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Pedagogical Strategy of Teaching-Learning Projectile Throwing in Third Year Baccalaureate Students of the “Santa Rita Educational Unit”

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Abstract---A pedagogical strategy is presented for teaching projectile launching to third-year high school students at the Santa Rita Educational Unit. It is focused on teaching concepts such as parabolic trajectory, initial velocity and launch angle, which are fundamental to understand the motion of projectiles in physics. To facilitate this learning, the PhET interactive simulator was used, which allowed students to manipulate different variables and observe how these affect the behavior of the projectiles in real time. The methodology was implemented in three phases: a theoretical introduction to the key concepts, an interactive experimentation phase with the PhET simulator, and an evaluation based on theoretical and practical tests. In addition, this pedagogical strategy seeks to promote active and participatory learning, where students become protagonists of their own learning process, exploring and discovering the effects of changes in launch parameters. The result was the evaluation of the students, which was carried out through tests that combined theoretical questions about the principles of projectile movement and practical exercises that required them to apply what they learned in simulations. This methodology not only aims to improve academic performance, but also to increase students' motivation towards the study of physics by allowing them to interact directly with physical phenomena.

Keywords---learning, parabolic trajectory, pedagogical strategy.

Introduction

Teaching physics at the high school level faces the challenge of making concepts accessible and understandable, since, in many cases, they are abstract and difficult for students to visualize (Lopez et al., 2013). Projectile launching is one of these fundamental topics, which involves understanding key concepts such as parabolic trajectory, initial velocity, launch angle, and the influence of gravity. The teaching of these concepts is often limited to a theoretical exposition on the blackboard or in the classroom, Flores García (2018), describe that all this may be insufficient for students to achieve a deep and meaningful understanding.

Projectile throwing is a type of two-dimensional movement that follows a parabolic trajectory. This physical phenomenon depends on several factors, among which the initial speed of the projectile and the angle with respect to the ground at the moment of launch stand out. The relationship between these factors is complex and, for many students, can be difficult to understand only through mathematical formulas or theoretical explanations. For this

reason, it is essential to have pedagogical strategies that allow students to visualize and experiment with these concepts in a practical way (Puzzella et al., 2013).

In this context, the use of virtual simulators in physics teaching has become increasingly relevant as a tool that facilitates the understanding of abstract concepts. The PhET simulator, developed by the University of Colorado, is one of the most used platforms in science education (Muñoz Giraldo et al., 2002). This simulator allows students to interact with a visual representation of projectile launch, adjusting parameters such as initial velocity, launch angle, air resistance, and projectile mass, among others. This gives them the possibility of directly observing the effects of these variables on the trajectory of the projectile and conducting experiments that, in a physical environment, would be more difficult to replicate.

The objective of this study is to implement a pedagogical strategy that combines theoretical teaching with the use of the PhET simulator to facilitate the teaching-learning of concepts related to projectile launching. The proposal seeks to integrate theory and practice so that students not only receive abstract information, but can actively interact with the concepts through simulations, which will allow them to develop a deeper and more meaningful understanding of the topic (Merseeth & Lacey, 1993; Zeichner, 1987; Kinach, 2002; Hepsiba et al., 2017).

The proposed approach consists of three main stages: a theoretical introduction on the basic principles of projectile launching, an interactive simulation phase using the PhET simulator, and an evaluation through tests that include both theoretical questions and practical exercises based on the simulation. It is expected that this methodology will contribute to an improvement in the academic performance of students, as well as an increase in their motivation and interest towards the study of physics.

To address the research problem, mixed methods were used, that is, both qualitative and quantitative. This will allow us a better appreciation of how this topic is addressed in the Santa Rita educational unit. To collect data, an interview was applied to the teacher and questionnaires to the students. By applying the PhET simulator in the teaching-learning process as a pedagogical strategy, it is expected to awaken motivation in both teachers and students on the topic of Projectile Launching, but above all they will recognize the importance of said topic and its applicability in practical life (Wu et al., 2021; Escobar et al., 2022; Hennessy et al., 2007; Macías et al., 2018).

Materials and Methods

PhET Simulator: Interactive tool used to model and visualize the phenomenon of launching a projectile, allowing students to manipulate variables such as angle, initial velocity and gravity to analyze their impact on the trajectory of the projectile. Structured questionnaires were implemented: Two questionnaires applied to third-year Baccalaureate students to measure their understanding of the topic. The first reflected a low performance by the students; later, after using the simulator, a second questionnaire was applied that showed a significant improvement in their grades. Traditional resources were used that included theoretical and practical exercises that complemented the use of the simulator, in addition to computers and projectors that were used to execute and show the simulations in the classroom collectively.

The intervention was carried out in two stages, in the first, traditional classes were taught on the topic of projectile throwing, evaluating the students' initial understanding through the first questionnaire. In the second, the PhET simulator was introduced, allowing students to interact directly with the simulations to experiment and analyze the behavior of the projectile under different conditions. Finally, the second questionnaire was applied to measure the impact of the simulator on their learning.

Analysis and Discussion of the Results

Projectile launching is a physical phenomenon widely studied in classical mechanics, specifically in the field of two-dimensional motion. This type of motion describes the trajectory of an object launched with an initial velocity that forms an angle with respect to the ground, following a parabolic path under the influence of gravity. The parabolic trajectory is due to the fact that, during flight, the object is subjected to a constant acceleration in the vertical direction (due to gravity), while its motion in the horizontal direction is uniform and constant, as long as resistance is ignored. of the air.

The study of this phenomenon is based on Newton's laws of motion, particularly on the second law, which establishes that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. In the case of projectile launching, the force acting on the object is gravity, which causes the object to describe a parabolic curve along its path. The equations that describe this movement depend on the initial velocity, the launch angle, and the gravitational acceleration (Mancera Baraona, 2017).

In the educational field, projectile launching is a fundamental topic for students to understand the relationship between launching parameters and the observable result (trajectory, maximum height, range, etc.); However, teaching these concepts can often be challenging, as students must be able to relate abstract formulas to actual observed motion. To overcome this obstacle, virtual simulation tools can offer a visual and practical way to understand how different factors affect the launch (Camelo-Clavijo, 2020).

Use of Virtual Simulators in Physics Teaching

In recent decades, virtual simulators have established themselves as an effective tool to improve the teaching-learning process in various areas of science, particularly in physics (Aranda et al., 2010). These simulators allow students to interact with visual and manipulative representations of physical phenomena that might otherwise be difficult or expensive to recreate in a traditional classroom. The PhET simulator, developed by the University of Colorado, is one of the most popular resources in science teaching. PhET offers interactive simulations that cover a wide range of concepts in physics, chemistry, biology and mathematics, allowing students to directly experiment and observe the effects of key variables in each simulation (Umbarila Benavides, 2021).

Guamán et al. (2023), describe that the use of simulators such as PhET in teaching physics has multiple benefits. First, it allows students to conduct virtual experiments in a safe and controlled environment, eliminating the risks and limitations associated with traditional physical experiments. In addition, it facilitates the understanding of complex concepts through the direct manipulation of variables, which helps students establish cause-effect relationships more intuitively.

Various studies have shown that the use of interactive simulators in physics teaching significantly improves students' academic performance. For example (Delgado-Flores & López-González, 2023), they found that students who used virtual simulators as a complement to theoretical explanations obtained better results in conceptual understanding tests compared to those who only received traditional instruction. On the other hand, (Cantos et al., 2024), mention that this is because simulators provide students with immediate feedback, allowing them to observe the effects of the changes they make and better understand the underlying mathematical and physical relationships.

Simulation in Projectile Study

The PhET simulator is especially useful in teaching projectile launching as it allows students to adjust key parameters such as initial velocity, launch angle, projectile mass, and the presence or absence of air resistance. This gives them the opportunity to experiment with how each variable affects the maximum height, flight time, and horizontal distance the projectile travels. This ability to experiment with different configurations in real time promotes learning based on exploration and discovery, which is consistent with constructivist learning theories (Sánchez, 2017).

Furthermore, simulation allows repeated experiments to be carried out without time or resource restrictions, which in a real physical context could be unfeasible. This helps consolidate the concepts learned and generate a stronger understanding of the laws that govern projectile motion. Simulations also allow students to correct their errors and make adjustments to their predictions, a trial and error process that is essential for active and autonomous learning (Barrera Casas, 2017). Through the simulator, students were able to adjust parameters such as initial speed and launch angle to observe how they influence the distance and height reached by the projectile, as well as the flight time. The use of the PhET simulator was chosen for its ability to transform theoretical concepts into visual and practical experiences, helping to improve understanding of topics that may be abstract to students in a traditional teaching environment.

The mixed approach arises as a concern of researchers who have seen the need to address the complexity of research in a holistic and integrative way (Faneite, 2023). The methodology worked with a qualitative-quantitative approach. Learning can be seen as a cumulative, self-regulated, directed, collaborative and individual process (Van den Bergh et al., 2006), For the implementation of this pedagogical strategy, 38 students belonging to all levels of the unified general high school of the Santa Rita Educational Unit were considered as a population, with the objective of making a general evaluation of the impact of teaching the throwing of projectiles throughout throughout the secondary school cycle. However, for the purposes of this study and to obtain accurate results, the experimental work and data collection was chosen as an intentional sample of 17 students who are only in the third year of high school. This level was chosen since it is assumed that they have the greater knowledge of the topic of parabolic motion and at this level students have the mathematical and conceptual preparation necessary to address these topics fluently.

There were three phases, in the first a diagnostic test was applied to evaluate the knowledge that the students had on the topic of parabolic shooting (Aglen, 2016; Napolitano et al., 2024; Postareff et al., 2007). Once this first phase was completed, the theoretical class was taught that addressed the topics: The concept and representation of parabolic movements, their equations and the maximum height reached by a body that moves according to parabolic movement, in the second class we continued doing the exercise on the blackboard, and what we did was find the time it is in the air, the range and the angle of the trajectory, all this was part of the second phase. In the third phase, they worked with the Phet simulator, where they were taught how to apply the parabolic shot. It was practiced in the simulator and the students found it very interesting. After this, another test was applied to see how much they learned with this class.

Interactive teaching tools, such as simulators, are dynamic systems that facilitate the construction of knowledge and the representation of significant learning processes (Fabara Vargas, 2022), showing that these simulators are effective for students since they teach them how to use it and teach them how to use it. They also motivate them to learn more. The Phet simulator is a tool that helps students understand more with the parabolic launch, since in it you can first find its orientation, which is the part of the angle that serves for the direction of the shot, you also obtain what it is. the projectile, its trajectory, its initial speed can be observed, etc. This application is very educational for students since first they learned how to use this simulator and second they learned about this parabolic launch (Paguay Maji, 2024). The findings obtained and their interpretation are presented for each of the dimensions of the questionnaire applied to the students. Figure 1 shows the first evaluation carried out on the students.

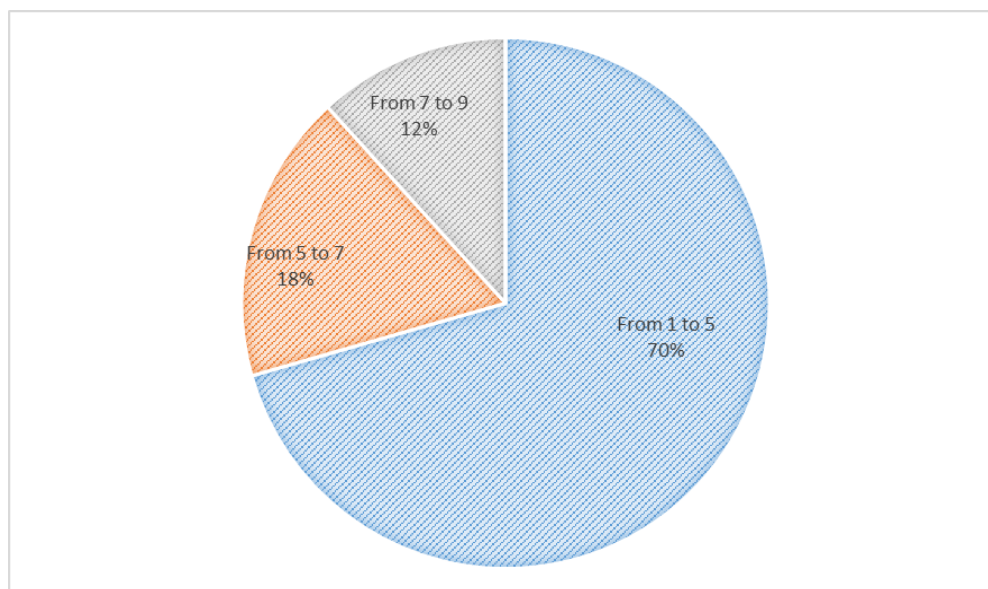


Figure 1. First evaluation carried out on the students

In the first evaluation, questions were asked to know the level of knowledge that the students had about the parabolic launch. When analyzing the results, the following was obtained: 70% of the students scored between 1 to 5 points, 18% scored between 5 to 7 points, another 12% scored between 7 to 9 points, while none achieved the maximum grade. As it could be seen, 70% of the students did not know or knew little about the parabolic shot launch. Based on these first results, two hypotheses were made: one of them is that the teachers are not fully prepared to teach these types of topics or they do not use the appropriate technological tools to address it, while the other hypothesis is that students have difficulty learning. After teaching classes, exercises and practicing in the simulator, a questionnaire was taken again where the results are shown in Figure 2.

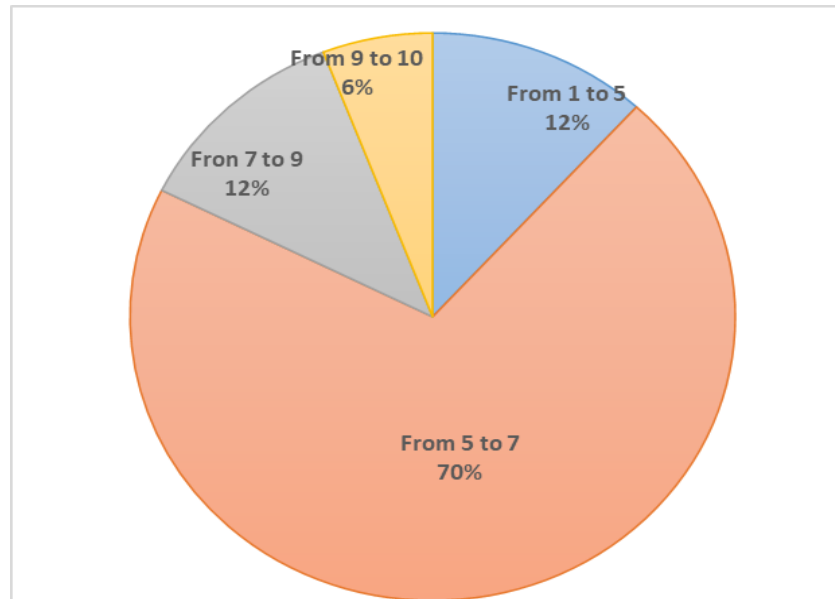


Figure 2. Final evaluation carried out on the students

The results obtained, as shown, 12% of the students scored 1 to 5, while 70% scored between 5 and 7 points, 12% scored between 7 and 9, and 6% scored 9 to 10 points. With the results obtained, an improvement was evident in the second questionnaire applied, all of this suggests that the teaching-learning process must improve both pedagogically and, in the tools, used by the teacher. On the other hand, the students achieved a positive impact by teaching the class with the Phet simulator since greater interest was noted in the class.

The Phet application leads to improving learning processes and adjusts to what the teacher teaches, being effective for live demonstrations and the scientific development of students (Carrión-Paredes et al., 2020); The Phet simulator is an effective tool for students to learn since it is a teaching strategy and it motivates them to know more about that tool, and thus they use it in practice with the topic of parabolic launch or among other topics with that simulator.

It is demonstrated that the implementation of technology in the classroom at this time is essential, since it has taken our daily lives and especially the attention of young people, in the case of the application of the Phet simulator (Alvarez Moreno et al., 2023), it can also be seen that the Phet simulator is very useful for students, they can learn very easily since for them it is something dynamic and that motivates them to learn more about the subject with this simulator.

Conclusions

The implementation of the Phet interactive simulator as a pedagogical strategy for teaching projectile throwing to third-year high school students proved to be highly effective. The results showed a significant improvement in the understanding of key concepts, such as parabolic trajectory, initial velocity and launch angle, as well as an increase in students' motivation and interest in learning physics. This methodology, which combines theory and practice through technological tools, allowed students to visualize and experiment with physical phenomena in an active and dynamic way, overcoming the limitations of traditional teaching. The success of this strategy highlights the importance of integrating technological resources in the classroom to facilitate more meaningful, interactive learning aligned with the needs of current generations.

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