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The Use of PhET to Enhance the Learning of Mechanical Energy in High School Students of the Fiscomisional Educational Unit “Cinco de Mayo”

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Abstract---*The use of the PhET simulation has proven to be an effective tool to improve the learning of mechanical energy in third-year high school students of the Fiscomisional Educational Unit "Cinco de Mayo". This research aimed to apply said simulator to facilitate the understanding of key concepts such as energy conservation, types of energy and energy transformation. Theoretical methods were used to collect information and empirical methods to evaluate its effectiveness, such as survey, interview and observation sheet. The results obtained showed that the use of the PhET simulation promoted a better understanding of mechanical energy concepts, allowing students to interactively visualize complex phenomena that would otherwise be difficult to illustrate with traditional methods. Furthermore, it was found that this digital tool made the teaching-learning process more attractive and dynamic, significantly improving the participation and motivation of students in the classroom.*
Keywords---*interactive methods, learning, mechanical energy, PhET simulator, secondary education*.

Introduction

Currently, teaching is influenced by a competency model, which proposes acquiring key and basic skills in which informational and digital competencies are found (Barahona, 2012). Physics and technology play a fundamental role in the educational and scientific development of students, however, the teaching of these concepts often lacks the use of innovative tools that facilitate meaningful and lasting learning.

The teaching of Mechanical Energy is carried out mostly through traditional methods that do not always manage to capture the interest of students, nor do they facilitate their deep understanding. The absence of teaching strategies that use advanced technological tools, such as the PhET simulator, which offers interactive simulations for teaching physical concepts, is notable. Villavicencio Vera (2021), describes, this simulator facilitates the visualization and understanding of the laws that establish a physical phenomenon, however, it is a complementary tool, but it does not replace the skills and abilities in the manipulation of equipment that can be acquired in laboratories. physical (p. 19).

As Ortíz Pérez et al. (2000), describe, the lack of innovation in the teaching of Mechanical Energy can result in a superficial understanding of the concepts by students, limiting their ability to apply this knowledge in practical situations. Therefore, the scientific question of this research was: How to contribute to the learning of mechanical energy in third-year high school students of the Fiscomisional Educational Unit “Cinco de Mayo”?

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This study proposes to address the problem identified by using the PhET simulator to improve the learning of Mechanical Energy. By analyzing and applying this educational technology, it is expected to demonstrate its effectiveness in improving the understanding and retention of physical concepts among students. This approach will not only enrich the learning process, but will also offer teachers new tools to address curricular content in a dynamic and participatory way (Krobthong, 2015; Wu et al., 2021; Wang, 2012; Wu et al., 2015).

Materials and Methods

Mixed methods that combine both qualitative and quantitative approaches will be used (Hamui-Sutton, 2013). These approaches will allow a comprehensive evaluation of the effectiveness of the PhET simulator, ensuring that the results obtained are robust and applicable in different educational contexts. The combination of methods such as the interview, questionnaire and observations in class with the teacher and students will provide a comprehensive vision of the impact of this technological tool with a qualitative-quantitative approach, a quasi-experimental design with two equivalent groups, one control and the other experimental. . The population consisted of 213 students and 2 teachers from the unified general high school, of which 77 students and 1 third-year high school teacher were taken as an intentional sample; This sample was considered because they are a representative group of the knowledge acquired in the first and second periods of high school.

In the same way, the use of theoretical, empirical and statistical methods was appropriate. Theoretical, because information was sought from reliable and updated sources for the support and validation of this work; empirical since the sample was divided into two groups to establish a comparison as a study technique; and statistical because statistical tables and graphs were used for the tabulation and interpretation of the results (Díaz-Ferrer et al., 2020).

In both groups, they talked about the basic and necessary concepts to introduce the new topic, then they worked with the topic of conservation of mechanical energy in terms of kinetic and potential energy, structured in 5 sessions: Session 1 Origin of mechanical energy and its formulas, Session 2 definitions and types of energy, Session 3 difference and identification between types of energy, Session 4 mathematical calculation of mechanical kinetic and potential energy, and Session 5 application of the PhEt simulator. In the control group, the subject was taught in a traditional way, that is, the blackboard and the planning carried out were used, while in the experimental group the use of the PhEt simulator was carried out, this simulation is called: "transformation of energy on the skate park."

This simulator contains the concepts of conservation of mechanical energy in relation to kinetic and potential energy, with a character that moves on a slope in style on a skating rink. This simulator contains a graphic section that shows the contents of how These energies interact, that is, how it is transformed from one energy to another. On the other hand, it has the option of manipulating the stage (ramp), speeds or position where said character descends, among other data. The simulation can be used online as long as you have any navigation platform, whether on a PC or mobile device (Mera-Menéndez & López-González, 2023).

Results and Discussion

The challenges of pedagogical practice that are increasingly greater and more complex in society, because currently, many of the teachers who teach physics are not pedagogues; causing their teaching to continue focusing on traditional methods and teaching action on mere transmission of knowledge, this incident directly affects the students' learning, causing them to not see physical science as anything more than a cluster of formulas that must be learned from memory (Castañeda Salazar, 2022).

Arruda (2003), describes the lack of pedagogical preparation that often leads to the adoption of traditional teaching methods that focus on adding knowledge instead of analyzing, interpreting and understanding physical concepts. Students may perceive physics as a boring and difficult subject, which reduces their interest and motivation to study it. This situation highlights the urgent need to provide teachers with adequate pedagogical tools and resources to effectively meet the learning needs of students and promote a deeper and more meaningful understanding of physics (Wohlever & Bernhard, 1992; Dagdeviren et al., 2016; Chen, 2010; Steg, 2008).

Mechanical energy learning

Mechanical energy is the combination of kinetic and potential energy in a system, it is essential to move objects and facilitate various activities (Travieso Carrillo, 2001), this energy acts as a driving force behind numerous technological innovations and improvements in operational efficiency (pp. 11-20). In other words, it is the force that drives much of our daily activities. This form of energy facilitates everything from the movement of objects to the creation of modern comforts. Its constant presence in our lives underlines its importance and the need to understand how it works to take advantage of it efficiently and sustainably.

In the mechanical energy part, another paradigm has been generated that consists of believing that everything works separately (Castañeda Salazar, 2022), students find great difficulty when relating the conceptual part with a number of equations that they consider difficult to work and that in order to perform well they must learn them by heart; This situation is even more complicated when a case of two-dimensional movement is presented.

For example, if a body is propelled in a horizontal direction that is at the edge of the surface and leaves with that horizontal impulse, this body will move horizontally and vertically simultaneously, its speed and acceleration with respect to its orthogonal axes will be different. Theoretically, the problem is very easy to analyze; However, learners must imagine or assume many factors (speed, acceleration, force, work, among others) that can be measured with appropriate instrumentation and allow reliable data to be obtained in real time.

Integration of technology in education

Currently, education and technology are constantly evolving with the aim of engaging students and encouraging problem solving in everyday situations. (Farfán & Gómez, 2023), mention "Young people play an active role in the evaluation of educational methodologies. In addition, a change is promoted in the role of the teacher, who becomes a guide of knowledge instead of the only voice in the classroom."

García-González et al. (2018), They point out that online simulators are compatible with the need to adapt education to new forms of learning and involve students. On the other hand, Gelves & Moreno (2012), state that these tools allow them to explore abstract physics concepts in a practical and experimental way, promoting active learning and problem solving in everyday situations. Furthermore, the idea that the teacher acts as a facilitator of information, with a constructivist pedagogical approach aimed at the development of skills and participation in learning.

PhET simulator

Today, learning has changed and includes various media that allow students to interact with theoretical concepts in a direct and practical way. In addition to clarifying understanding of complex topics, these tools foster student interest and curiosity by providing opportunities for exploration and experimentation. A clear example of this type of platform is PhET, which stands out for its interactive simulations aimed at the exact and natural sciences.

One of these simulators is the PhET simulation platform, which consists of a set of interactive and didactic simulations aimed at exact and natural sciences such as physics, mathematics, biology and chemistry. Among its general characteristics are the use of open source which makes it an affordable tool for anyone, in addition to being able to run online or without an internet connection by allowing all the simulators offered on the platform to be downloaded since it is designed to operate through Java, Flash and HTML5 (Mera-Menéndez & López-González, 2023).

The PhET platform, made up of simulators from different educational areas, has different characteristics that can help visually and practically understand the abstract concepts of these phenomena. These simulators "are designed for investigative and scientific strengthening, through the exploration of educational scenarios." (Pacheco et al., 2021).

Benefit of using the PhEt simulation in physics teaching

These simulators are designed to cover the topics of energy conservation, kinetic, potential, thermal and friction energy; Through the simulation, it is possible to manipulate a character who will get off a ramp with a certain size using a skateboard. It also has a table that allows graphics to be displayed that refer to the previously mentioned energies and speed, likewise, It has the option to show the height of the ramp or from where the character is launched; finally, the dimensions of the ramp can be modified (Malagón Amézquita, 2022).

Paguay Maji (2024), describes that Physics simulators, by recreating concrete situations such as a character sliding down a ramp with a skateboard, offer students a visually stimulating and practical experience to understand abstract concepts. Additionally, by providing visual tools such as energy and velocity graphs, as well as the ability to adjust parameters such as ramp height, it facilitates understanding through direct experimentation and promotes critical thinking by allowing students to observe how variables change. affect the final results.

In this section, the results obtained and their interpretation will be shared on each of the dimensions of the instruments (survey, observation sheet and questionnaire) applied to the student sample. Additionally, a comparison of the academic performance shown in the experimental group versus the control group.

As a result of the survey applied to the teacher with the purpose of evaluating the strategies used in the Fiscomisional Educational Unit “Cinco de Mayo”, the following was obtained: the challenges that the graduate has encountered are primarily the changes that come from the Ministry of Education such as schedules and topic prioritization, especially the different learning styles of students (Anastasi et al., 2009; Liu et al., 2010; Arcentales et al., 2017; Carrillo et al., 2022). Likewise, he stated that to date he has not used any technological tool to help him improve his teaching processes, however, he considers that it is good to be on par with technology; One of the strategies he uses is to apply theoretical concepts to examples or problems that are seen in daily life. On the other hand, it was possible to identify that the topic of mechanical energy is not addressed in said institution and the students are unaware of this topic, this is due to the schedules that are stipulated in the annual curricular plan of the institution, which leads to prioritizing certain topics, leaving the topic of mechanical energy out of the planning. In the same way, the results obtained from the survey using a Likert scale applied to the experimental group are reflected in table 1 in percentage values, which were calculated thanks to.

Table 1
Likert scale percentages: Survey applied to the experimental group

Survey applied to the experimental group	Strongly agree (%)	OK (%)	Moderately agree (%)	Disagree (%)	Strongly disagree (%)
1. Did you find the concepts taught in physics class challenging?	5	4	15	63	13
2. Do you think that incorporating additional resources, such as the phet simulator, helps to better understand mechanical energy?	69	17	2	7	5
3. Do you consider the teaching method used to learn the concepts of mechanical energy to be effective?	41	29	10	11	9
4. Can you identify examples of the application of mechanical energy in everyday life situations?	45	37	11	5	2
5. Did you feel motivated with the simulator to actively participate in physics classes?	47	29	11	9	4
6. Do you think that this simulator should be applied in subsequent classes?	47	39	10	2	2

From the experimental group made up of 38 students, the following were found as positive results from the use of the PhEt simulator: only 9% of the students found the class taught challenging, while 76% indicated that it was not; Regarding satisfaction with incorporating the PhEt simulator into classes, 86% expressed that the simulator is very helpful, compared to 12% who thought the opposite. Regarding the liking of the class teaching method, 70% said they were satisfied, while 20% were not; In the fourth question, 82% of the students stated whether they identified practical examples of the topics, while 7% did not; In the penultimate question, 76% of the students felt motivated by the class, while 13% did not experience that motivation; and in the last question, 86% of them said that it is necessary and important to continue using this simulator, while 4% did not agree with this statement.

In the instrument applied to the experimental group, an open question related to the use of the PhEt simulator in the “mechanical energy” class was included: How would you describe the PhEt simulator as a learning tool in a single word?mFigure 1 shows a cloud of words obtained by transcribing all the responses of the students surveyed. To represent it, the help of the Mentimeter software was needed, which was used thanks to the guide published by (University of Development Center for Teaching Innovation, 2020).

Figure 1. Word cloud on the use of the PhEt simulat

In the observation sheet, active participation and constant attention on the part of the majority of the students during class was identified. Most of them intervened by asking questions, expressing doubts and concerns about the topic, which reflected a high interest in the lesson. Furthermore, when the simulation was presented using the PhET tool, all students paid attention and showed enthusiasm for learning how to operate the simulator. Consequently, the use of the PhET simulator is a very useful tool for this educational level and to address these topics. The results obtained from the survey applied to the control group are shown in Table 2.

Table 2
Likert scale percentages: Survey applied to the control group

Survey applied to the control group	Strongly agree (%)	OK (%)	Moderately agree (%)	Disagree (%)	Strongly disagree (%)
1. Did you find the concepts taught in physics class challenging?	33	24	16	15	12
2. Did you know that the phet simulator helps you better understand the topic of mechanical energy?	11	4	7	25	53
3. Do you consider the teaching method used to learn the concepts of mechanical energy to be effective?	33	29	8	17	13
4. Can you identify examples of the application of mechanical energy in everyday life situations?	36	5	18	22	19
5. Did you feel motivated to actively participate in physics classes?	30	21	15	16	18

From the control group made up of 39 students, the following results were obtained: 57% of the students surveyed stated that they found the class challenging, while 27% said that it was not challenging; In the second question, 15% said they knew the importance of using the PhEt simulator, while 78% said they did not know about that simulator (this question was explained to the children in advance); In the third question, 62% considered that a good methodology was applied, while 30% said the opposite; In the penultimate question, 41% of the students said that they are able to exemplify mechanical energy, while 41% said that this is not easy for them; and in the last question, 51% of the students said they felt motivated in class, while 34% did not.

In general, it was observed that both groups showed interest in the topic presented. However, the experimental group, which used the PhET simulator, demonstrated a higher level of enthusiasm and participation compared to the group that did not have this tool. Verifying what was said by Paguay Maji (2024), The use of the simulator seems to have been a key factor in enhancing the interest of the students, facilitating the understanding of the topic in a more interactive way.

In both groups, it was evident that, although these topics are not part of their usual training, students have prior knowledge about basic concepts, such as international units, conversions and formula solutions. This allowed a better understanding of the content addressed during the class and facilitated the development of the session. However, it is important to note that, although the control group did not have the simulator, they also achieved an adequate understanding of the topic, which suggests that the digital tool, although valuable, is not the only determining factor in the teaching process. learning as indicated by Balladares et al. (2023).

Finally, a significant interest was noted on the part of the teacher in the use of the simulator, since he asked for guidance to learn how to use the simulator, recognizing its usefulness in the teaching process. He requested that the operation of the tool be explained to him so that he could also present it to the control group, so that all students were aware of its existence and potential.

Comparing these findings with previous research confirms that the use of simulators such as PhET facilitates the assimilation of complex concepts. However, an important point to highlight is that the impact of the simulator depends largely on the enthusiasm and commitment of the teacher. As described (Morán Peña et al. (2017), The way in which the teacher presents and guides learning is crucial, since his methodology can influence the level of understanding and motivation of the students, regardless of the resources he uses. This was evident when the teacher showed interest in learning the use of the simulator and sought to share it with the control group, which contributed to improving the educational experience of the students.

Conclusions

The use of PhET to enhance the learning of mechanical energy in the Fiscomisional Educational Unit "Cinco de Mayo" met the objectives set at the beginning of the research, showing favorable results in both the students and the teacher. The students in the experimental group not only managed to better understand the concepts of kinetic and potential energy, but they also showed more interest and motivation during classes. The tool allowed us to interactively visualize how kinetic energy is transformed into potential energy in a skating rink, which facilitated the assimilation of content that is usually abstract or difficult to understand with traditional methods.

It is notable that even the teacher, who had not initially incorporated technological tools into his pedagogical practice, recognized how stimulating this simulator can be with its numerous tools. The teacher's surprise at the observed benefits reinforces the idea that technology can positively transform teaching and motivate both students and educators. Their interest in learning how to use the simulator to implement it more frequently reflects the effectiveness of this tool in improving the educational process.

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