Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
ASEE
Paper ID #45922

Leveraging immersive environments in physics labs and flipped classrooms for engineering courses.

Prof. Rodrigo Cutri, Maua Institute of Techonology

Cutri holds a degree in Electrical Engineering from Maua Institute of Technology (2001), MSc (2004) and Ph.D. (2007) in Electrical Engineering - University of SÃo Paulo. He is currently Titular Professor of Maua Institute of Technology

Dr. Octavio Mattasoglio Neto, Instituto Mauá de Tecnologia

Undergraduate in Physics (1983), Master in Science (1989) and Phd in Education (1998) all of them from Universidade de São Paulo. Professor of Physics at Mauá Institute of Technology, since 1994 and President of Teacher's Academy at the same Institution.

Dr. Nair Stem, IMT

- Graduated at Physics (Bachelor) at IFUSP, Master at Electrical Engineering and Doctor at Electrical Engineering at EPUSP.

Leveraging immersive environments in physics labs and flipped classrooms for engineering courses.

This paper aims to explore the use of immersive (panoramic) video with hotspots as a pre-class activity for an investigative physics laboratory on the topic of oblique launches, in conjunction with the flipped classroom methodology. The goal is to study the effectiveness of immersive (panoramic) videos with hotspots as pre-class materials within the flipped classroom approach. This paper presents the implementation of this technology in a classic physics experiment on oblique launches, conducted with approximately 400 first-year engineering students at XXXXXX. These students were divided into laboratory classes, working in teams of 3 to 4.

The paper tests the hypothesis that an immersive video—explaining in detail the experimental apparatus, the concepts involved, and the experimental procedure through hotspots—before the class, would promote greater autonomy in modeling and executing the experiment. The proposal aimed at analyzing:

1. The increase in student engagement with the flipped classroom methodology using immersive videos.
2. How this approach benefits students with learning difficulties (such as dyslexia, ADHD, or other disorders), allowing them to study at their own pace and participate more equally in face-to-face classes.
3. The more effective use of classroom time, which can be devoted to broader discussions on modeling and data analysis.

The pre-class materials provided to the students included the laboratory script, a conventional 2D video explaining the physical concepts involved, and the immersive video. These immersive videos, recorded using a low-cost 360-degree camera (PANO VIEW), allowed for panoramic recordings or images with a 220-degree field of view. They demonstrated the trajectory of a steel ball from different angles, with launches at angles of 20, 30, and 40 degrees, showing the height the ball reaches when hitting the target and highlighting the precautions needed to minimize experimental error. The immersive videos were interactive, featuring explanatory hotspots to enhance student involvement in acquiring the required information.

Students were instructed to watch the materials provided and then complete an individual pre-class questionnaire. During class, teams carried out experiments, collecting and analyzing relevant data. After 15 days, they submitted a complete report in the form of a scientific article, aiming to develop their written communication skills. After the class, students completed a post-class questionnaire, like the pre-class one but with three additional applied problems.

With the pre-class immersive video, students were able to explore the experimental apparatus, the involved concepts, and the experimental procedure in detail. This pre-class preparation allowed students to work more autonomously during the class, avoiding "cookbook" experiments. Three types of instructional materials were provided to support the flipped classroom: a simplified laboratory script, a conventional 2D video explaining the concepts, and interactive immersive videos with hotspots.

According to students' feedback, 55% felt more engaged with the immersive videos, and about 52% believed it was important to provide all three types of material. Regarding the post-class problems, Problem 1 focused on the retention of the horizontal and vertical position-time functions in oblique launches. About 92% of students selected the correct answer. Problem 2 assessed how students learned to construct the trajectory equation in oblique launches; around 47% selected the correct answer, indicating the need for additional activities on this topic. Problem 3 involved the composition of two types of motion: first, an object descending an inclined ramp, then falling in an oblique launch. Only 38% of students answered correctly, highlighting the need for more activities that involve multiple concepts to help students develop and prepare for more complex modeling tasks.

The results show that the combination of immersive videos and the flipped classroom methodology was highly effective technology for increasing students' motivation to engage with the material before class. This approach also increased the complexity of the experiments, helping to avoid "cookbook" procedures in the laboratory.

Introduction

The use of immersive videos has been applied in various fields, for instance, to train professionals before practical exercises in complex industries, medical fields, or even prior to classes. 360° immersive videos have been recognized as tools that increase student engagement by providing a 3D spatial view, experiential learning (in this case, depending on interaction with the virtual environment), contextual learning, and the possibility of interaction with other colleagues when used together with 3D virtual environments, for example. 360° panoramic videos provide a certain degree of immersion and are low-cost, making them promising tools for dissemination in schools. However, in Brazil, when the frequence of number of articles that use of videos or immersive videos or panoramic videos is investigated in the period from 2019 to 2024, it can be noticed that still needs to be improved. Below is presented a map using Scopus database and the package *Bibliometrix* with R Studio. This technology is not so frequent in our country, it is about 10, while the US presents 52.

Figure 1: Map of use of videos or immersive videos or panoramic videos obtained with Scopus Database during from 2019 to 2024.

Lamproulos et al. [1] surveyed the use of immersive videos in education over the past decade and demonstrated that their use has been increasing, although there is still a need for professional training. Sviridova et al. [2] studied the role of immersive videos in higher education with two groups, one experimental and one control group. The authors observed increased engagement, but did not notice a change in grades, a factor commonly used as a reference for performance improvement. They analyzed positive and negative motivation, as well as positive or negative engagement.

At the same time, Broeck et al [3] emphasized the immersion provided by immersive videos on mobile devices, also highlighting the fact that it is a reasonably cheap technology that allows students to view an event from various perspectives in a more interactive way, as well as reducing student distraction while watching the videos.

However, these videos are still mostly used recreationally. The authors conducted a survey of feelings associated with these videos and found the following words referring to emotions: “anticipation” and “trustworthy.” At the same time, these authors point out that due to their interconnectedness, they can be used together with other technologies such as virtual reality, augmented reality, or with active learning methodologies like gamification, flipped classrooms, storytelling, among others.

Kapp, S. et. al. [4] used augmented reality videos in a flipped classroom setting in physics labs for teaching electric circuits. According to their results, they found no cognitive differences when comparing technologies with and without smart glasses. On the other hand, Fidan et. al. [5] integrated augmented reality into physics education with methodologies such as PBL, showing the potential of this technology when engagement and sentiment were analyzed. They also discussed the improvement in long-term memory retention and the importance of these new technologies for students with learning disabilities.

Aiming to study the effectiveness of these videos in conjunction with the flipped classroom methodology, this work represents the organization of applying this technology in a classic Physics 1 experiment, the oblique projectile. The proposed approach was the use of interactive videos as an instruction manual in a pre-class setting. It is believed that with immersive videos, it is possible to explain in detail the experimental apparatus, the involved concepts, and the experimental procedure through hotspots beforehand, allowing for greater autonomy in modeling and executing the experiment. Another highlight is that introducing active methodology with a flipped classroom could play an important role in three areas:

- Increasing engagement in a flipped classroom methodology using immersive videos (a technology contemporary to students).
- Supporting students with learning difficulties (dyslexia, ADHD, or other learning disorders), allowing them to participate more equally in in-person classes, as they can study in advance at their own pace.
- Saving time in class for broader discussion on modeling and data analysis.

The experiment – Oblique Projectile using a screen with an obstacle

The experiment chosen to test this methodology in conjunction with the flipped classroom methodology was the oblique projectile with a screen. This experiment consists of using a launcher to fire projectiles against an acrylic screen and a Pasco motion sensor, as shown in Figure 1a. By taking physical measurements with the equipment's protractor and a tape measure, one can obtain the height at which the projectile collides with the screen (where carbon paper is fixed to the screen over a sheet of paper), the firing angle, the projectile's initial height, and the horizontal distance between the launcher and the screen. During class, the theoretical modeling of the trajectory equation is performed based on plane kinematics equations, as shown in expressions (1) and (2). This model ignores rotational effects and air resistance.

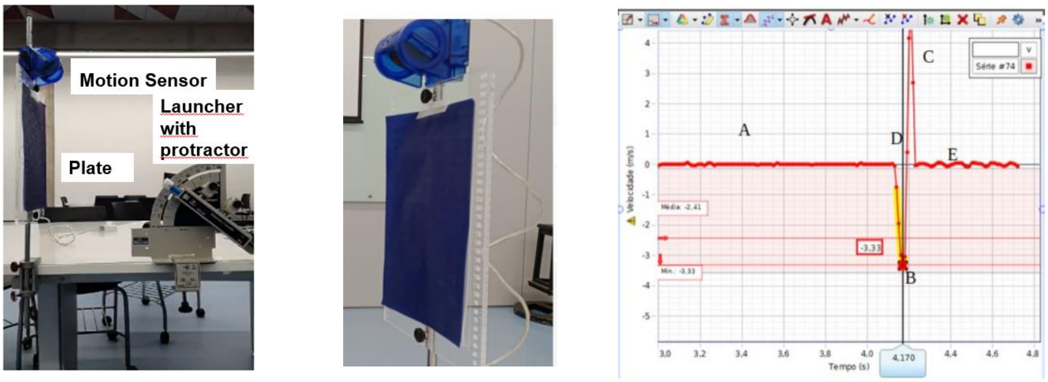
$x = xo + vo \cos(\theta)t$ (1)

$y = yo + vo \sin(\theta)t - (g/2)t^2$ (2)

By combining expressions (1) and (2), the theoretical initial launch velocity of the projectile is calculated using the measurements of the launch angle, horizontal distance, and height between the cannon mouth and the carbon mark fixed to the acrylic screen. In the experimental part, students will make launches and measure this velocity using a Pasco motion sensor at a 40-degree launch angle. Figure 2a shows the experimental apparatus used along with the sensor's positioning; Figure 2b shows sensor position variation to improve signal, and Figure 2c shows a typical measurement made with the Pasco motion sensor and the Pasco Capstone program. Note that initially, when the sensor is triggered, the system is at zero velocity. When the ball is launched and approaches the sensor, the velocity is negative, and after the collision, the ball moves away from the sensor, becoming positive.

The value we adopt as the initial velocity is precisely -3.33 m/s (immediately before the collision), which occurs 0.170 s after the launch. This is a reasonable approximation because it is obtained just seconds after launch. Experimental error sources include the method of firing and alignment between the cannon mouth and the motion sensor (otherwise, we would be measuring a component of the initial velocity).

***Figure 2**: a) Experimental Apparatus used; b) Variation of the motion sensor position to maximize the signal; and c) Typical measurement obtained with the Pasco motion sensor and Pasco Capstone program.*



(a) (b) (c)

Methodology

The work was divided into three stages: pre-class, in-class, and post-class.

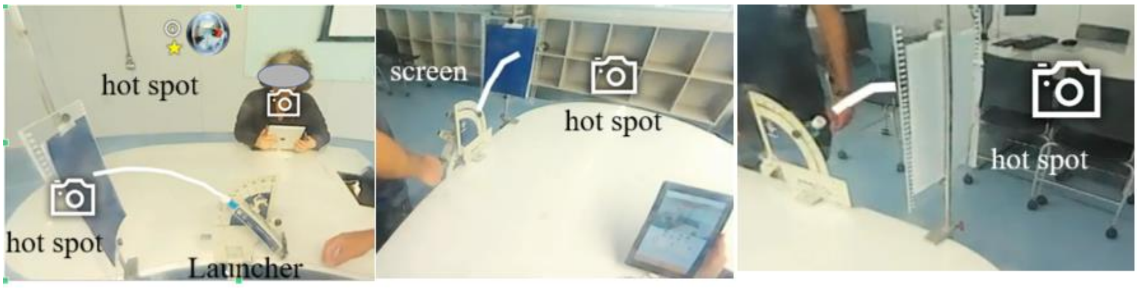
Pre-class (individual)

The pre-class material provided: laboratory instructions, a conventional 2D video explaining the physical concepts involved, and an immersive video. The immersive videos showed: the steel ball's trajectory from different angles; launches with different angles (20 degrees, 30 degrees, and 40 degrees) and the respective height the ball reached on the screen, as well as the experimental precautions to minimize experimental error. These panoramic and immersive videos were interactive with explanatory hotspots, aiming for greater student engagement in acquiring prior information.

Students were expected to read and watch the provided material and then answer the pre-class questionnaire individually.

Figure 3 shows a screenshot of some of the scenes from the immersive video using a low-cost 360-degree camera (PANO VIEW), allowing panoramic recordings or images with a 220-degree field of view. Since the experiment takes place on a plane, seeking an immersive view of the phenomenon, several takes were made by varying the camera position and using a video editor to obtain a single video. In all the takes, a virtual object corresponding to the ball's trajectory marking (represented by a white line in Figure 3) was inserted. The hotspots contain informative texts and supplementary videos. Sound was deliberately not used in the videos, encouraging attention to the reading and visual observation of the phenomenon being shown. These hotspots were inserted using Cloudpano software, after editing the different takes into a single video.

Figure 3*: Screenshot from the immersive videos provided to students (the experiment was recorded so that the student could view the same experiment from several different angles). The video was available at cloudpano.*



In-class (in teams of 3 or 4 students)

The experiment was carried out in class with teams of 3 or 4 students. Aiming to develop student skills and autonomy in instrumentation and physical measurements, the experiment presented to the students had problems in the setup, requiring them to identify the alignment and positioning errors of the acrylic screen. The teams were expected to submit a completed lab worksheet and, after 15 days, submit a full report in the format of a scientific article, promoting written communication skills.

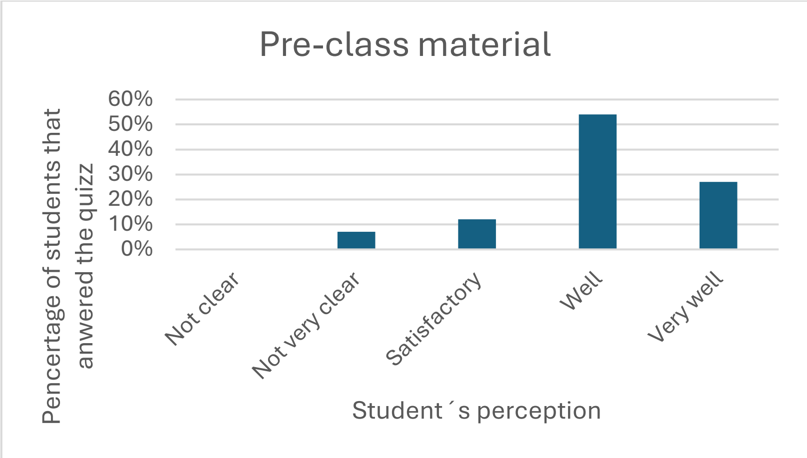
Post-class (individual)

Students answered a questionnaire similar to the one used in the pre-class. However, three multiple-choice problems were added. Two involved direct applications of the concept, and one was more complex, involving the composition of two types of motion. These problems are presented in Appendix 1.

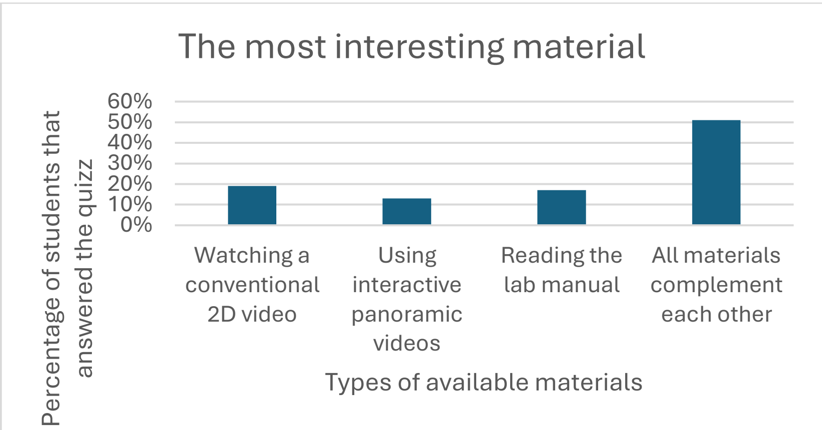
Results and Analysis

Pre-class questionnaire (218 students)

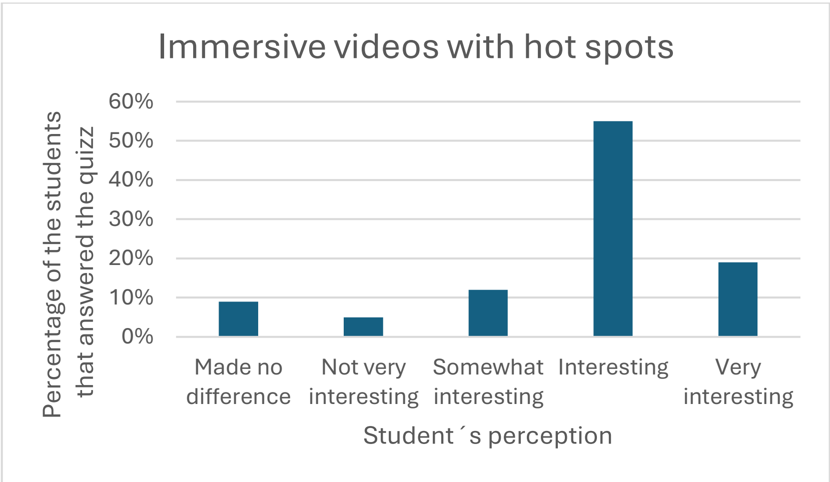
1) Did the pre-class material clearly explain the experimental procedure and analysis to be carried out?



2) Among the resources presented, which do you think is the most interesting to explain the lab experiment to you?



3) Did the use of videos with hot spots make you feel more engaged in reading the activity before the lab class?



Based on the pre-class questionnaire results from 218 students, the main conclusions are:

Clarity of Pre-Class Materials: The majority of students (81%) found the pre-class materials to be clear or very clear in explaining the experimental procedures and analysis, with 54% rating them as "Well" and 27% as "Very well." Only 7% considered the materials "Not very clear," and no students rated them as "Not clear."

Most Interesting Resources: The majority of students (51%) believed that all resources complemented each other, highlighting the importance of integrating multiple learning formats. When asked to identify specific resources, "Watching a conventional 2D video" (19%), "Using interactive panoramic videos" (13%), and "Reading the lab manual" (17%) were each selected by smaller but notable proportions of students, showing a preference for diverse resources rather than a single format.

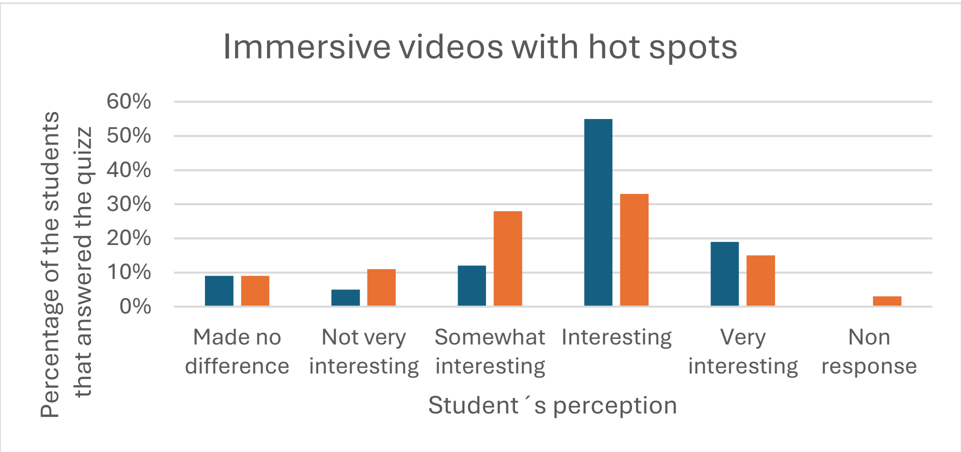
Engagement Through Hot Spot Videos: Over half of the students (55%) found the use of hot spot videos "Interesting," and another 19% rated them as "Very interesting," indicating that these videos positively impacted engagement. A minority of students felt the videos had little impact, with 9% stating they "Made no difference" and 5% rating them as "Not very interesting."

The pre-class materials effectively conveyed the experimental procedures and analysis, meeting the learning needs of most students. Students appreciate a combination of resources rather than relying solely on a single type, emphasizing the value of multimodal learning approaches. Hot spot videos are a valuable tool for increasing engagement, but there is room to further improve their effectiveness for a small segment of the student population.

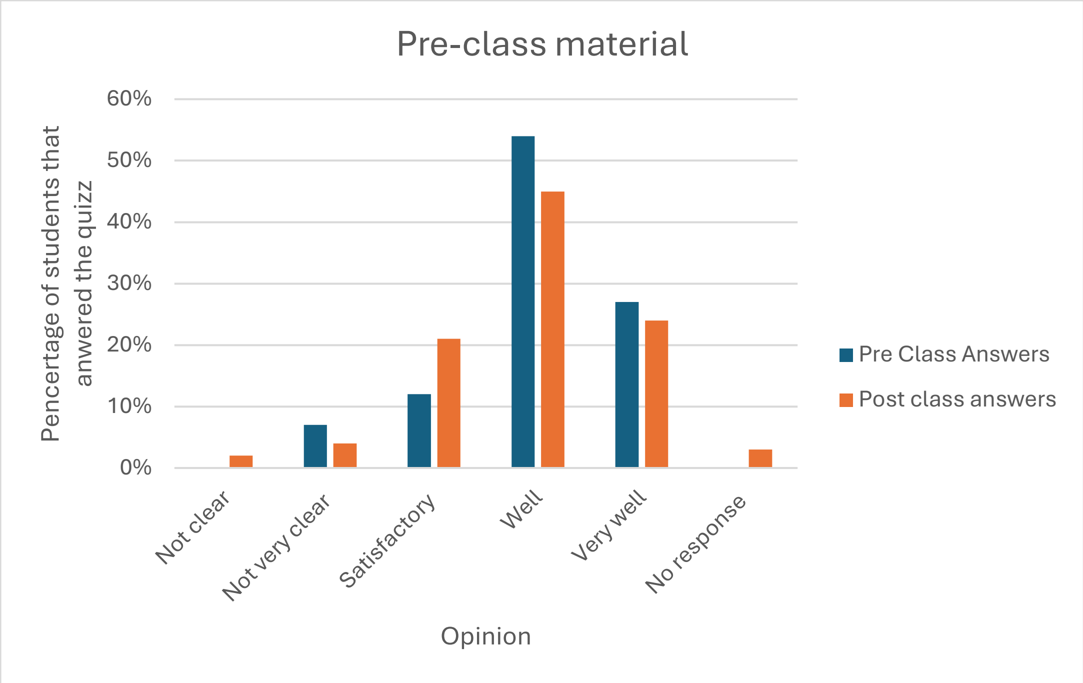
Post-class Results (263 students)

Below are the results of the students' evaluation regarding the use of 360° video:

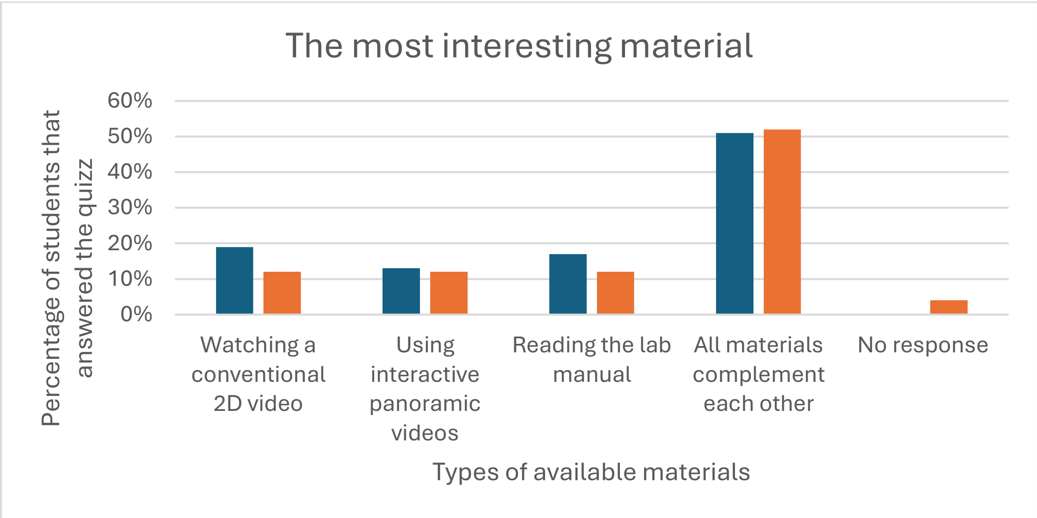
1) Did the use of 360° video as an introduction to the experiment motivate you to watch the tutorial before attending your lab class? On a scale of 1 to 5, where 5 means it motivated you a lot, and 1 means it did not motivate you.



2) After performing the experiment, can you confirm that the provided materials made the experimental procedure and analysis for the Projectile Motion class clear?



3) Among the resources presented, which do you think is the most interesting to help explain the lab experiment?



Key Conclusions from Post-Class Results (263 Students)

Motivation from 360° Video: The 360° video introduction had a positive impact on motivating students to watch the tutorial before attending their lab class, with 76% of respondents rating their motivation as 3 or higher (28% chose 3, 33% chose 4, and 15% chose 5). A smaller percentage of students (20%) rated their motivation as 1 (9%) or 2 (11%), indicating room for improvement in how the 360° video engages all learners. 3% of students did not provide a response.

Clarity of Materials Post-Experiment: A strong majority of students (69%) confirmed that the provided materials were either "Good" (45%) or "Very explanatory" (24%) in making the experimental procedure and analysis clear. 21% found the materials "Satisfactory," suggesting they met basic expectations but lacked some clarity. Only 6% of students reported the materials as "Not very clear" (4%) or "Did not make it clear" (2%), indicating that the materials were effective for most students. 3% of students did not respond.

Most Interesting Resources for Explaining the Experiment: Over half of the students (52%) highlighted that "All materials complement each other," emphasizing the importance of integrating multiple resources for explaining the experiment. Among individual resources, "Reading the lab manual" (20%) was the most preferred, followed by "Watching an interactive or conventional video" (12%) and "Using interactive panoramic videos" (12%), indicating varied preferences for learning styles. 4% of students did not provide a response.

Summary of Findings:

The 360° video was generally well-received, motivating a majority of students to engage with the tutorial, though a notable minority felt less engaged.

The clarity of post-experiment materials was strong, with nearly 70% of students rating them as clear or very clear. Only a small percentage found the materials unclear.

A multimodal approach is critical, as most students appreciate the complementary use of all resources. Individual preferences for the lab manual, videos, and panoramic content highlight the need to accommodate diverse learning styles.

Here are the main comments left by the students:

"The videos are informative and helped a lot with understanding." "The video itself is very interesting and self-explanatory, but some questions arose throughout the video."

"The videos helped to better understand the experiment in practice." "The videos provided were very useful for understanding the experiment, as they were very detailed and highly explanatory. A suggestion would be to provide more videos for future experiments."

"I loved the 360-degree video format, it's sensational. This really helps to see the theory in practice and serves as an attractive incentive for students."

“Videos without audio, slightly heavy, resolution could be improved a bit, but very explanatory.”

According to the students, the areas for improvement in immersive videos are: the lack of sound, and many are not used to watching panoramic videos. It is believed that if immersive glasses had been used, students might have felt more comfortable with this type of imagery.

After the class and the submission of the simplified team report, the students individually answered the post-class questionnaire. Three questions were provided in an online questionnaire, as presented in Appendix 1.

Problem P1 addressed the retention of the concept of horizontal and vertical position functions in projectile motion. About 92% of the students selected the correct answer. Problem P2 focused on the learning of how the trajectory equation in projectile motion is constructed; approximately 47% selected the correct answer, indicating the need to schedule more activities to promote student learning on this topic. Problem P3 involved the composition of two types of motion: initially, the object descended an inclined ramp and then fell in projectile motion. Only 38% answered this question correctly, indicating the need to work more on activities where more than one concept is involved, to develop and prepare our students for more complex modeling learning.

Final Considerations

The immersive video methodology combined with the flipped classroom methodology proved to be a promising technology from the perspective of increasing students' motivation to read the material before class. The use of this technology allowed for increased difficulty in performing the experiments, avoiding the so-called “cook recipes” in the laboratory. Regarding performance in solving the post-class exercises, it was found that more work is needed with “high-order thinking skills” activities, aiming to further develop this skill in our students.

Acknowledgment

To the students of the XXXXXXXXX for kindly answering the perception questionnaires. To the teachings of the professors from the graduate program in Applied Computing to Education and Educational Technologies at XXXXX, and to the technicians from the Physics Laboratory at XXX.

References

[1] Lamproulos et al. 360-degree video in education: An overview and a comparative social media data analysis of the last decade. Smart Learn. Environ., 8(20), 1-16. 2021. Available: https://doi.org/10.1186/s40561-021-00165-8 [Accessed Nov. 14, 2024].

[2] Sviridova et al. (2023). Immersive technologies as an innovative tool to increase academic success and motivation in higher education. Front. Educ., 8, 1192760. 2023. Available: https://doi.org/10.3389/feduc.2023.1192760 [Accessed Nov. 14, 2024].

[3] Broeck et al. It's All Around You: Exploring 360° Video Viewing Experiences on Mobile Devices. In Proceedings of the 25th ACM International Conference on Multimedia (pp. 1-10). 2017. Available: https://doi.org/10.1145/3123266.3123347 [Accessed Nov. 14, 2024].

[4] Kapp, S., Thees, M., Beil, F., Weatherby, T., Burde, J.-P., Kuhn, T., & Wilhelm, T. The Effects of Augmented Reality: A Comparative Study in an Undergraduate Physics Laboratory Course. In Virtual and Augmented Learning Environments (pp. 197-206). Springer, Cham. 2020. Available: https://doi.org/10.1007/978-3-030-49936-9_20 [Accessed Nov. 14, 2024].

[5] Fidan, M., & Tuncel, M. Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. Computers & Education, 147, 103635. 2020. Available: https://doi.org/10.1016/j.compedu.2019.103635 [Accessed Nov. 14, 2024].

[6] Tracker video analysis. (n.d.). Available: https://physlets.org/tracker/ [Accessed Nov. 14, 2024].

Appendix 1 - Problems provided in the post-class questionnaire

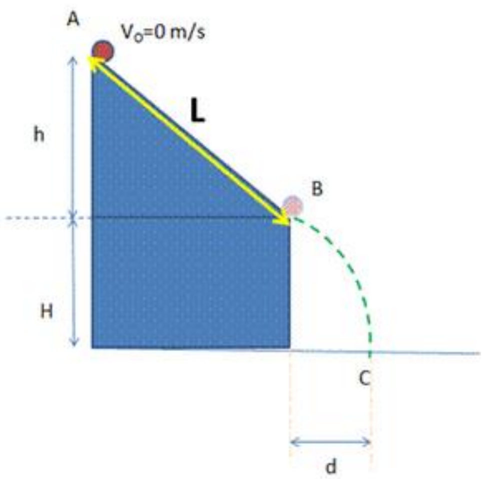
Question 1: What are the time-dependent equations for the horizontal position and the vertical position of an object launched by a cannon? Disregard air resistance and rotational effects, treating the steel sphere as a particle.
Answer options:

1. $x = x_0 + v_x t$ and $y = y_0 + v_{0y} t - (g/2)t^2$ – 241 respondents (92%)
2. $x = x_0 + v_x t - (g/2)t^2$ and $y = y_0 + v_{0y} t - (g/2)t^2$ – 6 respondents (2%)
3. $x = x_0 + v_x t$ and $y = y_0 + v_{0y} t$ – 7 respondents (3%)
4. They do not depend on time – 0 respondents (0%)
5. No answer – 9 respondents (3%)

Question 2: Given the equation of the trajectory of an object launched obliquely: $y(x) = 1.0 + \Delta x \times (4.9\ \Delta x^2) / (100 \cdot 0.5)$
Choose the correct alternative
Answer options:

1. The launch angle is 45 degrees above the horizontal – 123 respondents (47%)
2. The initial velocity is 100 m/s – 17 respondents (6%)
3. The initial vertical position is 10 m – 36 respondents (14%)
4. The acceleration in the y direction is 4.9 m/s² – 76 respondents (29%)
5. No answer – 11 respondents (4%)

Question 3: In an industry, the following transport system was set up. Bags containing products are released from point A, starting from rest. They then descend a ramp with a length L equal to 1.0 m, without friction, forming a 30º angle with the horizontal (h = 0.50 L), reaching point B.
After descending the ramp, the bags must hit a target located at point C, which is at a distance d of 2.0 m from the base of the ramp.



Statements:

(I) The flight time in the BC path is approximately 0.74 s, and the speed of the bag when it reaches point B is 3.13 m/s.

(II) The vertical component of the velocity of the bag when it reaches point B is approximately -1.56 m/s.

(III) The height H must be less than 1.0 m, otherwise the object will not reach the target.

(IV) The horizontal component of the velocity of the bag when it reaches point B is equal to the vertical component of the velocity when it reaches point C.

Only (I) is correct. – 31 respondents (12%)

Only (II) and (III) are correct. – 74 respondents (28%)

Only (III) is correct. – 49 respondents (19%)

Only (I) and (II) are correct. – 100 respondents (38%) (correct option)

No answer – 9 respondents (3%)