Enhancing Kinematics Understanding Through a Real-Time Graph-Based Motion Video Game

Mateo Dutra (1), Marcos Abreu (2), Martín Monteiro (3), Silvia Sguilla (2), Cecilia Stari (4), Álvaro Suárez (2), Arturo Martí (1)

(1) Instituto de Física, Facultad de Ciencias, Universidad de la República, Uruguay
(2) Consejo de Formación en Educación, Uruguay
(3) Universidad ORT Uruguay, Uruguay
(4) Instituto de Física, Facultad de Ingeniería, Universidad de la República, Uruguay

Abstract: Although kinematics concepts are key in high school and university physics courses, students face significant difficulties in understanding them. Research shows that real-time graph visualization can help improve comprehension of these concepts. In this oral presentation, we will describe a project we are currently developing, which involves the creation of a physical-computational video game environment where students replicate motion using their own bodies based on a given graph. A position sensor generates a real-time graph that is compared to the target graph, and students are scored on their accuracy. Preliminary results show improved comprehension and high student motivation.

What is the framework of our project?

The study of movement and its causes is essential in our interaction with the world. It allows us to understand phenomena related to the operation of vehicles, the trajectory of a ball, our own movements and even the mechanics of the solar system. This importance is reflected in the content of education at all levels. However, even after the students have gone through several courses in which they work on these contents, it has been reported that they present significant difficulties to understand fundamental concepts of kinematics [1-4].

Among the various conceptual difficulties, we can mention confusion between the concepts of position, displacement, distance, velocity, and acceleration stands out. Additionally, when working with position, velocity, or acceleration graphs as functions of time, common errors include assuming that a graph is a literal image of the situation or confusing the meaning of the slope at a point with its value on the vertical axis [1-2]. It has also been reported that students who visualize real-time graphical representations of movements achieve better results in understanding these concepts [3]. Another potentially effective tool, particularly for sparking students' curiosity and attention, is the use of video games and gamification [4].

What are we doing?

To overcome these difficulties in understanding kinematic concepts and graph interpretation, we are developing a physical-computational video game environment and several activities to be carried out within it. In these activities, students are given a position or velocity graph as a function of time, and they must interpret the motion and replicate it with their own body. As they move, a position sensor generates the corresponding graph in real time and overlays it on the target graph. Based on the similarity between the two graphs, students will receive a score according to their

performance. We will make use of non-expensive and easily accessible ultrasound sensors.

What do we expect?

We believe that integrating computational thinking, sensor technology, and fundamental physics concepts will be broadly appealing and contribute significantly to enhancing students' education. Leveraging students' own bodies in the learning process fosters deeper engagement with their environment while inspiring both students and educators. By making physics concepts tangible and interactive, we aim to bridge the gap between abstract theory and real-world application, making learning more accessible and enjoyable.

Through this project, we aim to develop instructional activities and sequences that will subsequently be evaluated using the methodologies currently established within the discipline. In addition to creating the gamified environment, we are committed to providing comprehensive teacher training programs. These programs will equip educators with the necessary skills and knowledge to effectively integrate the tools and associated activities into their curricula. The training will focus not only on the technical use of the sensors and software but also on pedagogical strategies to maximize student engagement and learning outcomes.

To assess the effectiveness of our approach, we will conduct rigorous impact evaluations involving groups of high school students, including pre- and post-intervention assessments to measure improvements in students' understanding of kinematic concepts and their ability to interpret motion graphs. We will also gather qualitative feedback from both students and teachers to gain insights into their motivations, experiences, and identify areas for further improvement. Preliminary results are very encouraging, and we have also observed high levels of student motivation while working on them.

Perspectives

We are at the final stages of developing the first version of the video game, which will be free to use. We hope it will be widely adopted in our country, Uruguay, and that educators in other parts of the world will also feel encouraged to use it in their courses.

Acknowledgements

We would like to express our gratitude to the National Agency for Research and Innovation (ANII, Uruguay) and Fundación Ceibal (Uruguay) for funding this project (FSED_2_2023_1_179226).

References

[1] Jufriadi, A., Kusairi, S., & Sutopo, S. (2021, April). Exploration of student's understanding of distance and displacement concept. In Journal of Physics: Conference Series (Vol. 1869, No. 1, p. 012195). IOP Publishing.

[2] Bollen, L., De Cock, M., Zuza, K., Guisasola, J., & van Kampen, P. (2016). Generalizing a categorization of students' interpretations of linear kinematics graphs. Physical Review Physics Education Research, 12(1), 010108.

[3] Duijzer, C., den Heuvel-Panhuizen, V., Veldhuis, M., Doorman, M., & Leseman, P. (2019). Embodied learning environments for graphing motion: A systematic literature review. Educational Psychology Review, 31(3), 597-629.

[4] Panthalookaran, V. (2018, April). Gamification of physics themes to nurture engineering professional and life skills. In 2018 IEEE Global Engineering Education Conference (EDUCON) (pp. 931-939). IEEE.