educational Research, 8(7), 3014–3025. https://doi.org/10.13189/ujer.2020.080730.

REB. (2015). Competence-Based Curriculum. 15Th International Conference the Knowledge-Based Organization: Behavioral and Social Sciences, Conference Proceedings 4, 4, 308–312.

Wieman, C. E., Adams, W. K., Loeblein, P. and Perkins, K. K. (2010). Teaching Physics Using PhET Simulations. The Physics Teacher, 48(4), 225–227. https://doi.org/10.1119/1.3361987