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Pilot Study: Investigating The Effects of The Low-Cost Projectile Launcher Experimental Kit on Student Learning

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Abstract
This pilot study demonstrates the effectiveness of using a Low-cost Projectile Launcher Experimental kit as a teaching tool. The Low-cost Projectile Launcher Experimental kit offers a unique visual and interactive approach to assist students, especially those encountering difficulties with projectile motion. Before conducting the experiment, students were asked a simple question about whether projectile motion is one of the challenging topics in fundamental physics. They were then given a period of time to solve a projectile motion problem using the Low-cost Projectile Launcher Experimental kit. The findings highlight the significant challenges of understanding two-dimensional trajectory, affected by launch angles and initial velocities. Introducing the experimental kit noticeably improved students' understanding. Approximately 60% of students agreed that projectile motion is one of the most challenging topics in fundamental physics. After implementing the kit, there was a significant increase in the percentage of students achieving a very good level of understanding (50%) and a good level (48.5%). Only a small percentage showed poor understanding (1.5%), while the majority fell into the good category. These outcomes suggest the efficacy of the projectile launcher experimental kit in strengthening students' grasp of projectile motion concepts. The study advocates for further research to uncover the root causes of initial difficulties and to develop targeted interventions for sustained progress. Furthermore, educators are encouraged to focus on addressing specific challenges highlighted in the study, such as visualizing two-dimensional trajectories and comprehending factors influencing horizontal distance.

Keywords: Two-Direction, Pre-University Level, Parabolic Path, Low-Cost Kit

Introduction

To effectively achieve the objectives outlined in Sustainable Development Goal (SDG) number 4, it is crucial to prioritize subjects that equip students with the necessary skills for pursuing careers in Science, Technology, Engineering, and Mathematics (STEM) fields. Within the realm of STEM, the physical sciences assume a significant role. However, student achievement in the physical sciences falls short of desired benchmarks, and there has been a decline in student interest in these subjects (Wang, Zhang & Pang, 2024; Okono et al., 2015; Sahin 2008; Prescott, 2005). Various research studies have explored the factors that influence student performance in the physical sciences, encompassing teaching methodologies, teacher expertise, teacher discipline, and parental involvement (Sikhosana & Mudau, 2022; Alharbi et al., 2019; McDermott, 2006). These investigations have shed light on both direct and indirect effects of these factors on student performance, particularly in foundational studies.

"Physics for Pre-University Level" refers to the study of physics concepts and principles typically taught to students who are preparing for university-level education but are still in high school or secondary school. This level of physics education serves as a foundation for more advanced studies in physics or related fields at the university level. The aim of physics education at the pre-university level is to provide students with a solid understanding of the fundamental principles of physics and to develop their problem-solving and critical thinking skills (Wang et al., 2024). This knowledge prepares them for further studies in physics or related fields at the university level (Nurhawani, 2020).

In introductory physics, students find projectile motion particularly challenging as it involves motion in two dimensions. Projectile motion, characterized by constant acceleration in the absence of air resistance, presents a challenge in pedagogy due to its complex nature (Piten et al., 2017). Traditional teaching methods often involve laborious explanations through whiteboards and PowerPoint slides, focusing on formulas and theoretical aspects (Mudau, 2014; Prescott). Teaching and demonstrating projectile motion to students can be challenging. Using just a whiteboard and PowerPoint slides to explain all the formulas requires a lot of effort and dedication. This would be the conventional way of teaching projectile motion (Mulhall & Gunstone, 2012).

Projectile motion, a fundamental concept in physics, occurs when an object is thrown at a certain initial velocity and angle with the horizontal, or when it is simply dropped and moves under the influence of gravity. It's crucial to emphasize that gravity does not affect the horizontal motion of the object. This separation of the horizontal and vertical components of the object's motion is commonly employed in analyzing projectile motion. This concept also explains the counterintuitive observation that an object thrown horizontally from the ground takes the same amount of time to fall to the ground as an object dropped from the same height (Yuliati & Mufti, 2020).

The conventional way that is lecturers usually must draw the trajectory of a certain projectile during lessons or perhaps with the aid of simulations that can easily be obtained from the internet. Other than that, the easiest would be to demonstrate a ball is thrown in the air however this isn't enough to explain projectile motion where there are too many variables involved like the initial velocity, height of the launch, range, time, projection angles and gravitational acceleration (Piten et al., 2017; Awelani, 2014; Robert 1983; Ibrahim & David, 1985). Thus, students often struggle to visualize the trajectory and solve related problems.

In response to these challenges, we have developed a low-cost experimental kit designed to serve as a teaching aid, specifically targeting the visualization and enhanced understanding of projectile motion concepts. This pilot study aims to investigate the efficacy of this innovative kit in transforming the educational experience for students. Our study seeks to evaluate the impact of this projectile experimental kit on teaching projectile motion. Lecturers benefit from a practical teaching tool, while students actively engage with the kit, adjusting angles to witness different trajectories. This hands-on approach aims not only to clarify the variables involved but also to ignite students' interest in a topic often perceived as complex. As we embark on this pilot study, we anticipate insights into the kit's effectiveness in enhancing the teaching and learning of projectile motion. The potential of this innovative approach lies in its adaptability, cost-effectiveness, and ability to make a traditionally challenging topic more accessible to students.

Method

This pilot study is done to explore the effectiveness of this innovative projectile experimental kit, assessing its impact on students' understanding and interest in projectile motion. A purposive sample of 63 participants among the Science and Engineering students responded to the survey. The questionnaire was designed based on understanding of projectile motion concept and student’s understanding on projectile kit. It was divided into two sections: Part A) students’ understanding on the concept of projectile motion and the difficulty part in projectile motion and part B) student’s understanding on the concept of projectile motion after they used the projectile launcher experimental kit.

This experimental kit, made from a PVC tube, wooden base, and spring launcher, makes teaching projectile motion easier. Students can see the path of a launched object, making learning more hands-on. The kit is simple and inexpensive, so it can be easily copied and used by different schools, indoors or outdoors.

Findings

The difficulty in projectile motion

Figure 1 represents the percentage of students who have difficulty understanding the concept of projectile motion. From 63 respondents, 60% of the students find it difficult to understand the concept of projectile motion.

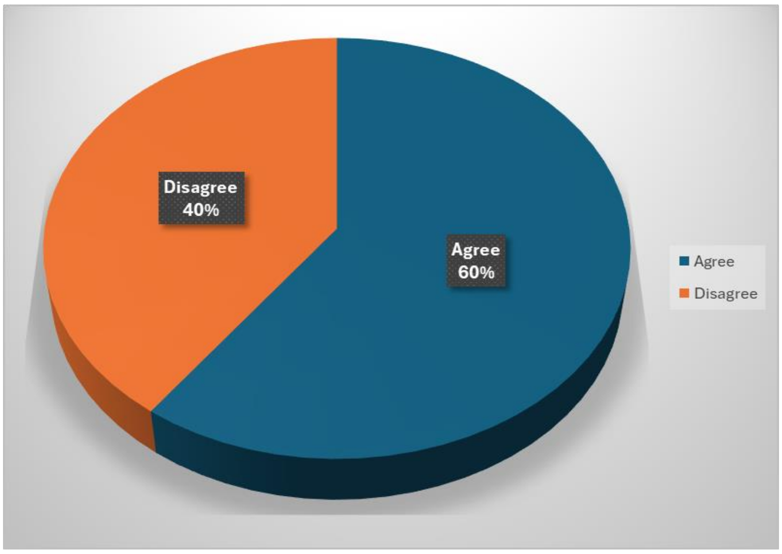

Figure 1: A chart of the percentages students agree and disagree to the difficulties on understanding the concept of projectile motion.

Table 1 shows the most part students find it difficult to understand the concepts of projectile motion. These include visualizing the trajectory of the object contributes to 50% of them finding it difficult to comprehend whereas 35.4% of the students difficult to visualize the horizontal and vertical components of the initial velocity. There 30.8% and 18.4% of the students hardly understand why the horizontal acceleration is equal to zero and hardly visualize the horizontal distance travelled by object respectively. Based on the results obtained, the majority of students had difficulty understanding the concept of projectile motion. The concept of trajectory in two dimensions was particularly challenging for students.

Many students struggled with the idea that the horizontal distance can be influenced by both the launching angle and the initial velocity. Approximately half of the students had difficulty understanding each of the four mentioned aspects of projectile motion. The percentage of students struggling with each difficulty ranged from 51.5% to 56.1%. The findings suggest that there is a need for improved teaching methods or additional resources to help students grasp the concept of projectile motion. Educators should focus on addressing the specific difficulties highlighted in the table, such as understanding the two-dimensional trajectory and the factors affecting horizontal distance. Further research could explore the reasons behind these difficulties and develop targeted interventions to enhance students' understanding of projectile motion.

Table 1
Pre Test Results

No.	Types of difficulty	Percentage
1	To visualize the trajectory of the object	50.0%
2	To understand why horizontal acceleration is equal to zero	30.8%
3	To visualize the horizontal distance travelled by the object	18.5%
4	To visualize the horizontal and vertical components of initial velocity	35.4%

Distance travelled of the object using the projectile launcher experimental kit

Table 2 shows the average distance travelled by an object at different angles of the trajectory using a projectile experimental kit. The distance travelled by the object varies with the angle of the trajectory. There is a decreasing trend in the average distance travelled as the angle of the trajectory increases from 30.0° to 60.0°. The object travelled the longest distance at an angle of 45.0° and the shortest distance at an angle of 60.0°. These results obeyed the law of projectile motion which is the maximum distance travel of the ball when it is projected at an angle of 45^{o}. this indicates that this kit is acceptable and can be used for education tools.

Table 2
The average distance travelled by the object at some angles of the trajectory

Mass (g)	**Angle (°)**	**Distance (cm)**			**Average distance (cm)**
118.3	30.0	96.0	98.0	96.0	96.7
	45.0	115.0	114.0	118.0	116.0
	55.0	79.0	76.5	72.0	76.0
	60.0	69.0	64.0	61.5	64.7

Student's understanding after using the projectile launcher experimental kit

After the kit has been implemented the percentage of students understanding the projectile concept after they used an experimental launcher kit increases. Figure 2 shows that the understanding of students increases by about 50% for very good and 48.5% for good understanding.

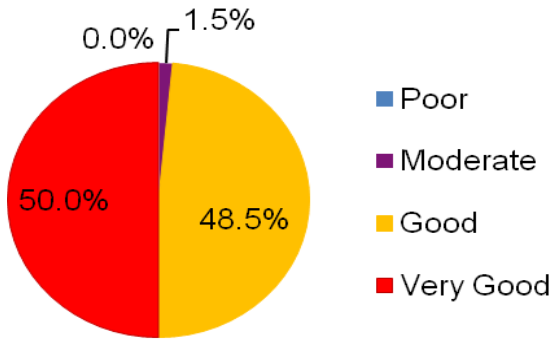

Figure 2: The percentage of student understanding towards projectile concept after they used experimental launcher kit.

Table 3 provides a comprehensive overview of the students' ability to visualize and comprehend the intricacies of projectile motion. Overall, the understanding of projectile motion concepts among the students can be characterized as moderate, with the percentage of comprehension ranging from 51.5% to 56.1%. Importantly, the concepts pertaining to the variation of horizontal distance exhibited a higher level of understanding compared to the concept of an object's motion solely dependent on gravitational acceleration. This improvement in understanding is clearly illustrated in Figure 3, showcasing a noticeable contrast between the pre-test and post-implementation of the experimental kit. It is evident that the implementation of the kit had a beneficial impact on the students' understanding of the topic, leading to a significant enhancement in their comprehension.

Table 3
The percentage students able to visualize understand and understand the concept of projectile motion

No.	The concept of projectile	Percentage of understanding
1	Trajectory of the object is in two dimension	54.5%
2	Object is solely depends on the gravitational acceleration	51.5%
3	Horizontal distance can be affected by varying the launching angle	56.1%
4	Horizontal distance can be affected by varying the initial velocity	54.5%

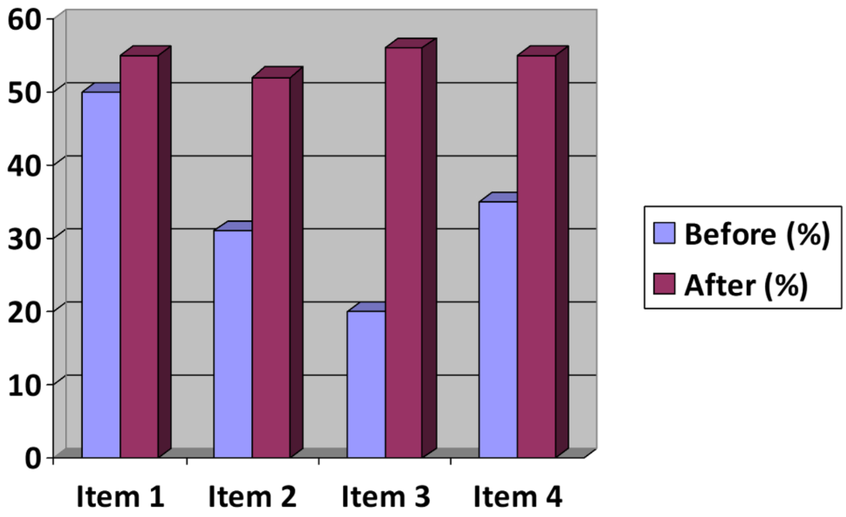

Figure 3: A comparison between before and after using the Low-Cost Projectile Experimental Kit.

Conclusion

The findings gathered through the study provide compelling support for the efficacy of the projectile launcher experimental kit in fostering a comprehensive understanding of projectile motion among students. The results emphasize the transformative impact of hands-on learning experiences, particularly when combined with innovative tools and resources (Balta, 2018). These findings have significant implications for educators and curriculum developers aiming to enhance teaching approaches in the realm of science education, specifically in the context of projectile motion instruction (Zandbergen, 2024).

In conclusion, the study thoroughly examined the challenges faced by students in comprehending the concept of projectile motion, uncovering that a substantial majority encountered difficulties across various aspects. The outcomes underscored the significant obstacles students encountered in grasping the intricacies of two-dimensional trajectory, which is influenced by factors such as launch angle and initial velocity (Sikhosana & Mudau, 2022). However, the utilization of the experimental kit resulted in remarkable improvements in students' comprehension. Importantly, the findings demonstrated a clear and substantial enhancement in students' understanding, particularly in relation to the variations in horizontal distance. Taken together, these findings strongly indicate that the projectile launcher experimental kit effectively bolstered students' grasp of projectile motion concepts. The results can be further analysed by using MATLAB as suggested by Jahangir et al., (2020).

Future Works

This study recommends further research to explore the reasons behind initial difficulties and to develop targeted interventions for sustained improvement. Additionally, educators are encouraged to focus on addressing specific challenges highlighted in the study, such as visualizing two-dimensional trajectories and understanding factors affecting horizontal distance. In addition, more respondents need to confirm the validity of the enhancement when using this new projectile launcher experimental kit.

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