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iJOINED ETCOR
P - ISSN 2984-7567
E - ISSN 2945-3577
The Exigency
P - ISSN 2984-7842
E - ISSN 1908-3181

Conceptual Understanding in Projectile Motion Using Computer Aided E-Games Among Grade 9 Students

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Received: 18 April 2025 **Revised**: 20 May 2025 **Accepted**: 22 May 2025

Available Online: 23 May 2025

Volume IV (2025), Issue 2, P-ISSN – 2984-7567; E-ISSN - 2945-3577

https://doi.org/10.63498/etcor330

Abstract
Aim: This study aimed to determine whether incorporating E-games into the lesson plan could significantly improve student learning outcomes compared to traditional methods. The objectives focused on evaluating the pre-test and post-test performance of students, assessing the impact of E-games on conceptual understanding, and examining how these games were effectively integrated into the structure of the developed lesson plan.
Methodology: The study employed a quasi-experimental design using a nonequivalent pre-test–post-test approach. Respondents were selected based on their Group Assessment of Logical Thinking (GALT) scores to ensure balanced grouping.
Results: The findings revealed that the experimental group, which used computer E-games, achieved higher and more consistent post-test scores, demonstrating the effectiveness of game-based learning.
Conclusion: The study concluded that incorporating E-games into the lesson plan enhances student understanding of projectile motion and suggested that integrating technology-based instructional tools be considered to improve science education.

Keywords: *Computer-Aided Games, Conceptual Understanding, Game-Based Learning, Projectile Motion, Quasi-Experimental Design*

INTRODUCTION

With evolving educational practices, the need for continuous professional development for educators has become crucial. Teachers must acquire diverse skills to meet the growing demands of modern classrooms. A key area of focus is integrating technology and personalized learning strategies, which enhance the learning experience and support student success by tailoring instruction to each student's needs.

The role of teachers has evolved significantly beyond traditional content delivery. Educators are now expected to master curricula, implement diverse and effective teaching methodologies, and adeptly utilize innovative tools and resources to cater to individual student needs (Amihan, et al., 2023; Carvajal, et al., 2025; Salendab & Sanchez, 2023). This shift aligns with the principles of personalized learning, which tailors educational experiences to each student's strengths, needs, skills, and interests, fostering a more engaging and effective learning environment (Pane et al., 2015).

Additionally, the modernization of education aims to establish a learner-centered system that creates favorable conditions for each student to engage in independent work, assimilate material at a personalized pace, and apply acquired skills effectively. This approach has led to significant changes in the education system, including a holistic approach to student development, the adoption of modular learning, and the integrating information technology across various learning areas. These advancements enhance the learning experience and prepare students to navigate and succeed in an increasingly complex and technology-driven world (Zhu & Engels, 2014).

By embracing these modern educational practices, teachers facilitate environments where students can develop critical thinking, problem-solving abilities, and adaptability—skills essential for success in the 21st century.

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This comprehensive approach ensures that education is about knowledge acquisition and equipping learners with the competencies necessary for lifelong learning and active participation in a rapidly evolving global society.

Science education helps students understand how and why things work, especially with computer-aided media. A strong foundation in scientific methods and concepts is essential in today's fast-paced, technology-driven world. Teaching science empowers students to think critically, enabling them to become effective, creative problem-solvers in their communities. Science education helps address global challenges and fosters cultural understanding. Learning the scientific method also enhances students' thinking, learning, problem-solving, and judgment skills, which are vital throughout their education and life (Rahman, 2019).

However, scientific education issues persist, with students and teachers facing ongoing challenges. Filipino students consistently score below average in international science assessments despite improving efforts. Studies by Bernardo et al. (2023) reveal that Filipino students' science literacy is significantly lower than their global peers, as seen in the PISA and TIMSS assessments (Cordova & Linaugo, 2022). In the 2018 PISA, the Philippines ranked lower than other ASEAN countries in scientific literacy (Department of Education, 2019). The 2022 PISA and OECD data show the country among the weakest performers globally in reading, math, and science. Moreover, the National Achievement Test (NAT) 2019 results indicated that students from Region VIII had an average Science proficiency score of 38%, lower than the national average of 41% (DepEd Region VIII, 2020).

In physics education, particularly projectile motion, students face challenges that require foundational knowledge and higher-order thinking skills such as analysis and problem-solving (Mutambo, Baliga, & Nkhata, 2018). A study by Boco and Malindog (2020) showed that second-year engineering students had a weak conceptual understanding of force and motion, influenced little by their beliefs about learning Physics. However, superstitious beliefs had a weak effect. Studies by Bullo and De Leon (2024) and Boller-Aying and Villegas-Mendaño (2024) highlight projectile motion as a problematic concept for Grade 9 students. At Calapi National High School, Science scores were low, with 42% of students showing poor proficiency and 58% showing no proficiency.

Building upon these observations, the challenges in understanding projectile motion highlight the need for innovative teaching strategies, such as computer-aided educational games. These games engage students, boost motivation, and make learning enjoyable. Mayer (2019) found that well-designed educational games enhance learning by combining cognitive engagement with motivational elements, particularly when they align with principles of multimedia learning, like clear goals, immediate feedback, and active problem-solving opportunities.

Additionally, computer-aided educational games reduce student boredom by creating an interactive, engaging environment that helps focus on learning outcomes and improves instructional effectiveness (Basher & El Din, 2017). Despite their potential, research on these games as a primary tool for enhancing understanding of complex physics topics remains limited, with most studies focusing on computer-assisted activities in science education.

Thus, this study investigated the effect of computer-aided educational games on the student's conceptual understanding of Projectile motion, explicitly focusing on projectile motion, including its horizontal and vertical components. By addressing the persistent challenges faced by Calapi National High School students and similar contexts, this research seeks to provide evidence-based insights into how innovative instructional strategies can improve academic achievement in physics.

Objectives of the Study

This study aimed to determine whether incorporating E-games into the lesson plan could significantly improve student learning outcomes compared to traditional methods.

Specifically, this study sought to accomplish the following:

1. determine the level of conceptual understanding of the two groups of respondents in projectile motion in terms of their results in:
    1.1. Pretest mean scores and
    1.2. posttest mean scores.
2. determine the significant difference among the test scores of the two groups of respondents in terms of.
    2.1. Pretest mean scores, and
    2.2. posttest mean scores.
3. determine the significant difference between the posttest scores of the two groups of respondents.
4. develop a lesson plan that integrates educational games.

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Hypothesis

Given the stated research problems, the following hypotheses were tested at 0.05 level of significance:

H_0: There is no significant difference in the pretest and posttest mean scores between the two groups of respondents.

H_o: There is no significant difference between the posttest scores of the two groups of respondents.

METHODS

Research Design

The research design used in this study is quasi-experimental design with a nonequivalent pre-test and post-test approach to evaluate the effectiveness of computer-aided educational games (E-games) on students' conceptual understanding of projectile motion.

Population and Sampling

This study involved Grade 9 students enrolled at Calapi National High School for the 2024–2025 school year. Two intact classes were selected, and the Group Assessment of Logical Thinking (GALT) was administered to assess students' cognitive abilities. Students were then paired by sex and GALT scores, with one student from each class per pair, ensuring comparable ability levels. A total of 20 pairs (40 students) were discreetly selected as respondents. One class served as the experimental group using computer-aided educational games (E-games), while the other received traditional instruction. Only students who completed both the pretest and posttest and had no more than two absences were included in the final analysis to maintain data.

Instrument

This study used a reliable, standardized 30-item multiple-choice test adapted from Aying and Mendaño (2024) to assess students' understanding of projectile motion, focusing on horizontal and vertical components. The test covers key concepts, applications, and mathematical analysis, and was chosen for its alignment with the study's goal of measuring the impact of computer-aided e-games on conceptual understanding.

Data Collection

The researchers secured permission from the Schools Division Superintendent and the principal of Calapi National High School. The GALT test was administered to two Grade 9 classes, and 40 students were paired based on scores and sex. A 30-minute pretest was then given to assess prior knowledge.Over six days, the experimental group was taught using computer-aided e-games, while the control group received traditional lectures. The researchers handled both groups to reduce bias. Afterward, a posttest with rearranged items was administered. Data collection and processing followed.

Treatment of Data

The study used several statistical tools for data analysis. Mean and standard deviation were applied to assess average scores and the variability of student performance. The Kuder-Richardson Formula 20 (KR-20) measured the reliability of the standardized test. A t-test for dependent samples was used to compare pretest and posttest scores within each group, while a t-test for independent samples compared the mean gain scores between the experimental and control groups to determine significant differences in learning outcomes.

Ethical Considerations

The researchers ensured that all ethical guidelines were followed, including obtaining informed consent from participants and ensuring the confidentiality and privacy of their responses throughout the study.

RESULTS and DISCUSSION

This chapter provides a comprehensive analysis and interpretation of the data collected, aligning the findings with the specific research objectives outlined in the study.

Level of Conceptual Understanding of Students in Projectile Motion

The table below compares the levels of conceptual understanding between the control group and the experimental group for both pre-test and post-test results.

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Table 1. Levels of Conceptual Understanding in Pre-Test and Post-Test Results of the Control and Experimental Groups

Levels of Conceptual Understanding	Control Group				Experimental			
	Pre-Test		Post Test		Pre-Test		Post Test	
	f	%	f	%	f	%	f	%
Outstanding	-	-	1	5%	-	-	1	5%
Very Satisfactory	-	-	2	10%	-	-	3	15%
Satisfactory	-	-	2	10%	-	-	4	20%
Fairly Satisfactory	1	5%	2	10%	-	-	6	30%
Did Not Meet Expectations	19	95%	13	65%	20	100%	6	30%
Total	20	100%	20	100%	20	100%	20	100%

Table 1 presents the levels of conceptual understanding in the pre- and post-tests for both control and experimental groups. In the control group, most students did not meet expectations in both tests (95% in pre-test, 65% in post-test), with only slight improvements—10% reached Satisfactory and 10% Fairly Satisfactory levels in the post-test.

In contrast, the experimental group showed significant progress. While all students initially fell under "Did Not Meet Expectations," the post-test revealed marked gains: 30% achieved Fairly Satisfactory and 20% reached Satisfactory. This improvement is attributed to the intervention involving PhET simulations and Quizlet e-games.

Supporting research by Villada and Montoya (2022) and Liao and Liu (2020) affirms the effectiveness of game-based and simulation tools in enhancing conceptual learning, particularly in topics like projectile motion. Overall, the findings suggest that interactive computer-based tools can substantially improve conceptual understanding compared to traditional methods.

In Table 2, the pre-test and post-test comparison of levels of conceptual understanding between the control and experimental groups is shown.

Table 2. Pre-Test and Post-Test Comparison of Levels of Conceptual Understanding Between Control and Experimental Groups

Levels of Conceptual Understanding	Pre-Test				Post-Test			
	Control		Experimental		Control		Experimental	
	f	%	f	%	f	%	f	%
Outstanding	-	-	1	5%	-	-	1	5%
Very Satisfactory	-	-	2	10%	-	-	3	15%
Satisfactory	-	-	2	10%	-	-	4	20%
Fairly Satisfactory	1	5%	2	10%	-	-	6	30%
Did Not Meet Expectations	19	95%	13	65%	20	100%	6	30%
Total	20	100%	20	100%	20	100%	20	100%

Table 2 shows that both groups improved from pre- to post-test, but the experimental group showed greater gains. Initially, 95% of control group students and 65% of experimental group students were in the lowest category. After the intervention, the control group saw modest improvement, while the experimental group had students reaching higher performance levels, including "Very Satisfactory" and "Outstanding."

The experimental group's stronger results are linked to using interactive tools like PhET simulations and Quizlet, which enhanced understanding of projectile motion. Studies support the effectiveness of such tools in improving conceptual learning and problem-solving.

Table 3 compares pre- and post-test mean scores for both groups, highlighting baseline knowledge and the impact of the instructional intervention on learning outcomes in projectile motion.

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Table 3.Student's Level of Conceptual Understanding in terms of Pretest and Posttest Mean Scores

Group	n	Pre-Test			Post-Test		
		Mean	Grade	Description	Mean	Grade	Description
Controlled	20	10.25	68	Did Not Meet Expectations	16.15	73	Did Not Meet Expectations
Experimental	20	8.50	67	Did Not Meet Expectations	19.60	78	Fairly Satisfactory

Table 3 shows that both groups had low pretest scores, indicating limited prior understanding of projectile motion. The control group scored a mean of 10.25 (grade 68), while the experimental group scored 8.50 (grade 67), both falling under the "Did Not Meet Expectations" category.

After the intervention, the control group improved to a mean score of 16.15 (grade 73), still within the same category. In contrast, the experimental group significantly improved to 19.60 (grade 78), reaching the "Fairly Satisfactory" level.

This improvement is attributed to the use of PhET simulations and Quizlet e-games, which enhanced conceptual understanding. Research supports the effectiveness of such interactive tools in improving students' grasp of complex physics concepts like vectors and projectile motion.

Difference in the Pretest and Posttest Mean Scores Between Controlled and Experimental Groups

Table 4 provides a detailed comparison of the pre-test and post-test mean scores for both the controlled and experimental groups, offering insights into the effectiveness of the instructional approaches applied to each group.

Table 4. Comparison of the Pre-Test and Post-Test Mean Scores of the Students

Group	Mean		Difference	t	p-value	Interpretation
	Pretest	Posttest				
Controlled	10.25	16.15	5.90	5.949	0.000	S/Reject Ho
Experimental	8.50	19.60	11.10	13.222	0.000	S/Reject Ho

The Level of Significance is at 0.05, two-tailed

The paired samples t-test showed significant improvement in both groups' scores from pretest to posttest. The control group improved from a mean of 10.25 to 16.15 (t=5.949, p<.05), while the experimental group showed a greater gain—from 8.50 to 19.60 (t=13.222, p<.05). These results confirm that both instructional methods were effective, with the experimental group showing more substantial improvement.

This greater gain is attributed to the use of PhET simulations and Quizlet, which provided interactive, game-like learning experiences. Research supports the effectiveness of such tools in improving engagement, inquiry, and conceptual understanding. PhET simulations, with their embedded play features and implicit scaffolding, guide students through active, student-centered learning processes, making abstract physics concepts more accessible.

These findings highlight the value of integrating digital, game-based tools into science education to enhance understanding and close learning gaps.

Difference in Post- Test Scores Between the Controlled and Experimental Groups

Table 5 presents the results of the independent samples t-test, comparing the post-test scores of the control and experimental groups on the topic of projectile motion.

Table 5. Comparison of the Post-test Mean Scores of the Students in Projectile Motion

Group	PostTest Mean	t	p-value	Interpretation

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Controlled	16.15			
Experimental	19.6	2.391	. 022	S/Reject Ho

Level of Significance is at 0.05,two-tail,df = 38

The post-test results show that the control group had a mean score of 16.15, while the experimental group scored significantly higher at 19.60. A *t*-value of 2.391 and *p*-value of .022 indicate a statistically significant difference, leading to the rejection of the null hypothesis. This suggests that the experimental group's performance gains were due to the instructional intervention, not chance.

These findings support the effectiveness of technology-enhanced instruction, such as interactive simulations and game-based tools. Similar results were reported by Lashari et al. (2024), who found that platforms like Kahoot improved motivation and learning outcomes. The use of tools like PhET simulations likely promoted engagement, hands-on learning, and deeper conceptual understanding—especially in topics like projectile motion.

This study aligns with previous research (Clark & Mayer, 2016; Wieman et al., 2008; Zacharia & Olympiou, 2011; Rutten et al., 2012) showing that digital and interactive approaches enhance science education. The results also reflect Hake's (1998) findings on the benefits of interactive learning in physics.

Overall, the significant improvement in the experimental group highlights the value of integrating digital tools and active learning strategies to boost student performance and engagement in science education.

Lesson Plan with the Integration of Educational Games

Table 6 outlines a detailed structure for the Lesson Plan with the Integration of Computer-Aided Educational Games in Projectile Motion. This table is designed to seamlessly blend traditional teaching methods with interactive digital tools, enhancing students' understanding of projectile motion concepts.

Table 6. Lesson Plan Structure with Integration of Computer-Aided Educational Games in Projectile Motion

Phase	Activity	Details	Resources/Materials
Engage	Game Based Activity: Students explore projectile motion using Quizlet.	Learn the Concepts of Projectile Motion and it's Vertical and Horizontal Component thru interactive games	-Laptops, -Quizlet Live
	Show videos/animations of projectile motion (basketball shot, fireworks, cannon).	- Explain vertical (gravity, initial velocity) and horizontal (constant velocity) components of projectile motion.	- PowerPoint Presentation, Diagrams
Explore	Game Based Activity: Students explore projectile motion using PhET simulation and Quizlet.	Experiment with variables affecting projectile motion (velocity, angle, gravity).	-Laptops, PhET Simulation, Quizlet Live

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		Apply the Concepts of Projectile Motion and it's Vertical and Horizontal Component thru interactive games	-Laptops, PhET Simulation, Quizlet Live
	Hands-on experiment: Throw balls at different angles (30°, 45°, 60°) and measure range, time of flight, and height.	Apply knowledge in a practical experiment to observe and record data.	Balls, measuring tape, stopwatch, protractor
Explain	Game Based Activity: Students explain concepts in projectile motion using Quizlet.	Define and clarify projectile motion and break it into its components.	PowerPoint Presentation, Diagrams
	Teacher explains projectile motion and its components (horizontal and vertical motions).	Define and clarify projectile motion and break it into its components.	PowerPoint Presentation, Diagrams

The integration of computer-aided educational games, such as Quizlet and PhET simulations, into the lesson on projectile motion was based on pre-test data identifying gaps in students' understanding—particularly in grasping the vertical and horizontal components and applying them to real-world contexts.

In the Engage phase, students used Quizlet to learn foundational terms and concepts, addressing weaknesses revealed by the pre-test, such as the effects of gravity and initial velocity on vertical motion and constant velocity on horizontal motion.

During the Explore phase, students applied their knowledge using PhET simulations and Quizlet Live. These tools allowed them to manipulate variables like angle, velocity, and gravity, helping them understand how these factors affect a projectile's range, height, and flight time—areas where the pre-test showed limited mastery.

The Explain phase focused on reinforcing conceptual understanding. Students revisited key ideas through Quizlet and teacher-led discussions, helping them articulate the relationship between vertical and horizontal motion—another area of difficulty identified in the pre-test.

Overall, the data-driven integration of Quizlet and PhET proved effective in addressing learning gaps. By combining interactive games with simulations, students improved both their conceptual understanding and ability to apply knowledge in practical scenarios. This approach supports the conclusion that game-based learning is a valuable strategy in teaching complex physics concepts like projectile motion.

Conclusions

The study concludes that integrating computer-aided educational games (E-games) into instruction significantly enhances students' understanding of forces and motion compared to traditional methods. Pre-test results showed low baseline knowledge in both groups, but the experimental group using E-games achieved notably higher and more consistent post-test scores. Statistical analysis confirmed a significant improvement, leading to the rejection of the null hypothesis. E-games proved more effective in addressing complex concepts, promoting equitable learning, and fostering deeper engagement. Their structured integration into the lesson plan provided interactive simulations and problem-solving activities, resulting in improved conceptual mastery and active student participation.

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Recommendations

To enhance science teaching, particularly for complex topics like projectile motion, educators are encouraged to integrate computer-aided educational games (E-games) into their lessons. Professional development programs can help teachers effectively adopt these tools. Using adaptive or customizable E-games can address diverse learning needs, while combining them with traditional methods may offer a more balanced approach. Lesson plans involving E-games should be regularly evaluated and refined based on student performance and feedback. Schools should support this integration by providing resources and promoting innovative teaching practices. Lastly, further research is recommended to explore the effectiveness of E-games across other science topics and their long-term impact on learning retention and application.

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