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Development of the Physics Flight Quest (PFQ) Activity Packet Using PhET Simulation for Projectile Motion in Grade 9

Almairah C. Regaro., Elesar V. Malicoban., Monera A. Salic-Hairulla., Vanjoreeh A. Madale., Ariel O. Ellare., Arlyn R. Alcopra

Department of Science and Mathematics Education, College of Education, Mindanao State University – Iligan Institute of Technology, Bonifacio Ave. Tibanga, Iligan City, 9200 (Philippines)

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ABSTRACT

This study employed a research and development (R&D) design to develop and validate an inquiry-based Physics Flight Quest (PFQ) activity packet integrated with PhET simulations for teaching projectile motion in Grade 9. A needs assessment was conducted among in-service Science teachers to identify instructional challenges and common student misconceptions related to projectile motion. Guided by the 4D model (Define, Design, Develop, and Disseminate), the activity packet was systematically designed and refined through iterative revisions. Validation was conducted by five in-service teachers and science education specialist who evaluated the content accuracy, instructional clarity, and pedagogical effectiveness of the material using an adapted instrument. Revisions were made based on their recommendations, emphasizing clearer instructions, contextual examples, and improved visual aids. Result indicated that the developed PFQ activity packet was highly valid across learning outcomes, instructional characteristics, and effects on learning, suggesting its readiness for classroom implementation. The study highlights the potential of inquiry-based instructional materials integrated with PhET simulations to support conceptual understanding and learner-centered physics instructions.

Keywords: Inquiry-based learning, PhET simulations, projectile motion, instructional materials, science education

INTRODUCTION

Projectile motion is a fundamental yet challenging topic in physics, as students must understand the combined effects of horizontal and vertical motion (Boller-Aying & Villegas-Mendaño, 2024). Many struggle to visualize the parabolic trajectory and grasp how horizontal constant velocity interacts with vertical acceleration, with air resistance adding further complexity (Chudinov et al., 2022; DaSilva, 2024). Misconceptions, such as believing the force at the top of the path is zero or that range is independent of angle, are common due to limited hands-on experience (Fongsamut et al., 2022). Traditional teaching methods in the Philippines, often lecture-based and uniform, fail to address diverse learning needs, especially given large class sizes, limited resources, and rigid curricula (Yue, 2024; Ummi et al., 2024). PISA 2022 results highlight persistent gaps in Filipino students' science literacy, reasoning, and problem-solving skills (OECD, 2023).

Inquiry-based learning (IBL) and interactive tools like PhET simulations have been shown to improve engagement and conceptual understanding by allowing students to manipulate variables, visualize motion, and analyze data (Boller-Aying & Villegas-Mendaño, 2024; Gillies, 2023). This study aims to develop a PFQ activity packet complemented by PhET simulations for Grade 9 students, promoting active learning, critical thinking, and deeper comprehension of projectile motion, while providing effective strategies for science education.

Objectives Of the Study

The primary objective of this study is to develop and implement an inquiry-based learning PFQ activity packet that incorporates PhET simulations to improve students' understanding of projectile motion. Specifically, the study aims to:

1. Conduct a needs assessment for teachers to identify learning gaps, challenges, in teaching and learning projectile motion.

2. Develop an inquiry-based PFQ activity packet incorporating PhET simulations.

METHODS

This study employed a Research and Development (R&D) research design aimed at systematically developing and validating an inquiry-based Physics Flight Quest (PFQ) activity packet integrated with PhET simulation. The study was guided by the 4D specifically the Define and Design/Develop phases, as these were the portions completed by the researcher. Five in-service Grade 9 Science teachers participated in the needs assessment to identify existing instructional challenges, common student difficulties, and teachers' preferences regarding materials for teaching projectile motion. Five validators composed of in-service teachers and science education specialists evaluated the activity packet using an adapted validated instrument. It covered three domains: learning outcomes, instructional characteristics, and effects on learning. Each indicator was rated using a 5-point Likert scale ranging from 1 (Not Valid) to 5 (Extremely Valid). Weighted means and standard deviations were computed to determine the level of validity of the instructional material.

Data Gathering Procedures

Data were gathered through a Needs Assessment Questionnaire administered to in-service Science teachers to identify instructional gaps, common student misconceptions, and challenges encountered in teaching projectile motion. The questionnaire, adapted from Jumawan (2022), was distributed after securing permission from the school administration and the participating teachers. All responses were coded anonymously and analyzed to determine the essential features needed for the development of the instructional material. Using the insights obtained from the needs assessment, the researcher designed and developed the initial draft of the inquiry-based Physics Flight Quest (PFQ) activity packet, ensuring that its activities, guiding questions, and simulation components aligned with the instructional needs expressed by the teachers and the competencies outlined in the Science curriculum. Ethical considerations were observed throughout the process, ensuring voluntary participation, confidentiality of responses, and secure handling of all collected data.

Data Analysis

Data from the Needs Assessment Questionnaire were analyzed using qualitative descriptive analysis, wherein teachers' responses were coded and grouped into themes reflecting instructional challenges, student misconceptions, and needed support in teaching projectile motion. These themes guided the initial design of the PFQ activity packet. Validator feedback was then summarized by examining their ratings and comments, which were organized into thematic areas such as clarity, content accuracy, and usability. These analyses informed the refinement of the instructional material.

RESULTS AND DISCUSSION

Table 1. The Summary of the Responses of In-service Science Teachers on the Need Assessment

Theme	Coded For	Exact Quote (NO changes)
Difficulty in Conceptual Understanding of Projectile Motion	Students' conceptual gaps	*"Even if it is very common (projectile) to our everyday life, integration of mathematics in sciences made it more complicated." (NAST1)*
	Misconception: continuous push	*"students mix up horizontal and vertical components, or assume there's still acceleration horizontally. Misconception: 'the projectile keeps being pushed forward,'*

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		instead of moving with constant horizontal velocity." (NAST2)
	Misconception about angle	*"Students often think a higher angle always means a farther distance and have trouble seeing how angle and speed affect both height and range. They also find it hard to understand that horizontal and vertical motions work independently." (NAST4)*
	Understanding velocity vs acceleration	*"Velocity and acceleration confusion" (NAST5)*
Difficulty in Mathematical Problem Solving	Steps in solving	*"Most students have a hard time remembering the steps to solve problems and one wrong solution leads to wrong answer." (NAST3)*
	Math and trigonometry	*"Projectile motion requires solving equations. Students sometimes get overwhelmed by formulas, substitution steps, and the need to use trigonometric functions like sine and cosine correctly." (NAST3)*
Visualization Challenges	Trouble visualizing trajectory	*"Visualization of the students especially the distance covered at different angles." (NAST1)*
	Need clearer demonstrations	*"having limited equipment or simulations to demonstrate the motion clearly is also a problem." (NAST4)*
Lack of Resources	Limited gadgets and internet	*"the lack of resources contributes to the challenge in teaching projectile motion. Thus, misconception persist…" (NAST2)*
	Connectivity issues	*"the challenge is having a slow internet connection." (NAST4)*
	No devices for PhET	*"not every student have their gadget or laptop to do it in their own" (NAST3)*
Current Interventions Used by Teachers	Traditional instruction	*"More examples and application" (NAST1)*
	Offline resources	*"Providing resources that are accessible offline and downloading videos online to visualize the motion better" (NAST2)*
	Step-by-step guidance	*"I guided students through problems one step at a time, emphasizing how to identify given quantities, what is being asked, and which formula to use." (NAST3)*
	Use of multimedia	*"I think by only using multimedia such videos and presentations" (NAST4)*
	Real-world examples	*"use real world examples" (NAST5)*

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Benefits and Need for PhET Simulation	Visualization	*"It helps the students visualize the concepts and let them understand fully the lesson" (NAST1)*
	Enhancing understanding	*"Using PhET helps us visualize and better understand the lesson…" (NAST4)*
	Improving motivation	*"Improve conceptual understanding and student motivation" (NAST5)*
Need for Inquiry-Based Activity Packet	Active learning	*"It encourages active student participation, gives abstract ideas more substance, and fosters critical thinking abilities through interaction." (NAST5)*
	Supports exploration	*"This will help students visualize the projectile motion and let students explore and discover the principle." (NAST3)*
	Correcting misconceptions	*"PhET makes projectile motion easier to visualize, corrects misconceptions, and through inquiry-based activities, helps students actively explore and understand the concepts even with limited resource." (NAST2)*

Table 1 reveals the major learning gaps, challenges, and instructional needs in teaching and learning projectile motion as observed by the participating teachers. Teachers reported that students have difficulty understanding projectile motion concepts, particularly in distinguishing horizontal and vertical motion, the effect of launch angle and speed, and the difference between velocity and acceleration. Misconceptions include believing the projectile is continuously pushed forward or assuming a higher angle always results in a farther range. These observations are consistent with Dilber, Karaman, and Duzgun (2009), who found that students often incorrectly assume total velocity is zero at the peak of motion, and Prescott & Mitchelmore (2005), who emphasized the persistence of intuitive, non-Newtonian ideas. Kwpublications (2024) also highlighted the difficulty in integrating horizontal constant velocity with vertical acceleration, reflecting the challenges observed by teachers.

Mathematical problem-solving was also highlighted as a major challenge. Teachers indicated that students often struggle with formulas, substitution steps, and trigonometric functions such as sine and cosine, resulting in incorrect answers. A single mistake can lead to an entirely wrong solution, reducing confidence and reinforcing rote memorization. These findings are consistent with Kwpublications (2024) and Dilber et al. (2009), who noted that reliance on formula memorization without conceptual understanding hampers problem-solving.

Students also experience difficulty visualizing trajectories, distances, and height at varying angles, particularly when limited equipment or interactive demonstrations are available. Mckagan et al. (2008) emphasized that dynamic visualization is essential for building accurate mental models, while Aslan & Buyuk (2021) found that interactive visual tools improve comprehension of abstract physics concepts.

Resource limitations further affect instruction. Teachers reported that not every student has access to a gadget or stable internet, limiting the use of PhET simulations. These constraints echo the observations of Henderson & Dancy (2007) and Perez Jr. et al. (2024), who reported that infrastructural and access issues can prevent the effective implementation of technology-based instructional strategies.

To address these gaps, teachers implement interventions such as step-by-step guidance, real-world examples, multimedia presentations, and offline resources. While these practices are useful, they remain largely teacher-centered and do not fully resolve misconceptions. This aligns with Gerace & Beatty (2005), who argued that traditional instruction often results in low-level learning outcomes.

Teacher familiarity with PhET simulations and the Inquiry-Based Learning (IBL) approach informs these learning needs. Teachers experienced with PhET reported that it improves visualization and supports conceptual understanding, whereas teachers with limited experience indicated the need for instructional materials that are

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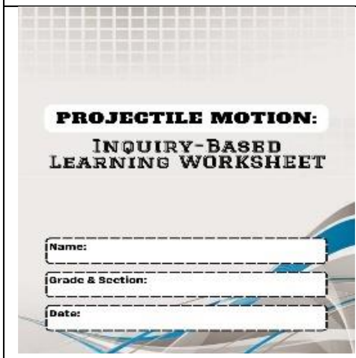
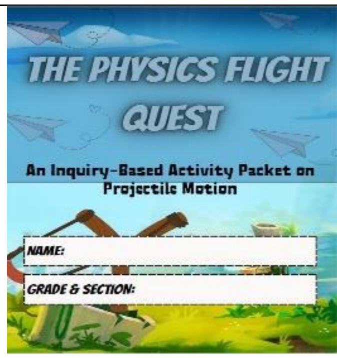
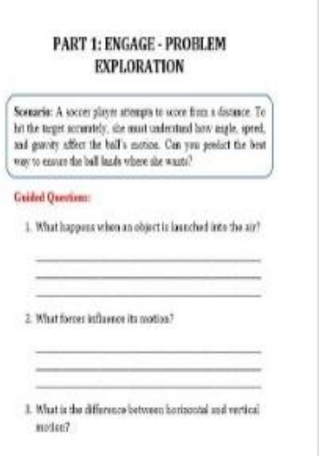
accessible in low-technology settings and provide scaffolded guidance for students. This demonstrates that learning needs depend not only on student conceptual and procedural skills but also on teachers' readiness to implement simulation-enhanced and inquiry-based instruction effectively. Finally, teachers and students need accessible instructional materials that function effectively even in resource-constrained environments, addressing the limitations in gadgets and connectivity. Collectively, these learning needs justify the development of an inquiry-based PFQ activity packet integrated with PhET simulations.

Table 2. Development of the PFQ activity packet on Projectile motion

Prototype 1 First revision made to the developed PFQ activity packet

Before Revision	Comments	After Revision
	Revised the title to make it more engaging and appealing to learner	
	Adding an image to the example to enhance clarity and students understanding	

As presented in Table 2, the comments and suggestions by the panel members guided the refinement of the material. One of the key suggestions was to revise the activity title to make it more engaging and appealing to learners. In response, the title was modified into a more student-friendly version that better reflects the interactive nature of the PFQ activity packet. This approach is supported by Moro and Billote (2023), who found that incorporating culturally relevant and engaging elements in physics learning modules significantly improved students' motivation, attitudes, and overall understanding in the Philippine context.

The panel also recommended adding an image to the example provided to improve clarity and support students' visualization of the concept. The inclusion of an appropriate image aligns with findings by Wieman et al. (2008) and McKagan et al. (2008), who emphasized that interactive visuals and simulations strengthen students' mental models of abstract physics concepts such as projectile motion. Perez (2017) further supports this by demonstrating that the use of contextualized and computer-simulated learning materials, which included visual aids, significantly enhanced academic achievement and conceptual clarity among Grade 9 students in the Philippines. Adding images helps address common student difficulties in visualizing two-dimensional motion, improving comprehension and engagement.

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Prototype 2 Second revision to the developed PFQ activity packet on Projectile Motion

Before Revision	Comments	After Revision
 	"Replace the term 'Part' with 'Activity' for consistency with an activity-based format."	
Scenario: Red the Angry Bird wants to knock down a tower of pigs from distance. To hit the pigs accurately, Red must figure out how the angle of the slingshot, the speed of his launch, and gravity will affect his flight. Can you predict the best way to launch Red so he lands exactly where you want? 	"Change the scenario to something more realistic and relatable to students, such as a sports activity that they are familiar with." "Use realistic and relatable images."	**Scenario:** A volleyball player wants to spike the ball into the opponent's court from a distance. To make an accurate spike, the player must figure out how the angle of the hit, the speed of the ball, and the gravity will affect its flight. Can you predict the best way to hit the volleyball so it lands exactly where the player wants? 
Activity: PhET Simulation – Projectile Motion **Instructions:** 1. Open the PhET simulation and set the speed to 15 m/s. 2. Launch the projectile at three angles: 30°, 45°, and 60°. 3. Record your observations in the table below: Angle / Range (m) / Max Height (m) / Time of Flight (s) 30° 45° 60°	"Add an unlocking of terms to help students understand key concepts before starting the activity."	**Activity:** PhET Simulation – Projectile Motion *Unlocking of difficult terms • Projectile – any object that is thrown, launched, hit, or kicked into the air. • Launch angle – the angle at which the projectile is released in the simulation (ex. 30°) • Range - the horizontal distance the projectile travels before landing. • Maximum height – the highest vertical point reached by the projectile. • Air resistance – a force in the simulation that slows down the projectile due to the air pushing against it. Instructions: 1. Open the PhET simulation and set the speed to 15 m/s. 2. Launch the projectile at three angles: 30°, 45°, and 60°. 3. Record your observations in the table below: Angle / Range (m) / Max Height (m) / Time of Flight (s) 30° 45° 60°

The second revision addressed the panel's recommendation to replace non-realistic pictures with more authentic and relatable images. Visual materials originally included in the activity were abstract and did not fully support student connection or understanding. By revising these images to realistic sports-related visuals, such as a basketball, the activity packet now provides clearer context and enhances students' ability to relate the concepts to familiar situations.

The panel also suggested changing the scenario to a more realistic and relatable context**.** In response, the fictional Angry Birds example was replaced with a volleyball spike scenario. This adjustment made the learning task more meaningful and aligned with experiences that students commonly encounter, thereby increasing engagement and contextual understanding.

Finally, the panel recommended adding an unlocking of terms to support students' comprehension of essential concepts prior to completing each activity. This addition ensures that learners have access to clear definitions and foundational ideas, making the activities more accessible and improving conceptual understanding.

Table 3 Evaluation on the Developed PFQ Activity Packet

Summary of Validators' Evaluation on the Developed PFQ Activity Packet

Indicators	Weighted Mean (WM)	SD	Verbal Interpretation
1. Learning Outcomes (The learning outcomes of the Inquiry-based activity packet with PhET Simulation are:)			
1.1 Specific	4.00	0.707	Highly Valid

1.2 Measurable	4.20	0.447	Highly Valid
1.3 Attainable	4.20	0.837	Highly Valid
1.4 Relevant	4.60	0.548	Extremely Highly Valid
1.5 Time Bound	4.00	0.707	Highly Valid
2. Instructional Characteristics (Inquiry-based activity packet with PhET Simulation)			
2.1 Develop critical thinking skills and analyzing skills of students at their present grade level.	4.20	0.837	Highly Valid
2.2 Present real-life situations.	4.00	0.707	Highly Valid
2.3 Give appropriate and relevant information for the development of physics concepts.	4.60	0.548	Extremely Highly Valid
2.4 Have exercises aligned to the learning competencies of two-dimensional motion.	4.00	1.414	Highly Valid
2.5 Focus on specific skills and concepts.	4.00	1.000	Highly Valid
3. Effects On Learning (Inquiry-Based Activity Packet with Phet Simulation)			
3.1 Develop creativity and ignite curiosity of the students.	4.40	0.894	Highly Valid
3.2 Simplify the task to make it more manageable and achievable to a learner.	4.20	1.304	Highly Valid
3.3 Provide some direction to help the student focus on the learning outcome.	4.40	0.548	Highly Valid
3.4 Model and clearly state activities to be performed.	4.40	0.548	Highly Valid
3.5 Promote active learning.	4.00	0.707	Highly Valid
3.6 Introduce ideas/concepts in logical learning sequence.	4.20	0.837	Highly Valid
3.7 Are engaging and challenging.	4.60	0.894	Extremely Highly Valid
3.8 Are learner-centered.	4.80	0.447	Extremely Highly Valid
3.9 Allow students to engage and motivate students to a greater degree.	4.00	1.000	Highly Valid
3.10 Provide more opportunities for independent, self-focus on learning outcome.	4.20	0.837	Highly Valid
Average Mean for Effects on Learning	**4.28**	**0.79**	**Highly Valid**

Table 3 presents the weighted mean, standard deviation, and verbal interpretation of the learning outcomes, instructional characteristics, and effects on learning of the Inquiry-Based Activity Packet with PhET Simulation. The results reveal that the indicator “Are learner-centered” obtained the highest weighted mean of 4.80 (SD = 0.447), interpreted as Extremely Highly Valid, showing that the respondents strongly agreed that the activity packet effectively focused on student-centered learning. Indicators such as “Relevant”, “Give appropriate and relevant information for the development of physics concepts", and "Are engaging and challenging" each received a weighted mean of 4.60, also interpreted as Extremely Highly Valid. Meanwhile, most other indicators such as "Specific," "Time Bound," "Present real-life situations," "Have exercises aligned to competencies," and "Promote active learning" obtained a weighted mean of 4.00, interpreted as Highly Valid. The computed overall average weighted mean is 4.28 (SD = 0.79), which falls under the Highly Valid interpretation, indicating that the respondents strongly agree on the effectiveness and validity of the activity packet across all aspects.

The data suggest that the Inquiry-Based Activity Packet with PhET Simulation successfully meets essential learning outcomes and instructional characteristics aligned with student-centered education. The dominance of Highly Valid to Extremely Highly Valid ratings indicates that teachers perceived the material as well-designed, relevant, and effective in promoting inquiry and engagement. The highest-rated indicators emphasize learner-centeredness and contextual relevance, reflecting how PhET simulations encourage independent exploration and experiential learning. The moderate variation in standard deviation values suggests that while teachers generally agree on the activity's validity, there are slight differences in individual perceptions, possibly due to teaching experience or exposure to technology-enhanced instruction. Overall, the data highlight that the PFQ Activity Packet effectively integrates inquiry-based principles that promote critical thinking, creativity, and autonomy in student learning.

The findings imply that PhET-based inquiry activities can serve as a powerful tool for promoting conceptual understanding and student engagement in science education, particularly in Physics topics like projectile motion. The activity packet's learner-centered design supports the principles of constructivism, where students actively construct knowledge through exploration and guided discovery. The results further imply that such instructional materials can enhance both teaching efficiency and student motivation, especially in classrooms with diverse learning abilities. Implementing the PFQ Activity Packet across other science domains may further strengthen students' analytical and experimental competencies, making it a practical and scalable approach to 21st-century science learning.

Several studies support these findings. Ali and Cruz (2019) emphasized that inquiry-based learning integrated with simulations significantly improves students' conceptual understanding and engagement in physics. Similarly, Nguyen et al. (2020) found that interactive simulations promote critical thinking and make abstract concepts more comprehensible. Santos and Rivera (2021) revealed that learner-centered materials enhance motivation and self-efficacy among students in STEM classes. In the study of Lopez and Gutierrez (2023), it was noted that PhET simulations provide contextualized learning experiences that deepen understanding and promote active participation. Additionally, Khan et al. (2024) highlighted that inquiry-based and simulation-supported learning fosters creativity and independent problem-solving. Finally, Tan and Espino (2025) concluded that teacher-developed digital learning materials aligned with learning competencies significantly enhance instructional delivery and learning outcomes. These studies affirm that the integration of inquiry-based strategies with simulation tools such as PhET is an effective method in promoting deeper, learner-driven engagement and conceptual understanding in science education.

CONCLUSION AND RECOMMENDATION

This study concluded that in-service physics teachers recognize the potential benefits of integrating PhET simulations within inquiry-based activities to support understanding of projectile motion. Findings suggest that such interactive tools can promote active engagement, critical thinking, and visualization of abstract concepts while aligning with learner-centered approaches.

Based on these insights, the following are recommended:

- Provide professional development for teachers to effectively integrate digital simulations and inquiry strategies.
- Conduct future studies to evaluate the impact of simulation-supported activities on student learning and concept retention.

These findings emphasize the promise of technology-enhanced, student-centered materials in physics education and the need for continued development and evaluation before classroom implementation.

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