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Design of a strategy for the use of digital simulators in the teaching of physics to university students

Diseño de una estrategia para el empleo de simuladores digitales para la enseñanza de la física en estudiantes universitarios

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Abstract

There is a great problem in Mexican Higher Education Institutions due to the deficiencies of knowledge that the students present in the science area, this because, among other factors, to the lack of motivation and interest to learn it. This article proposes the design of a strategy for the use of free access digital simulators for Physics Foundations course students, seeking to increase their interest in learning physics and improve their learning outcomes, as well as offer a basic starting point that helps teachers and researchers to consider all the necessary characteristics for the design of strategies to use them in various subjects. In this strategy, three digital simulators were used: the virtual laboratory of free fall movement simulates throwing different objects from Pisa Tower and selecting the gravity, it returns the results of time, speed and route; I.E.S. Aguilar and Cano simulator allows the user to experiment the result of throwing a ball up, playing with the values of initial velocity and initial height, thus being able to observe the variations obtained as soon as to height-time and velocity-time and the projectile movement; finally the Phet simulator, allows launching various objects from a cannon, varying the values of height, angle, mass and diameter, this simulator is part of the PhET Interactive Simulations project at the University of Colorado which creates free interactive math and science simulations. In addition, evaluation instruments were designed for each simulator, which were applied to the students after the teacher's explanation on two different occasions.

Keywords: educational technology, digital simulators, motivation to learn, learning physical sciences, ICT in education

Resumen

Existe un problema en las Instituciones de Educación Superior mexicanas debido a las deficiencias de conocimientos que presentan los estudiantes en las ciencias debido, entre otros factores, a la falta de motivación e interés por aprenderla. Este artículo propone el diseño de una estrategia para el uso de simuladores digitales de libre acceso para estudiantes de la asignatura Fundamentos de Física, buscando incrementar su interés por aprenderla y mejorar sus resultados de aprendizaje, así como ofrecer un punto de partida que ayude a docentes e investigadores a considerar todas las características para el diseño de estrategias para utilizarlas en diversas asignaturas. En esta estrategia se utilizaron tres simuladores digitales: el laboratorio virtual de movimiento en caída libre simulando lanzar diferentes objetos desde la Torre de Pisa y seleccionando la gravedad, devuelve los resultados de tiempo, velocidad y recorrido; IES simulador de Aguilar y Cano permite al usuario experimentar el resultado del lanzamiento de una pelota hacia arriba, jugando con los valores de velocidad inicial y altura inicial, pudiendo observar las variaciones obtenidas en cuanto a altura-tiempo, velocidad-tiempo y el movimiento del proyectil; finalmente el simulador Phet, permite lanzar diversos objetos desde un cañón, variando los valores de altura, ángulo, masa y diámetro, este simulador es parte del proyecto PhET Interactive Simulators de la Universidad de Colorado el cual crea simulaciones interactivas gratuitas de matemáticas y ciencias. Se diseñaron instrumentos de evaluación para cada simulador y se aplicaron a los estudiantes luego de la explicación del docente en dos ocasiones diferentes.

Palabras clave: tecnología educativa, simuladores digitales, motivación para aprender, aprendizaje de ciencias físicas, TIC en educación

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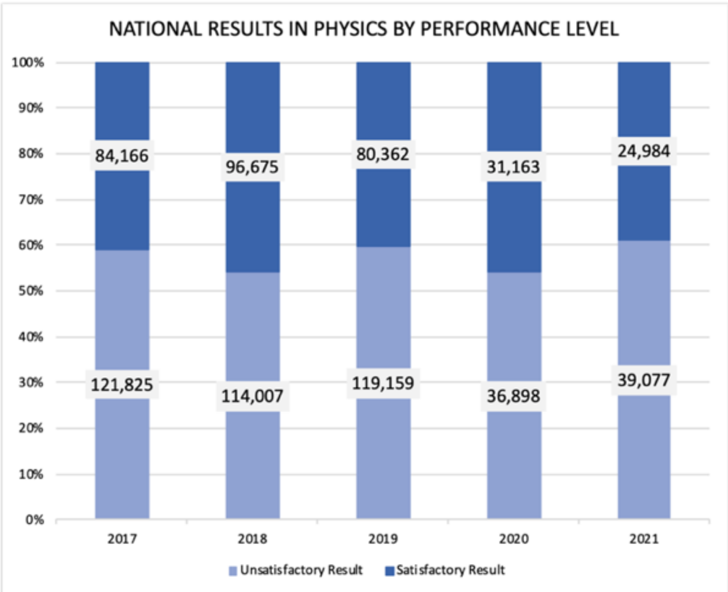
INTRODUCTION

In the graphic 1 can be seen that in the results of the year 2021 in the area of science, according to the Centro Nacional de Evaluación para la Educación Superior [CENEVAL] (2021) Results Report, 61% of young Mexicans who took EXANI II as a selection method for admission to a University in the area of Engineering and Technology, obtained an unsatisfactory result in the physics area, while 39% managed to obtain a satisfactory result (CENEVAL, 2021). In the previous year 2020, according to the CENEVAL 2020 Results Report, 54% obtained an unsatisfactory result in the physics area, while only 46% obtained a satisfactory result (CENEVAL, 2020). In the 2019 results for the science area, according to the CENEVAL 2019 Results Report, 59.72% obtained an unsatisfactory result in the physics area and only 40.27% managed to obtain a satisfactory result (CENEVAL, 2019). In 2018, 54% obtained an unsatisfactory result and 46% obtained a satisfactory result (CENEVAL, 2018). Finally, according to the CENEVAL 2017 Results Report, 59% obtained an unsatisfactory result in the physics area and only 41% obtained a satisfactory result (CENEVAL, 2017), this demonstrates the deficiency in knowledge of physics that young people present when entering their university studies.

Graphic 1

Results of the national entrance examination to higher education in the years 2017 to 2021



Source: EXANI-II Diagnosis: Engineering and Technology Module.

Derived from the results obtained in the EXANI-II Diagnosis: Engineering and Technology Module, there is a great problem in Higher Education Institutions in Mexico, due to the fact that new students have knowledge deficiencies in the area of science. The teaching methodologies in traditional education cause students to lose interest in learning sciences such as physics by not using the information technologies that characterize this new generation of digital natives, as tools to support the learning process.

The students' demotivation and their lack of interest in learning, is a continuous subject of debate and reproach among the educational community. Many authors say that the cause of this demotivation is the fact that we still use traditional education in the classroom. In the article "Schoolchildren without motivation" presented in the newspaper La Vanguardia, specialists agree that there are problems of adaptation, content, methods, strategies and even commitment on the part of teachers and families (Rius, 2010). “Many students, even without being fully aware, become demotivated due to lack of sufficient stimuli in the classroom; their interests are not always taken into account in programming, and the educational process continues to be more focused on teaching and teachers than on learning and students” (Martínez-Otero, 2009). "The school is a modern institution, but society is already postmodern, you can not continue using the traditional school of modern times in the classroom" (Feito, 2009). And finally, other specialists believe that adolescents are currently apathetic towards studying and expect to be motivated by their parents or by their teachers to arouse and maintain their interest in it, which represents a risk in that it implies the other pole of apathy: rebellious aggression, point out that the first challenge is to make the school seduce, interest and provoke curiosity (Flores et al., 2013).

This article proposes the design of a strategy for the use of free access digital simulators, for the Physics Foundations course students in the second quarter of the Academic Program of Engineering in Animation and Visual Effects of the Polytechnic University of Sinaloa (UPSIN), seeking to increase their interest in learning physical sciences, as well as offer a basic starting point that helps teachers and researchers to consider all the necessary characteristics for the design of strategies for the use of free access digital simulators in various subjects.

In section II of the article, concepts related to the use of technology, the role they play in education, as well as the advantages that digital simulators represent as enhancers of student learning are discussed. In section III, the methodology developed in the research is explained, as well as the digital simulators used to fulfill the learning objectives to be achieved in the Physics Foundations subject, which are PHET, I.E.S. Aguilar and Cano and Freefall Motion Virtual Lab. In section IV, the results obtained by putting into practice in the classroom the use of simulators to analyze the topics of free fall, vertical shooting and parabolic shooting are analyzed. Finally, in section V of conclusions, it is warned about the advantage of the implementation of free digital simulators in the use for educational training in students since it encourages learning through their own experience, posing situations similar to reality.

METHODOLOGY

The subject Fundamentals of Physics taught in the second quarter of the UPSIN Animation and Visual Effects Engineering Academic Program aims to enable students to understand natural phenomena related to movement, electricity and optics through the understanding of the elementary laws of physics that provide the bases to develop new knowledge. The third learning unit consists of the fundamentals of statics, kinematics and dynamics and it explains the basic concepts of movement, movement in two dimensions, the applications of statics, as well as the concepts and applications of dynamics. One of the expected learning outcomes is that the student is able to calculate the displacement, velocity and acceleration of the particles without considering the causes that generate them to describe their movement.

Seeking to comply with the expected learning result, the design of a strategy for the use of digital simulators for the teaching of free fall, vertical shooting and parabolic shooting is proposed; thus, allowing students to carry out the necessary simulations to analyze these issues and to solve a series of exercises that will allow them to reason about the use of each simulator.

After analyzing the various existing free access digital simulators to explain freefall, vertical shooting and parabolic shooting, it was determined that the simulators to be used for each of the topics are those shown in Table 5; This is due to the fact that these simulators are free of charge, their affinity with the expected learning results in the third unit of the Physics Foundations subject, their attractive design, the ease of use and the feasibility of using them from any computer with access to Internet.

Table 1

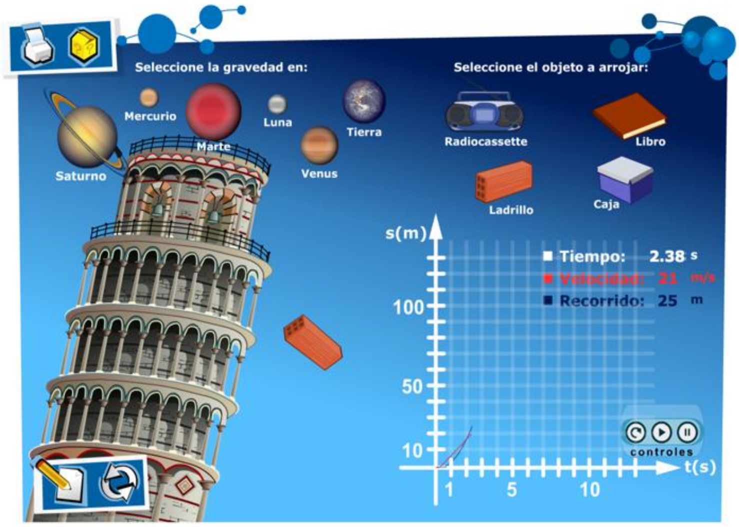
Selected free access digital simulators

Phenomena	Simulation Tool	Reference
Freefall	Freefall Motion Virtual Lab	https://conteni2.educarex.es/mats/14357/contenido/
Vertical Shot	I.E.S. Aguilar y Cano	http://www.iesaguilarycano.com/dpto/fyq/clibre.html
Parabolic Shot	PHET proyectil movement	https://phet.colorado.edu/es/simulation/projectile-motion

In the simulator called Freefall Motion Virtual Lab, students can understand in a practical way the theme of freefall, experiencing the result of throwing a brick, a box, a book and a radio cassette player on various planets such as Earth or Venus, thus being able to appreciate the time, the speed and the route that each object presents if they are thrown from the same height that corresponds to the last level of the Pisa Tower. This simulator can be seen in figure 1.

Figure 1

Digital freefall simulator



On the other hand, in figure 2 you can see the simulator called I.E.S. Aguilar and Cano, in which students can understand in a practical way the subject of vertical shooting, experiencing the result of throwing a ball up playing with the values of initial velocity and initial height, thus being able to observe the variations obtained as soon as to height-time and velocity-time.

Figure 2

Vertical shot digital simulator

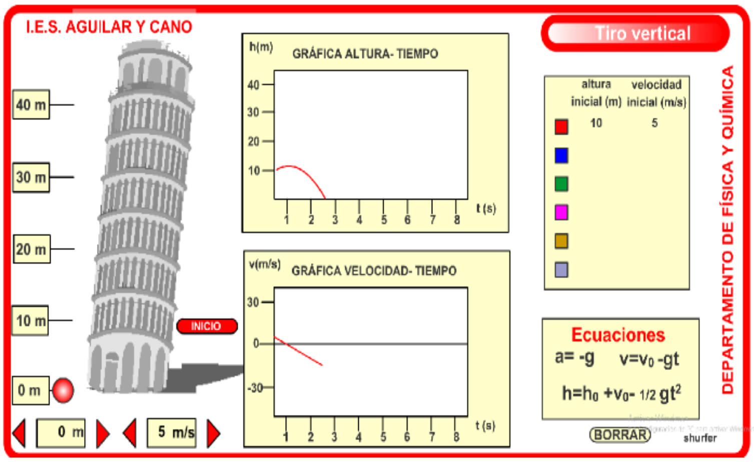
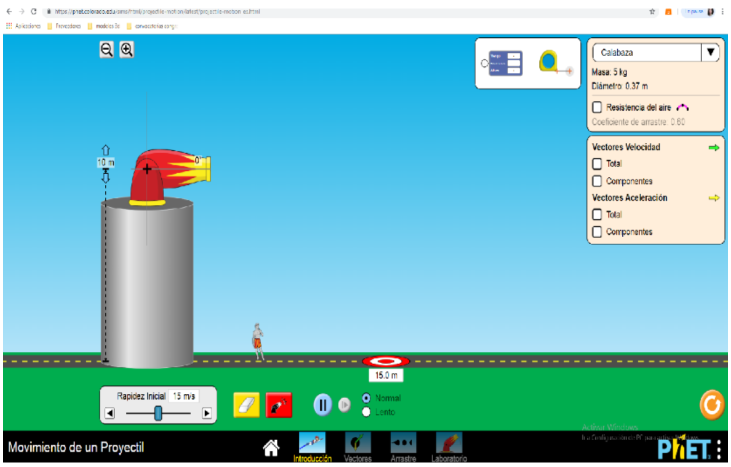


Figure 3 shows the projectile movement Phet simulator, where students can understand the topic of parabolic shooting by experiencing the result of launching various objects from a cannon such as a pumpkin, a ball, a piano, a human, among others, varying the values of height, angle, mass and diameter; managing to observe in this way the speed, acceleration, height and distance obtained in each shot variant.

Figure 3

Parabolic shot digital Simulator



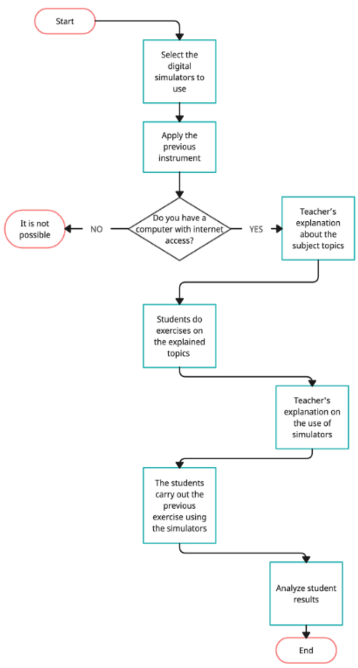
Before designing the strategy to implement the use of digital simulators in the teaching of physics, it is necessary to analyze the situation and characteristics that correspond to the group of students that will use them, this through the application of an instrument that has the objective to know common descriptive information about them in terms of age, gender, if they have a computer with internet access, as well as qualitative information about their opinion about digital simulators, if they know them, if they have used them, what do they think about them and if they think they would help to learn physics. The information collected with this instrument will make it possible to determine if it is feasible to implement this strategy with the selected group of students and adapt it to their particular characteristics, clarifying that if the students do not have a computer with Internet access or if the Educational Institution cannot provide it, implementing this strategy is not feasible.

The next step in the strategy, as can be seen in figure 4, corresponds to the explanation by the teacher of the subjects topics in which the digital simulators will be used, in this case the topics of free fall, vertical shooting and parabolic shot; in such a way that later the students can solve a series of exercises on these topics. Once the students finish to solve the exercises, the teacher must explain to the students how to use each of the simulators and thus solve the previous exercises again, but now supported by the use of digital simulators. Finally, it will be necessary to analyze the results obtained by the students in both applications of the exercises, seeking in this way to have a clarity of the benefits generated by the use of digital simulators.

In relation to the user interfaces of the simulators used in the research, it is important to comment that in the three practices carried out by the students, previously designed and developed free access digital simulators were used, one of them by the interactive simulations project of PhET from the University of Colorado at Boulder who create free interactive math and science simulations. PhET simulations are based on extensive educational research and engage students through an intuitive, game-like environment where they learn by exploring and discovering. The interfaces of the three simulators used were designed in a friendly way so that anyone with little experience in the use of technologies will be able to understand. The three simulators require internet access in order to be used, so it is important to mention that 90% of the students who participated in the research have a laptop and internet access, so there were no comprehension problems about the use of the simulators nor with the access to them.

Figure 4

Flowchart of the teaching strategy using digital simulators



In the research, a total of 105 students participated using free access simulators to teach them the topics free fall, vertical shot and parabolic shot, during the third grade cut of the quarter January-April 2019, in the subject Fundamentals of Physics, which is part of the Engineering in Animation and Visual Effects curriculum at the Polytechnic University of Sinaloa. Worked with a population size of 35 students per group, with a desired confidence level of 95% and a desired precision of 6%. Therefore, the representative sample size is 31 students per group, making a total of 93 students corresponding to the three groups involved in this research project.

LITERATURE REVIEW

Use of technology in education

Information and communication technologies (ICT) are a set of technologies developed to store, process and manage information. Today, ICTs have been integrated into our lives in such a way that they have transformed it, and have allowed us to access knowledge, information and learning (Mendoza & Placencia, 2018). In this context, United Nations Educational, Scientific and Cultural Organization [UNESCO] (2013) indicates that: The use of ICT in education has a multiplier effect throughout the entire educational process, emphasizes learning and provides students with new skills, facilitates and improves the training of teaching, it also gives people a better chance to compete in the global economy (pp. 5-19).

The concept of educational technology is the training in science, technology, research and ethics that is responsible for the study of media and information and communication technologies, in terms of forms of representation, dissemination, access to knowledge and culture, of according to the different didactic and psychological paradigms applied to different educational contexts such as formal, non-formal and informal education (Jiménez-Saavedra, 2014).

The role of computers, based on models and simulations, is becoming increasingly important in the teaching-learning process of science classes, due to the explosion in scientific information and its availability through the wide world wide web. Computer simulations help students understand the invisible conceptual world of science through animation, which can lead to a greater understanding of scientific concepts. The strength of simulations is that they force students to retrieve or discover relevant knowledge and experience problem-solving skills in authentic situations (Hwang, 2006, pp. 91-100).

Dynamic and interactive educational computer simulations designed to teach complex concepts and processes are becoming increasingly popular in all areas of science education, including chemistry, physics, and biology. A great advantage of learning with interactive simulations is that it allows the student to change variables in complex systems, manipulate parameters and receive direct feedback on the changes made (Holzinger et al., 2009).

Simulators are learning objects that, through a software program, try to model part of a replica of the phenomena of reality and their purpose is for the user to build knowledge from exploratory work, inference and discovery learning (Díaz, 2017). Digital simulators are interactive applications that simulate situations of real physical experiments or that illustrate mathematical topics (Díaz, 2018). They are programs that represent a model or dynamic environment, and that through graphics or animations provide the student with a vision of what is happening in the environment that is being simulated, so that, by interactively modifying the characteristics of the environment, they can better understand what is happening in the environment you are trying to learn about. Given the updating of technology, we must always be looking for new simulators that are more effective and interesting (Ortega & Bravo, 2001).

The literature suggests that the success of computer simulations in science education depends on how they are incorporated into the curriculum and how teachers use them. Simulations have developed a great interest due to the potential that their interactivity offers to achieve constructivist learning, where the student interacts with real world experiences (Sahin, 2006).

Educational simulations allow students to learn more from simulated experiences built into the game than from teacher-delivered lectures or explanations. These authors establish that the simulation teaching model requires careful articulation by the teacher and that their capacity is crucial to enhance the learning that emerges from the simulation and make the activities really meaningful situations (Joyce et al., 2002).

In the study at Midwestern State University with 78 students from the GNSC 1104 (Life/Earth Science) and GNSC 1204 (Physical Science) course whose objective was to know the effectiveness of simulations integrated into the traditional curriculum of a general level science course undergraduate, demonstrated that they can motivate students to commit to their learning and have a more active role. Through quantitative and qualitative methods, it was documented that the simulations have a positive impact on the learners, which is evidenced in the test scores (Lunce, 2007, pp. 88-104).

There are a wide variety of digital simulator developers that make them available to the general public, such as those provided by PhET, UNAM, Logisim, CircuitLab, LogicJy, the logic lab, logic circuit test, DC/AC lab, ohm zone, among others. In addition to this, it is possible to develop simulators tailored to the academic needs of each topic of a subject, through the use of programming languages, as well as graphics and animation generation software; making practically unlimited the possibility of using digital simulators in the teaching field.

Historical results of CENEVAL in physics area

The academic lag at the regional level that the young people of the Millennial generation presented in the area of physics in 2017 and 2018, can be observed in the results of CENEVAL 2017 and CENEVAL 2018. According to the results obtained in the Northwest Region, to which the Polytechnic University of Sinaloa belongs, in 2017 55.99% of the supporters obtained unsatisfactory results and 43.87% obtained satisfactory results, while in 2018, 52.25% obtained unsatisfactory results and only 47.61% obtained satisfactory results, as shown in Table 1. Even if the information shows a balance between unsatisfactory and satisfactory results, there is evidence that a large percentage of students have deficiencies in the area of physics, the ideal would be to obtain a very low or zero percentage of unsatisfactory results. In table 2, it can be seen that in 2019, 60.23% obtained an unsatisfactory result in the area of physics while only the 39.61% obtained satisfactory results, in 2020, 50.27% % of the supporters obtained unsatisfactory results and 47.65% obtained satisfactory results; finally, in 2021, 55.12% obtained unsatisfactory results and 39.71% obtained satisfactory results, which shows a high deficiency of knowledge in the area of physics in students from the Northwest region of Mexico.

Table 2

Results of the NORTHWEST region of the national entrance exam for higher education in 2017 and 2018, EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2017 and EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2018

			2017					2018				
Region	**Variable**	**Category**	**N**	**Region %**	**Physics**			**N**	**Region %**	**Physics**		
					SD %	**I %**	**S %**			**SD %**	**I %**	**S %**
Northwest	Gender	Men	24 218	74.92	0.1	40.06	34.76	25 361	74.98	0.11	37.55	37.32
		Women	8 097	25.05	0.04	15.91	9.10	8 455	25.00	0.04	14.68	10.29
		NVA	9	0.03	0	0.02	0.01	9	0.03	0.00	0.02	0.01
	Regime	Public	28 293	87.53	0.11	49.18	38.24	29 307	86.64	0.12	45.49	41.03
		Private	3 824	11.83	0.03	6.48	5.32	4 298	12.71	0.02	6.47	6.21
		NVA	207	0.64	0	0.33	0.31	220	0.65	0.00	0.28	0.37
	Modality	General high school	17 250	53.37	0.08	29.10	24.19	18 117	53.56	0.07	27.12	26.37
		Technological high school	10 873	33.64	0.03	18.22	15.38	11 262	33.29	0.04	16.72	16.53
		Technical Professional	3 537	10.94	0.02	7.35	3.57	3 696	10.93	0.02	7.02	3.89
		Intercultural high school	19	0.06	0	0.03	0.03	30	0.09	0.00	0.04	0.04
		International high school	85	0.26	0	0.15	0.11	99	0.29	0.00	0.13	0.16
		TV high school	353	1.09	0	0.80	0.29	401	1.19	0.01	0.93	0.24
		NVA	207	0.64	0	0.33	0.31	220	0.65	0.00	0.28	0.37
	Average	6.0-6.9	626	1.94	0	1.34	0.59	821	2.43	0.00	1.55	0.88
		7.0-7.9	8 090	25.03	0.05	16.01	8.97	7 581	22.41	0.03	13.81	8.57
		8.0-8.9	15 106	46.73	0.06	26.86	19.82	15 316	45.28	0.07	24.92	20.29
		9.0-9.9	8 122	25.13	0.02	11.28	13.82	8 970	26.52	0.03	10.50	15.99
		10	173	0.54	0	0.17	0.36	387	1.14	0.00	0.27	0.87
		NVA	207	0.64	0	0.33	0.31	750	2.22	0.01	1.19	1.01
	Total		32 324	100	0.13	55.99	43.87	33 825	100	0.14	52.25	47.61

Source: Northwest EXANI-II Diagnosis: Engineering and Technology Module.

Table 3

Results of the NORTHWEST region of the national entrance exam for higher education in 2019 to 2021, EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2019, EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2020 and EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2021

			2019					2020					2021				
Region	Variable	Category	N	Region %	Physics			N	Region %	Physics			N	Region %	Physics		
					SD %	I %	S %			SD %	I %	S %			SD %	I %	S %
Northwest	Gender	Men	24 659	75.58	0.12	43.30	32.17	9 294	75.95	1.70	36.41	37.84	46,300	75.75	4.10	39.75	31.91
		Women	7 942	24.34	0.04	16.88	7.42	2 943	24.05	0.38	13.87	9.81	17,226	24.24	1.08	15.36	7.80
		NVA	24	0.07	0.00	0.05	0.02	0	0.00	0.00	0.00	0.00	535	0.01	0.00	0.01	0.00
	Regime	Public	28 963	86.02	0.12	51.60	34.30	10 674	87.23	1.88	44.73	40.61	54,004	87.00	4.56	49.30	33.14
		Private	4 474	13.71	0.04	8.45	5.22	1 563	12.77	0.20	5.54	7.04	9,531	12.98	0.61	5.80	6.57
		NVA	88	0.27	0.00	0.18	0.09	0	0.00	0.00	0.00	0.00	526	0.01	0.00	0.01	0.00
	Modality	General high school	17 108	52.44	0.07	30.59	21.78	6 982	57.06	1.05	27.46	28.55	35,084	59.08	2.99	31.61	24.48
		Technological high school	10 670	32.70	0.08	19.23	13.40	3 800	31.05	0.71	15.26	15.09	20,711	29.82	1.56	16.53	11.73
		Technical Pressional	4 287	13.14	0.01	9.09	4.04	1 306	10.67	0.29	6.77	3.61	6,819	9.58	0.55	5.98	3.06
		Intercultural high school	20	0.06	0.00	0.03	0.03	9	0.07	0.00	0.04	0.03	53	0.07	0.00	0.03	0.04
		International high school	101	0.31	0.00	0.20	0.11	30	0.25	0.00	0.07	0.18	107	0.22	0.00	0.15	0.07
		TV high school	351	1.08	0.01	0.91	0.17	110	0.90	0.02	0.69	0.19	761	1.22	0.08	0.81	0.33
		NVA	88	0.27	0.00	0.18	0.09	0	0.00	0.00	0.00	0.00	526	0.01	0.00	0.01	0.00
	Average	6.0-6.9	872	2.67	0.00	1.87	0.81	152	1.24	0.02	0.79	0.43	1,329	1.16	0.07	0.81	0.29
		7.0-7.9	7 063	21.65	0.04	15.07	6.54	2 418	19.76	0.47	12.09	7.20	15,580	18.94	1.17	12.52	5.24
		8.0-8.9	14 761	45.24	0.06	28.37	16.81	5 608	45.83	1.05	24.97	19.82	28,783	43.16	2.28	26.01	14.87
		9.0-9.9	8 874	27.20	0.04	13.11	14.06	3 906	31.92	0.54	12.18	19.20	17,167	34.80	1.58	15.02	18.20
		10	327	1.00	0.00	0.32	0.67	153	1.25	0.00	0.25	1.00	529	1.57	0.07	0.44	1.06
		NVA	728	2.23	0.02	1.50	0.72	0	0.00	0.00	0.00	0.00	673	0.37	0.00	0.33	0.04
	Total		32 625	100	0.16	60.23	39.61	12 237	100	2.08	50.27	47.65	64,061	100	5.17	55.12	39.71

Source: Northwest EXANI-II Diagnosis: Engineering and Technology Module.

On the other hand, in Table 3 it can be seen that at Sinaloa the percentage of unsatisfactory results for the physics area increases, reaching 60.70% against 39.21% of satisfactory results in 2017; while in 2018 the unsatisfactory results were 53.57% and the satisfactory results were 46.36%. In table 4 it can be observed that in 2019, 59.42% of the supporters obtained unsatisfactory results and 40.50% obtained a satisfactory result, then in 2020, 51.29% obtained unsatisfactory results and 46.63% obtained a satisfactory result, and finally in 2021, 55.13% obtained unsatisfactory results and 39.17% obtained a satisfactory result.

Table 4

Results of the Sinaloa State of the national entrance exam for higher education in 2017 and 2018, EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2017 and EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2018

2017								2018				
State	**Variable**	**Category**	**N**	**State %**	**Physics**			**N**	**State %**	**Physics**		
					SD %	**I %**	**S %**			**SD %**	**I %**	**S %**
SINALOA	Gender	Men	5 794	75,76	0,07	43,92	31,77	6 002	74,89	0,06	39,07	35,76
		Women	1 849	24,18	0,03	16,74	7,41	2 009	25,07	0,01	14,46	10,59
		NVA	5	0,07	0,00	0,04	0,03	3	0,04	0,00	0,04	0,00
	Regime	Public	6 826	89,25	0,08	55,06	34,11	7 109	88,71	0,06	48,40	40,24
		Private	780	10,20	0,01	5,41	4,77	786	9,81	0,01	4,55	5,24
		NVA	42	0,55	0,00	0,22	0,33	119	1,48	0,00	0,61	0,87
	Modality	General high school	5 195	67,93	0,07	42,17	25,69	5 366	66,96	0,04	35,66	31,26
		Technological high school	1 658	21,68	0,03	11,66	9,99	1 765	22,02	0,04	11,50	10,48
		Technical Professional	678	8,87	0,00	5,90	2,97	653	8,15	0,00	4,80	3,34
		Intercultural high school	3	0,04	0,00	0,00	0,04	3	0,04	0,00	0,01	0,02
		International high school	24	0,31	0,00	0,25	0,07	24	0,26	0,00	0,17	0,09
		TV high school	48	0,63	0,00	0,50	0,13	87	1,09	0,00	0,80	0,29
		NVA	42	0,55	0,00	0,22	0,33	119	1,48	0,00	0,61	0,87
	Average	6.0-6.9	136	1,78	0,00	1,40	0,38	138	1,72	0,00	1,26	0,46
		7.0-7.9	1 569	20,52	0,01	14,50	6,00	1 532	19,12	0,02	12,89	6,20
		8.0-8.9	3 290	43,02	0,05	27,81	15,15	3 318	41,40	0,04	24,42	16,95
		9.0-9.9	2 508	32,79	0,03	16,29	16,47	2 673	33,35	0,01	13,64	19,70
		10	103	1,35	0,00	0,47	0,88	234	2,92	0,00	0,75	2,17
		NVA	42	0,55	0,00	0,22	0,33	119	1,48	0,00	0,61	0,87

	Total	7 648	100	0,09	60,70	39,21	8 014	100	0,07	53,57	46,36

Source: Sinaloa EXANI-II Diagnosis: Engineering and Technology Module.

Table 5

Results of the Sinaloa State of the national entrance exam for higher education in 2019 to 2021, EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2019, EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2020 and EXANI-II Diagnosis: Engineering and Technology Module of CENEVAL 2021

2019								**2020**					**2021**				
State	**Variable**	**Category**	**N**	**State %**	**Physics**			**N**	**State %**	**Physics**			**N**	**State %**	**Physics**		
					SD %	**I %**	**S %**			**SD %**	**I %**	**S %**			**SD %**	**I %**	**S %**
Sinaloa	Gender	Men	5 487	75,43	0,05	43,21	32,17	3 911	76,94	1,59	38,05	37,30	2.448	75,86	4,37	40,01	31,48
		Women	1 787	24,57	0,03	16,21	8,33	1 172	23,06	0,49	13,24	9,33	779	24,14	1,33	14,81	7,69
		NVA	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00
	Regime	Public	6 515	89,57	0,06	54,29	35,22	4 550	89,51	1,89	46,78	40,84	2.822	87,45	4,96	49,67	32,82
		Private	747	10,27	0,03	5,07	5,17	533	10,49	0,20	4,51	5,78	405	12,55	0,74	5,45	6,35
		NVA	12	0,16	0,00	0,05	0,11	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00
	Modality	General high school	5 113	70,29	0,05	41,85	28,39	3 458	68,03	1,24	35,53	31,26	1.919	59,47	4,09	39,45	26,87
		Technological high school	1 440	19,80	0,03	11,04	8,73	1 132	22,27	0,59	9,94	11,75	615	19,06	1,08	9,98	8,96
		Technical Pressional	636	8,74	0,00	5,60	3,15	440	8,66	0,22	5,06	3,38	247	7,65	0,40	4,77	3,01
		Intercultural high school	2	0,03	0,00	0,03	0,00	4	0,08	0,00	0,08	0,00	0	0,00	0,00	0,03	0,00
		Internacional high school	20	0,27	0,00	0,19	0,08	6	0,12	0,00	0,02	0,10	5	0,15	0,00	0,15	0,03
		TV high school	51	0,70	0,00	0,66	0,04	43	0,85	0,04	0,67	0,14	36	1,12	0,12	0,74	0,31
		NVA	12	0,16	0,00	0,05	0,11	0	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	0,00
	Average	6.0-6.9	105	1,44	0,00	1,17	0,27	53	1,04	0,02	0,69	0,33	38	1,18	0,09	0,68	0,40
		7.0-7.9	1 424	19,58	0,03	14,17	5,38	862	16,96	0,43	11,06	5,47	566	17,54	1,18	11,62	4,74

		8.0-8.9	3 034	41,71	0,03	26,85	14,83	2 115	41,61	0,98	23,75	16,88	1.293	40,07	2,45	24,42	13,20
		9.0-9.9	2 521	34,66	0,01	16,50	18,15	1 939	38,15	0,65	15,33	22,17	1.226	37,99	1,83	17,14	19,03
		10	178	2,45	0,01	0,67	1,76	114	2,24	0,00	0,47	1,77	78	2,42	0,15	0,56	1,70
		NVA	12	0,16	0,00	0,05	0,11	0	0,00	0,00	0,00	0,00	26	0,81	0,00	0,71	0,09
	Total		7 274	100	0,08	59,42	40,50	5 983	100	2,09	51,29	46,63	3.227	100	5,70	55,13	39,17

Source: Sinaloa EXANI-II Diagnosis: Engineering and Technology Module.

In summary, the recurring prevalence of unsatisfactory physics outcomes among the Millennial generation, particularly in the Northwest region of Mexico, underscores a substantial knowledge deficit in this field. These findings emphasize the pressing need for innovative strategies, such as the proposed utilization of digital simulators, to foster interest and enhance comprehension among students, thereby addressing the persisting academic gap in physics education.

RESULTS

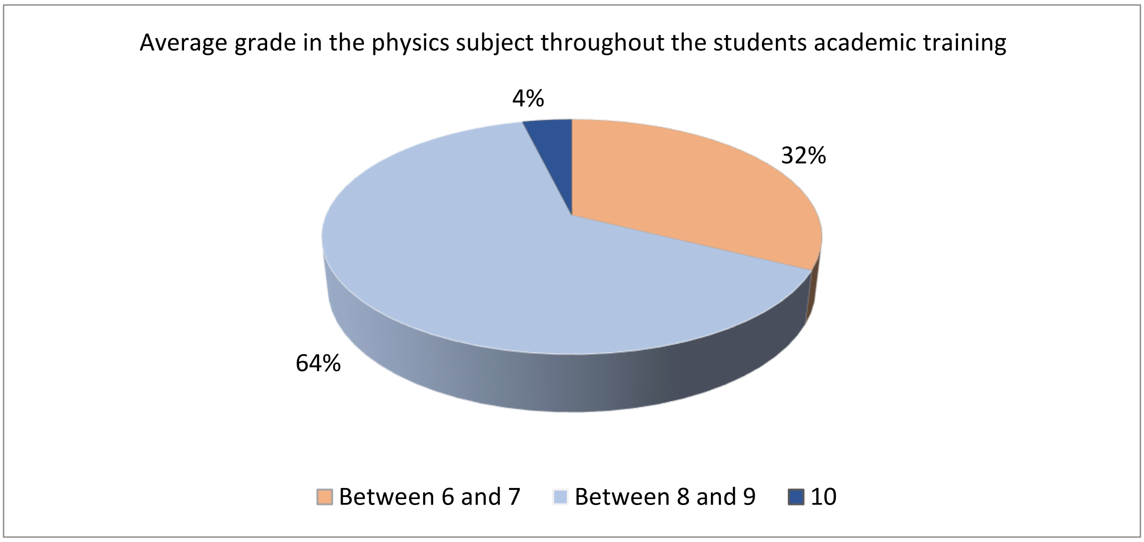
Prior to the application of the didactic strategy using digital simulators for the teaching of physics, a survey was applied to 105 students of the second quarter of the Engineering in Animation and Visual Effects Academic Program at UPSIN, to know the population subject to study, which is made up of 58% men, 39% women and 2.8% without gender specification, while 87% are between 17 and 19 years old and 13% are between 20 and 30 years old.

For this research project it is important to define the number of students who have a computer and Internet access. When applying the previous instrument, the students defined that 86% have a desktop or laptop computer, while 14% do not have one, in addition, 90% have internet at home and only 10% do not have internet, it is important to mention that this 10% will be able to access the digital simulators because UPSIN has free internet in its facilities. On the other hand, 97% of the students to whom the previous instrument was applied have a mobile device and only 3% do not have one.

Within the previous instrument, the students were consulted about their like and interest in learning physics, obtaining that 63% indicate having an interest in learning physics and 37% are indifferent or without interest in learning it; on the other hand, 36% indicate that they like the physics subject and 64% do not show a real like for the subject. In the same way, they were asked about their academic performance throughout their academic training in the physics subject, it can be seen in figure 6, that 64% of the students have obtained grades between 6 and 7, that is, only what minimum necessary to pass, while only 4% have obtained grades of 10 and 32% grades between 8 and 9.

Graphic 2

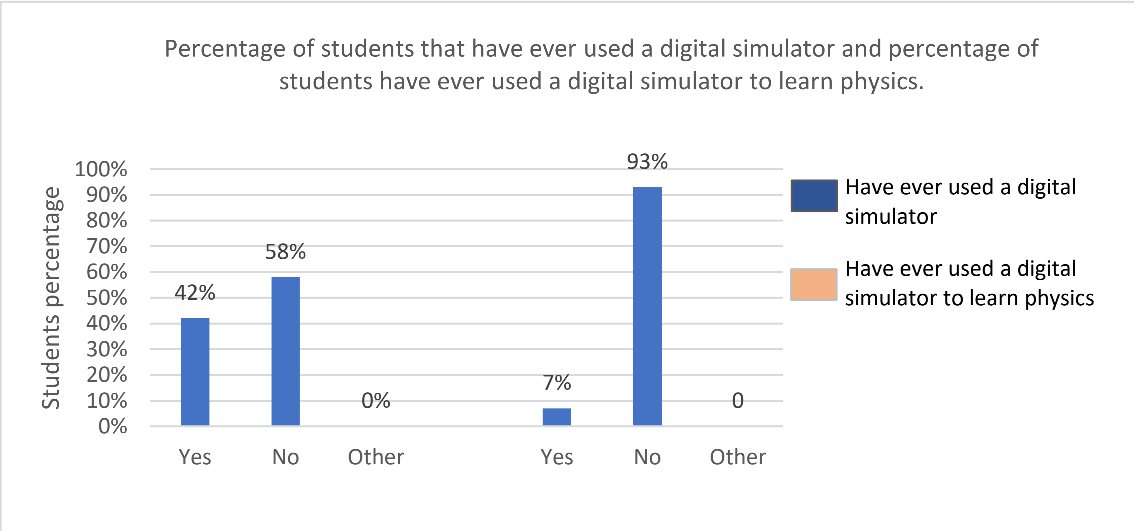
Average grade in physics throughout the academic training of the second quarter students who are studying the subject Fundamentals of Physics in the Academic Program of Engineering in Animation and Visual Effects, surveyed in the previous instrument



In figure 7, it can be seen that 42% of the students indicate that they have ever used a digital simulator and 58% indicate that they have never used it; while only 7% indicate having ever used a digital simulator to learn physics and 93% have never used it. In addition, 97% indicated that if they had access to a digital physics simulator they would use it and only 3% would not use it, while 99% of the students established that using digital physics simulators would increase their interest in learning this subject and 98% consider that it would increase their academic performance.

Graphic 3

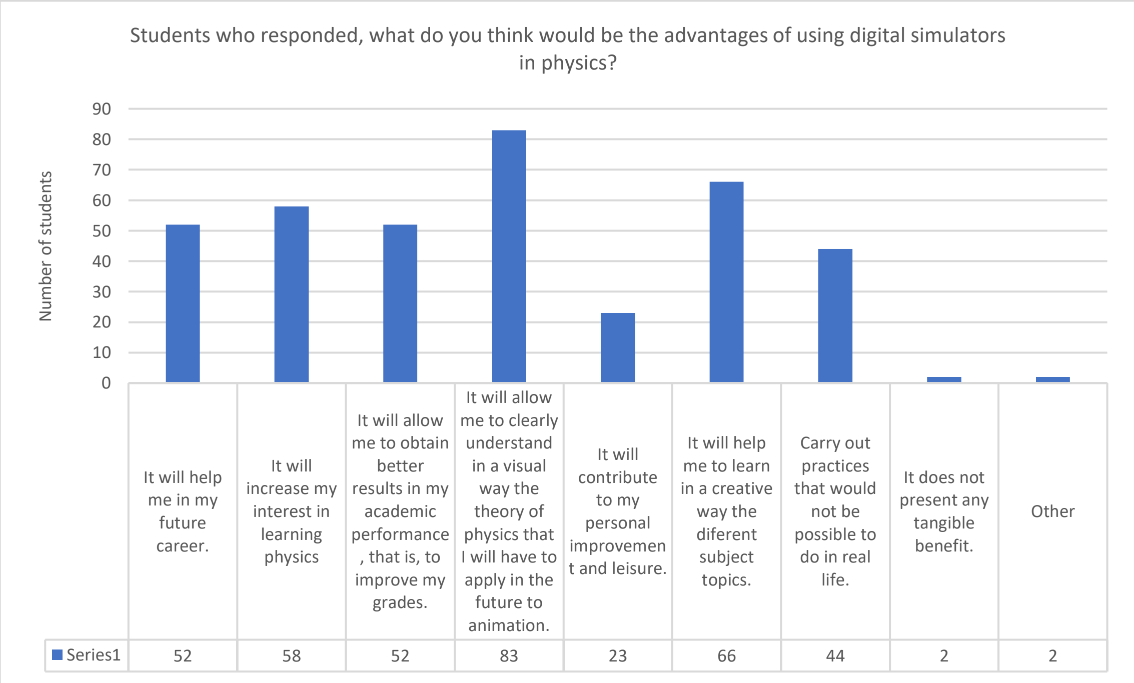
Use of digital simulators by second quarter students who are studying the subject Fundamentals of Physics in the Academic Program of Engineering in Animation and Visual Effects, surveyed in the previous instrument



The students were consulted about the main advantages of using digital simulators in the physics subject, resulting as the main advantage, obtaining better results in their academic performance, that is, improving their grades and secondly that it would help them learn from a creative way the various topics of the subject. These results can be seen in figure 8. Finally, the students were asked about their interest in using digital simulators in the Physics Fundamentals subject, to which 97% indicated that they were interested in using them and only 3% did not agree to do so. These results can be seen in graphic 4.

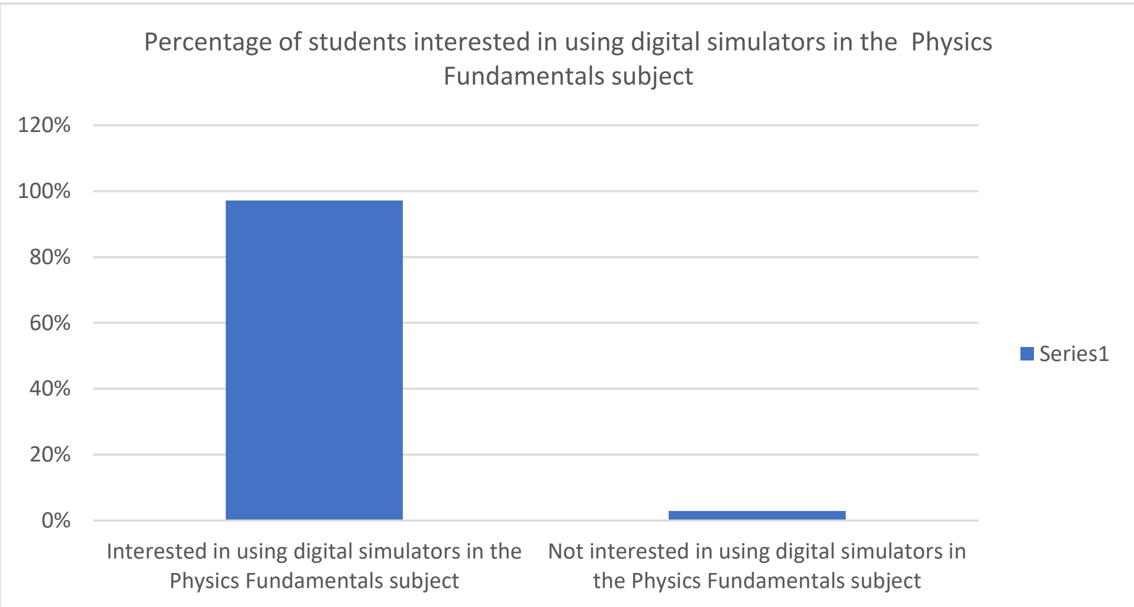
Graphic 4

Advantages of using digital physics simulators, by second quarter students who are studying the subject Fundamentals of Physics in the Academic Program of Engineering in Animation and Visual Effects, surveyed in the previous instrument



Graphic 5

Percentage of students interested in using digital simulators in the Physics Fundamentals subject

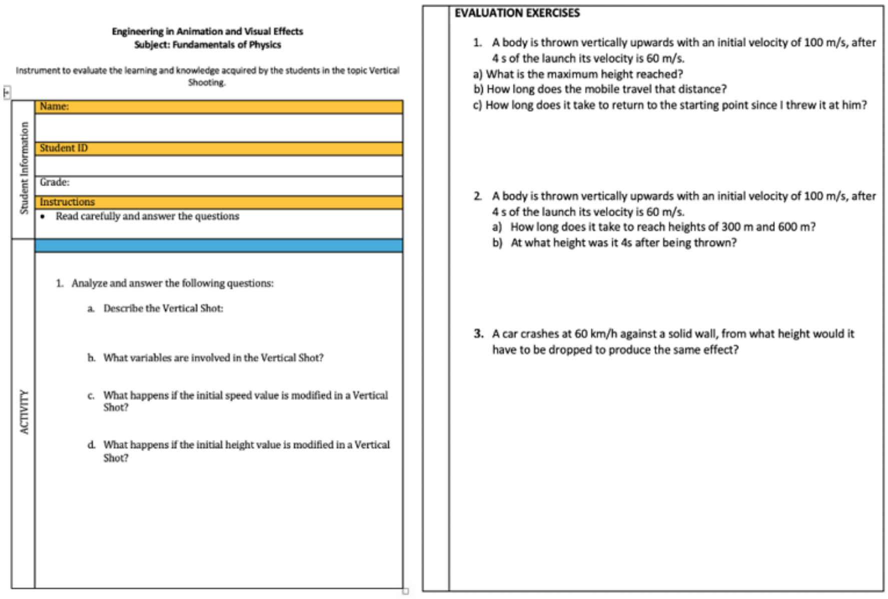


Derived from the results obtained in the application of the instrument, it was determined that there is viability to generate the design of a strategy that allows the use of digital simulators in the teaching of the subject fundamentals of physics for the students of the second quarter of Engineering in Animation and Visual Effects at UPSIN. Within the design of this strategy, an exercise was generated for each topic, which must be applied to the students before using the digital simulators. It is recommended that the teacher previously explain the concepts of free fall, vertical shot and parabolic shot and thus know the scope of the knowledge acquired by the students with the teacher's explanation. Finally, students must perform the same exercises again using digital simulators, thus seeking to compare both results.

The instrument to evaluate the topic vertical shot can be seen in figure 10, it consists of 4 open questions on the topic that allow the student to reason about the concepts involved; as well as the approach of 3 problems in which they have to obtain results related to the topic of vertical shooting.

Figure 4

Evaluation applied to the students of the second quarter of Engineering in Animation and Visual Effects at UPSIN studying the subject Fundamentals of Physics, to determine the knowledge acquired on the topic Vertical Shooting



Engineering in Animation and Visual Effects
Subject: Fundamentals of Physics

Instrument to evaluate the learning and knowledge acquired by the students in the topic Vertical Shooting.

Student Information
Name:
Student ID
Grade:
Instructions
- Read carefully and answer the questions

ACTIVITY
1. Analyze and answer the following questions:
   a. Describe the Vertical Shot:
   b. What variables are involved in the Vertical Shot?
   c. What happens if the initial speed value is modified in a Vertical Shot?
   d. What happens if the initial height value is modified in a Vertical Shot?

EVALUATION EXERCISES

1. A body is thrown vertically upwards with an initial velocity of 100 m/s, after 4 s of the launch its velocity is 60 m/s.
a) What is the maximum height reached?
b) How long does the mobile travel that distance?
c) How long does it take to return to the starting point since I threw it at him?

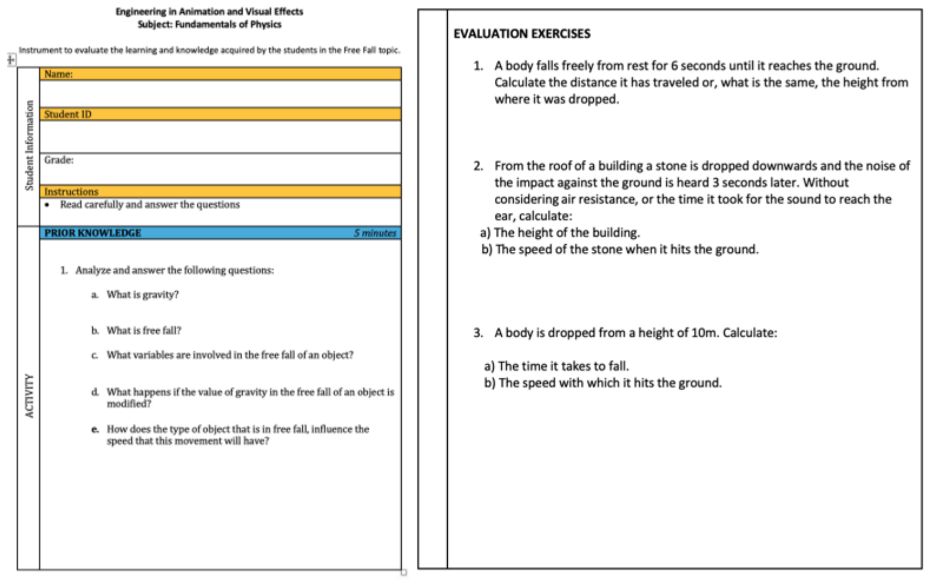
2. A body is thrown vertically upwards with an initial velocity of 100 m/s, after 4 s of the launch its velocity is 60 m/s.
   a) How long does it take to reach heights of 300 m and 600 m?
   b) At what height was it 4s after being thrown?

3. A car crashes at 60 km/h against a solid wall, from what height would it have to be dropped to produce the same effect?

The instrument to evaluate the topic free fall can be seen in figure 5, it consists of 5 open questions on the topic that allow the student to reason about the concepts involved; as well as the approach of 3 problems in which they have to obtain results related to the topic of free fall.

Figure 5

Evaluation applied to the students of the second quarter of Engineering in Animation and Visual Effects at UPSIN studying the subject Fundamentals of Physics, to determine the knowledge acquired on the topic Free Fall


Engineering in Animation and Visual Effects
Subject: Fundamentals of Physics

Instrument to evaluate the learning and knowledge acquired by the students in the Free Fall topic.

Student Information

Name:

Student ID

Grade:

Instructions

- Read carefully and answer the questions

PRIOR KNOWLEDGE — 5 minutes

ACTIVITY

1. Analyze and answer the following questions:
   a. What is gravity?
   b. What is free fall?
   c. What variables are involved in the free fall of an object?
   d. What happens if the value of gravity in the free fall of an object is modified?
   e. How does the type of object that is in free fall, influence the speed that this movement will have?

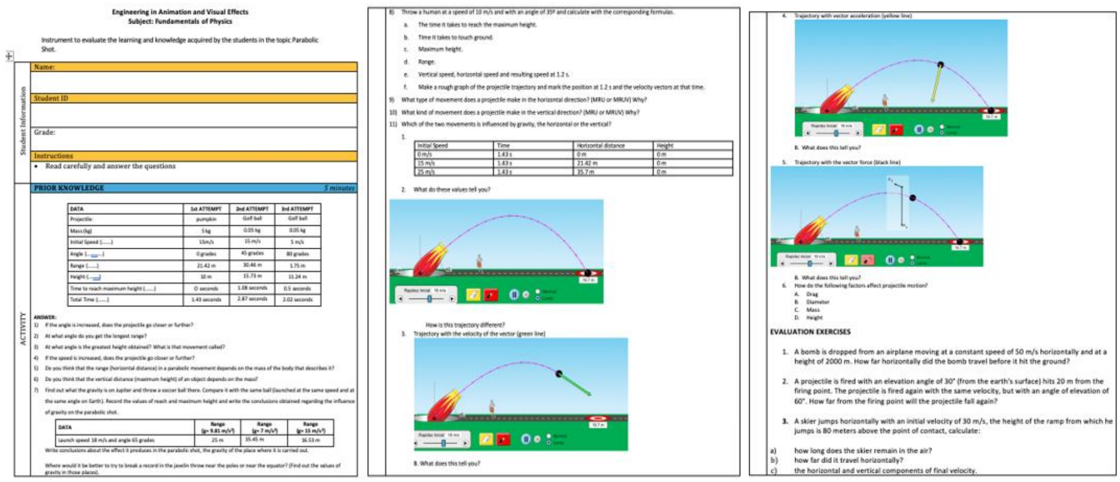
EVALUATION EXERCISES

1. A body falls freely from rest for 6 seconds until it reaches the ground. Calculate the distance it has traveled or, what is the same, the height from where it was dropped.
2. From the roof of a building a stone is dropped downwards and the noise of the impact against the ground is heard 3 seconds later. Without considering air resistance, or the time it took for the sound to reach the ear, calculate:
   a) The height of the building.
   b) The speed of the stone when it hits the ground.
3. A body is dropped from a height of 10m. Calculate:
   a) The time it takes to fall.
   b) The speed with which it hits the ground.

The instrument to evaluate the topic parabolic shot can be seen in figure 6, it consists of a table with the launch data of 4 different projectiles, which serve as a reference to answer questions 1 to 7; questions 8 to 12 seek for the student to reason about the concepts involved in the parabolic shot, while the following 4 proposed exercises seek to achieve an in-depth understanding of the variables involved in this topic; finally, the instrument has 3 problems in which the students have to obtain results related to the parabolic shot.

Figure 6

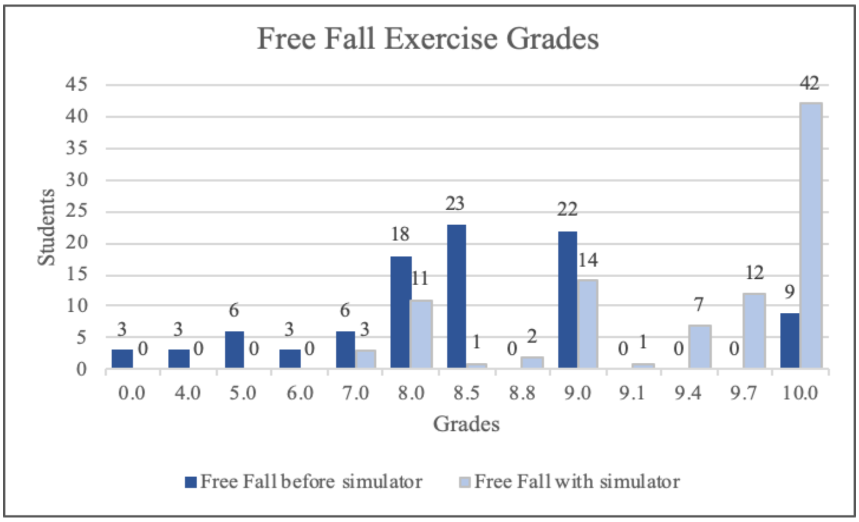
Evaluation applied to the students of the second quarter of Engineering in Animation and Visual Effects at UPSIN studying the subject Fundamentals of Physics, to determine the knowledge acquired on the topic Parabolic Shot



Applying the evaluation instruments to the students first without the use of digital simulators and then with their support, makes it possible to compare the grades obtained by the students and measure the efficiency of their use to improve academic performance in learning physical sciences. Regarding the free fall section or exercise, it can be seen in graphic 6, that 100% of the students who obtained failing grades, that is, less than 7, before using digital simulators, managed to obtain a passing grade with the use of digital simulators. Only 24% of the students obtained a grade of 9 when performing the free fall exercises without the use of simulators, while when using them, 37% of the students obtained a grade of 9, thus observing an increase in the grade obtained by the students. Only 10% obtained a grade of 10 when performing the free fall exercises without the use of simulators, against 45% who obtained a grade of 10 when using them to perform the exercises, once again observing an increase in the grade obtained by the students. when using digital simulators for the subject of free fall.

Graphic 6

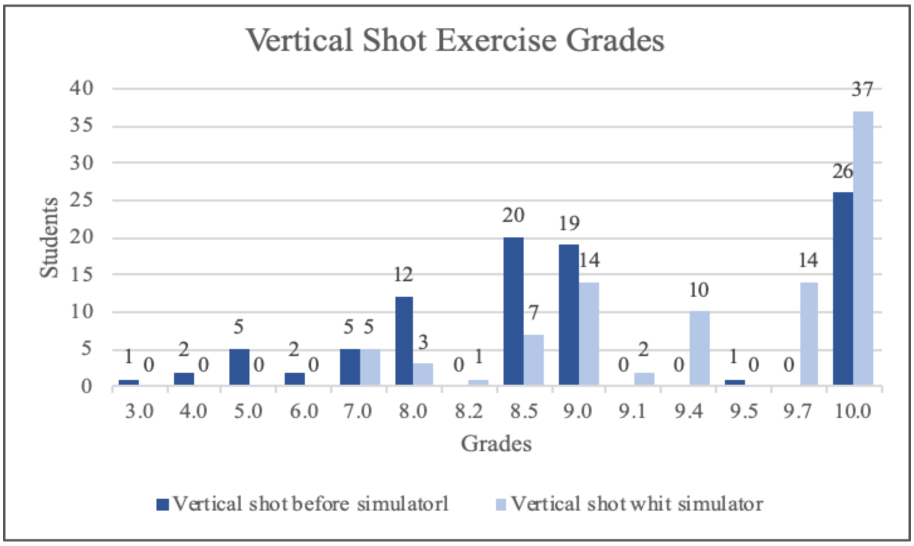
Comparison of the grades obtained by students in the free fall exercise when not using digital simulators versus using them



Regarding the vertical shooting section or exercise, it can be seen in graphic 7, that 100% of the students who obtained failing grades, that is, less than 7, before using digital simulators, managed to obtain a passing grade with the use of digital simulators. Only 22% of the students obtained a grade of 9 when performing the vertical shooting exercises without the use of simulators, while when using the digital simulators, 43% of the students obtained a grade of 9, thus observing an increase in the grade obtained by students. Then only 28% obtained a score of 10 when performing the free fall exercises without the use of simulators, against 40% who obtained a score of 10 when using digital simulators to perform the exercises, once again observing an increase in the score obtained by students when using digital simulators for the subject of vertical shooting.

Graphic 7

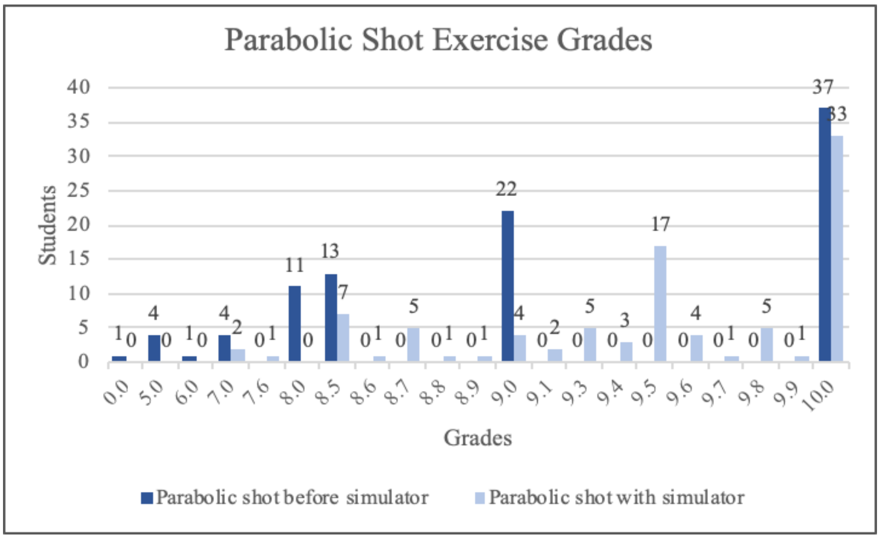
Comparison of the grades obtained by students in the vertical shot exercise when not using digital simulators versus using them



On the other hand, in the parabolic shooting section or exercise, it can be seen in Figure 8 that 100% of the students who obtained failing grades, that is, less than 7, before using digital simulators, managed to obtain a passing grade with the use of digital simulators. 24% of the students obtained a grade of 9 when performing the parabolic shooting exercises without the use of simulators, while when using the digital simulators, 45% of the students obtained a grade of 9, thus observing an increase in the grade obtained by students.

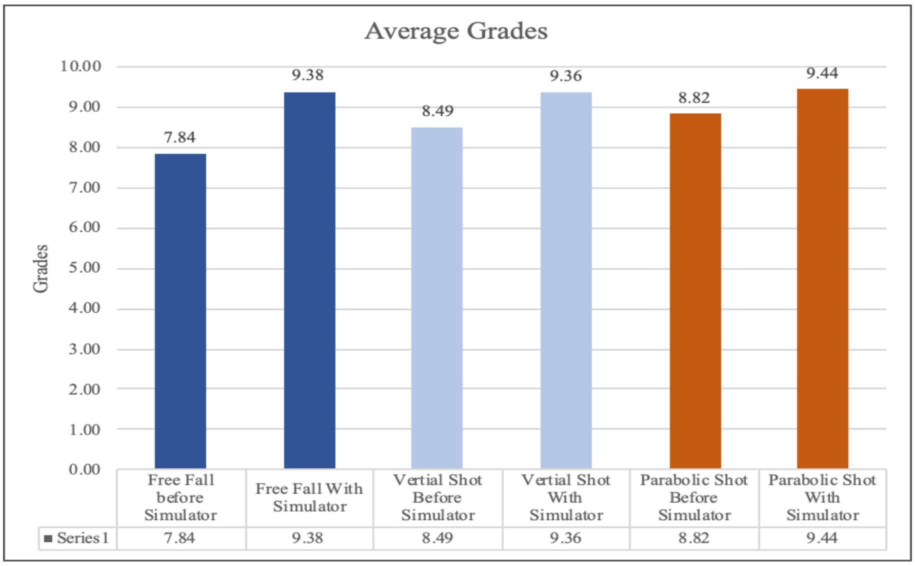
Graphic 8

Comparison of the grades obtained by students in the parabolic shot exercise when not using digital simulators versus using them



Graphic 9

Comparison of the average grades obtained by the students in the three exercises without using the simulators against those obtained when using the simulator



In addition to the increase presented in the grades of each student in the free fall, vertical shot and parabolic shot exercises, it is possible to analyze the averages obtained in the grades of each exercise without the use of digital simulators and those obtained when using them, this can be can be seen in figure 16, where it is evident that the average grade obtained in each exercise increased for the three subjects when the students used digital simulators as support for solving the exercises; in the case of free fall subject, the average grade obtained by the students without using digital simulators was 7.8, while the average obtained by the students when performing the same exercises for said subject but with the support of digital simulators was 9.38; similarly, in the subject of vertical shooting, there is an increase in the average grades obtained by the students, registering an average of 8.49 without using simulators against an average of 9.36 when using them; finally, regarding the subject of parabolic shooting, an increase in the average of the grades obtained by the students is appreciated again, registering an average of 8.82 in the exercise without the use of simulators and an average of 9.44 when doing it with the support of the them.

COMMENTS

The evolving social landscape compels nations' educational sectors to reevaluate their strategies, methodologies, and pedagogical processes, aiming to cultivate more proficient citizens capable of meeting the demands of modern societies. The challenge in education transcends the mere integration and enhancement of technological infrastructure within the digital era. It also entails a fundamental reevaluation of instructional approaches in light of contemporary knowledge production, harnessing the potential of technological tools to craft novel and enhanced multimedia content and facilitating access to more intricate procedures.

Current cohorts of students exhibit diminishing levels of interest and motivation in their learning pursuits, potentially stemming from an array of factors that span both internal and external spheres of influence. Internally, this challenge arises from the persistence of traditional teacher-centric instructional methodologies employed by educators. Externally, the omnipresence of information technologies in the daily lives of individuals compels the educational sector to acknowledge these technologies as indispensable tools for bolstering the teaching-learning process.

The results of the admission tests applied to the new students in the Mexican Higher Education Institutions, show a high deficiency in knowledge of physics, this has been generating great problems in the Educational Institutions as well as big challenges, where the Polytechnic University of Sinaloa is not exempt from the situation. Given the need to find mechanisms to minimize deficiencies in knowledge, the incorporation of information technologies through free access digital simulators in the area of physics teaching was devised, seeking to improve the academic performance of the students in the subject Fundamentals of Physics at the second quarter of UPSIN's Animation and Visual Effects Engineering Academic Program, as well as increasing their interest in learning it.

The use of three free access digital simulators was proposed as support tools in solving physics exercises that allow understanding the concepts of free fall, vertical shooting and parabolic shooting. According to the surveys applied to the students, prior to the use of the digital simulators, it was concluded that 64% show an apathy for learning and knowing the Physical Sciences; less than half of the students usually get high marks in the subject. Regarding teachers, only 11% have used information technology in their teaching processes in the subject of Physics and only 7% of students have ever used digital simulators to learn Physical Sciences. On the other hand, 99% of the students surveyed state that using digital physics simulators would increase their interest in learning the subject and 98% believe that it would increase their academic performance.

Upon evaluating the results of the analysis conducted on the students' grades, first without using digital simulators and then with their support, it is evident that employing information technologies through freely accessible digital simulators in the field of Physical Sciences contributes to the enhancement of academic performance for students in the Physics Foundations course during the second quarter of the Academic Program of Animation and Visual Effects Engineering at UPSIN.

The foregoing shows that the feasibility of acceptance by students is evident, of incorporating digital simulators for teaching in the subject Fundamentals of Physics, so it is viable to generate the design of a strategy that allows the use of digital simulators in teaching this subject for the students of the second quarter of Engineering in Animation and Visual Effects at UPSIN. Which promotes the use of technology in teaching, breaking paradigms of traditional education, by using digital simulators that are also playful games and allow attracting young students who are digital natives to learning science and particularly physics.

This strategy has three exercises designed in such a way that they can be carried out both through the use of digital simulators and without them, looking for the same exercise to be applied twice to the students under study in order to analyze the academic benefit that generates the use of digital simulators; It will also be necessary to analyze the perception generated in the students when using them, to determine if their interest in learning physics actually increased.

The educational challenge extends beyond merely introducing and enhancing technological infrastructure within the digital age, including the utilization of innovative technologies such as the simulators employed in this research. It also necessitates a fundamental restructuring of teaching methodologies to align with the evolving landscape of knowledge production. Leveraging the advantages offered by technological tools becomes pivotal in creating advanced multimedia content and facilitating access to more intricate procedures.

This transformation implies a comprehensive reorganization of pedagogical practices, prompting a reconsideration of the instructional process itself. The conventional model, wherein students interact solely with information and knowledge directed by the teacher, has evolved. In the realm of contemporary education, technology has fostered multifaceted communication avenues, challenging educators to respond promptly and effectively to this new dynamic.

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