CAPÍTULO 11

TEACHING PHYSICS THROUGH AUGMENTED REALITY AND ACTIVE LEARNING IN HIGH SCHOOL EDUCATION

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Cesar Augusto López Linares
CICATA Legaria, Instituto Politécnico Nacional, Ciudad de México, México.

Jesús Alberto Flores Cruz
CICATA Legaria, Instituto Politécnico Nacional, Ciudad de México, México.

Cesar David Ramírez Ortiz
ESIME Zacatenco, Instituto Politécnico Nacional, Ciudad de México, México.

ABSTRACT: Physics is one of the sciences that has contributed the most to the development of humanity, as the knowledge spread across its different subareas impacts almost every aspect of daily life. However, students perceive the study of physics as overly intricate and demanding, reserved for a minority of intellectuals. Therefore, it is imperative to take actions aimed at academically motivating students in physics learning units from early stages of their education. Consequently, the main objective of this study was to implement a didactic strategy supported by augmented reality to promote an active learning model and improve the academic engagement of students in Physics I course at the upper secondary level.
To achieve this purpose, the level of engagement of students in two groups, namely the control and experimental groups, was determined at the beginning and end of the third semester (Physics I). The intervention of the didactic strategy was carried out only in the experimental group, alternately over two semesters. The scores obtained by students in both groups were compared in three progressive assessments conducted at different points throughout both semesters. The results showed a significant increase in the academic engagement values of the experimental group and a significant difference in the academic performance between both groups, attributable to the implemented didactic strategy.
KEYWORDS: *Augmented Reality*, *Physics*, *Active Learning*.

1 I INTRODUCTION

This chapter describes the results obtained from the application of a combination of active learning methodology and augmented reality for teaching physics at the high school level. For this purpose, a didactic sequence was designed and implemented which made use of a particular application of augmented reality through the so-called *merge cube®*, as a means to represent the contents in the students' cell phones, thus seeking to increase their academic commitment.

1.1 Active Learning

Unlike traditional teaching methods, where the student plays a passive role and the class revolves around the teacher, active learning methodologies aim to give the student a leading role in the teaching process. It has been documented that traditional methodologies, which involve the unilateral transmission of knowledge, do not promote students' understanding of physical concepts (Duit, 2009). Furthermore, these traditional methods have contributed to a decline in young people's interest in studying natural and exact sciences (Lyons, 2006).

In contrast, active learning methodologies prioritize engaging students actively in the learning process. By actively participating in their own education, students are more likely to develop a deep understanding of physics concepts and foster their interest in the subject. These methodologies encourage interactive and collaborative activities, such as problem-solving, group discussions, and hands-on experiments, which have been shown to enhance comprehension and retention of scientific knowledge. By shifting the focus from teacher-centered instruction to student-centered engagement, active learning methodologies strive to create a dynamic and stimulating learning environment that promotes a genuine interest in the natural and exact sciences among students.

Recent studies have shown that active learning methodologies offer the opportunity to significantly enhance physics learning compared to traditional methodologies. Active learning, as pointed out by Meltzer and Thornton (2012), involves students in their own learning more deeply and intensely than traditional teaching, particularly during class time, in ways that can be explicitly identified. This is particularly important because it has been documented that students who are not engaged in the teaching process are passive recipients, show negative emotions, become bored easily, and are quick to give up (Skinner & Belmont, 1993). On the other hand, engaged students remain attentive and participate in classroom discussions, exhibit interest and motivation for learning, and as a result, are diligent in class activities (Fredricks et al., 2004; Skinner & Belmont, 1993).

In this regard, multiple studies indicate that active learning methodologies can contribute to improving students' academic performance (Freeman et al., 2014; Ojediran et al., 2014; Aji & Khan, 2019) and their academic engagement (Hake, 1998; Mohib & Mahmoud, 2018), with the latter being an important ally in preventing students from dropping out of their studies (Christenson, 2008).

1.2 Augmented Reality

Augmented reality can be defined as the additional information obtained from observing an environment, captured through the camera of a device that has specific software installed. This additional information, known as augmented reality, can be presented in various formats. It can be an image, a slideshow of images, an audio file, a video, or a link (Blázquez, 2017).

In essence, augmented reality enhances our perception of the physical world by overlaying digital content onto our real-time view. By utilizing the capabilities of cameras and software, augmented reality provides users with an enriched experience that combines the real world with virtual elements. It enables us to interact with and access additional information, enhancing our understanding and engagement with the environment around us.

The versatility of augmented reality allows for a wide range of applications across various industries, including education, entertainment, marketing, and more. As technology continues to advance, augmented reality is becoming increasingly sophisticated and accessible, opening up new possibilities for innovative and immersive experiences.

Since then, technology has advanced significantly, leading to the development of portable devices such as laptops, tablets, and smartphones. These devices are equipped with processors and cameras that not only allow us to visualize augmented reality elements wherever we are but also enable us to interact with them, making augmented reality a highly immersive technology.

The progress in technology has expanded the possibilities of augmented reality, making it more accessible and engaging for users. It has found applications in various fields, including education, entertainment, and industry, offering unique and interactive experiences that enhance our perception of the physical world. As technology continues to evolve, augmented reality holds great potential for further advancements and widespread integration into our everyday lives.

1.3 Academic engagement

The interest in the concept of academic engagement has grown exponentially over the past decades. However, similar to active learning, there is still considerable variation in how academic engagement is defined and measured. One of the earliest theories on academic engagement was the participation-identification model (Finn, 1989). This theory defines academic engagement in school as "*having both a behavioral component, referred to as participation, and an emotional component, referred to as identification*" (Finn & Voelkl, 1993).

Another significant model was developed by Connell and colleagues (Connell, 1990;

Connell & Wellborn, 1991; Skinner & Belmont, 1993), which distinguishes two extremes on a continuum: engagement and patterns of discontented behavior. Given the diversity of conceptions found in the literature regarding academic engagement (Table 1), it can be generally said that academic engagement is a complex term that focuses on the various patterns of motivation, cognition, and behavior exhibited by students (Alrashidi et al., 2016).

The understanding and measurement of academic engagement continue to evolve as researchers explore different perspectives and dimensions of this construct. It encompasses not only the active involvement of students in their learning but also their emotional connection and identification with the academic tasks and goals. Academic engagement plays a crucial role in students' overall educational experience and outcomes, as it influences their motivation, persistence, and success in their academic endeavors. As researchers deepen their understanding of academic engagement, it paves the way for the development of effective strategies and interventions to enhance student engagement and promote positive educational outcomes.

To explain the wide range of patterns associated with academic engagement, Fredricks et al. (2004) propose that student engagement has multiple dimensions: behavioral, emotional, and cognitive. The first two dimensions have been described in earlier proposals (Finn, 1989), while subsequent proposals (Reeve & Tseng, 2011) have confirmed the three dimensions mentioned by Fredricks et al. (2004), with the addition of a fourth dimension called "agency," which refers to the constructive contribution of students to the flow of the instruction they receive.

Despite the lack of a universal definition of academic engagement and the ongoing updates to the term, measurements have shown that student engagement correlates positively with performance and negatively with the likelihood of dropping out of school (Fredricks et al., 2004). Furthermore, recent studies suggest that the use of technology can have positive effects on improving students' academic engagement (Fonseca et al., 2014; Rashid & Ashgar, 2016).

Understanding and promoting academic engagement is crucial for educational institutions and policymakers as it plays a vital role in students' academic success and well-being. By recognizing and addressing the multiple dimensions of engagement, educators can design interventions and learning environments that foster active participation, emotional connection, cognitive processing, and agency among students. Incorporating technology as a tool for enhancing academic engagement offers new opportunities to create engaging and interactive learning experiences that cater to diverse student needs and preferences.

2 | CASE STUDY

2.4 Type of research

This research was approached from a mixed-methods perspective, as both the results of the Commitment and Detachment Scale in a course (CEDS), administered by the professor at the beginning and end of the semester, were used to determine the improvement in students' academic commitment, as well as the results obtained by students in progressive assessments conducted on both groups at three different time points throughout the semester to determine if there were significant differences in this improvement over time. Simultaneously, while measuring academic commitment, the potential effects of augmented reality as a motivational tool and driver of active learning were explored.

To carry out this research, the Commitment and Detachment Scale in a course (CEDS) was used in its short version of 12 questions, to assess students' academic commitment at the beginning and end of the semester. The main methodology employed was experimental research, with the aim of establishing cause-effect relationships between augmented reality, active learning, and students' academic commitment through the implementation of different treatments.

2.5 Experimentation

The methodology was carried out with two groups, Physics I and Physics II, of the upper middle school level in the afternoon shift following the sequence indicated in Figure 1.

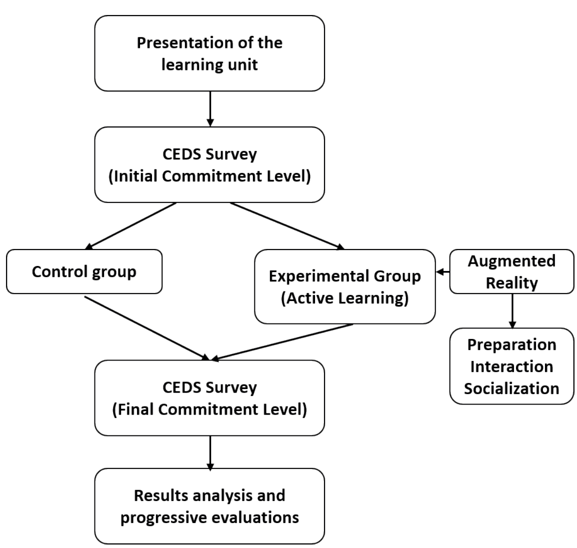

Figure 1. Diagram of the experimental development.

Source: Own elaboration

The implementation of augmented reality in the classes was done using the *Merge Cube* by ©Merge Labs Inc., which served to activate the augmented reality application on students' mobile phones. This process consisted of three phases, which are detailed in Table 1.

Phase	Preparation	During this phase, the student was provided with instructions on the use of the Augmented Reality tool (*Merge Cube*). In addition, they were provided with the objectives of the learning experience, as well as the code needed to visualize specific content.
	Interaction	During this phase, students scanned the cube using a smartphone or tablet to access the content and interact with its elements. Additionally, they made observations that were used to collaboratively draft a report on the relationships between concepts and variables of a specific physical system.
	Socialization	Finally, the students shared their findings with their peers and formulated conclusions based on the discussion of their own observations and those of their classmates.

Table 1. Augmented Reality Implementation Phases

Source: Own elaboration

3 I RESULTS ANALYSIS

Initial Academic Commitment

According to the diagram shown in Figure 1, the level of initial academic commitment was measured in two groups of students enrolled in the August-December 2020 semester in the Physics I course. The instrument used was the CEDS scale, which consists of 12 items or statements grouped into four dimensions: emotional commitment, behavioral commitment, emotional detachment, and behavioral detachment. The instructions for the instrument were, "On a Likert scale from 1 (False) to 5 (True), please indicate how true each of the following statements is in reference to the physics classes." Both groups belong to the afternoon shift, have a very similar number of students, and a similar distribution of males and females (Table 2).

Group	Semester	Shift	Gender	Age (years)	Number of students
Control	Third	Evening	Mixed	16 - 17	37
Experimental					39

Table 2. Description of the Physics I Course Groups

Source: Own elaboration

A descriptive analysis of the obtained responses (Table 3) revealed a higher level of academic commitment among students in both groups compared to detachment. For both groups, higher values were obtained for behavioral commitment compared to emotional commitment, and both groups scored the lowest in the commitment section for the statement "*I study for the physics class*." In the same section, students in the experimental group obtained a slightly lower score than students in the control group for the statement "*It is exciting when I make connections between the ideas learned in the physics class*."

		Beginning of the course				End of the course			
Engagement		**M**	**SD**	**A**	**K**	**M**	**SD**	**A**	**K**
	Emotional engagement								
1	I pay attention in my physics class	4.33	0.59	-0.20	-0.58	3.86	1.02	-1.08	1.64
2	I study for my physics class	3.19	1.28	-0.30	-0.85	3.72	0.94	-0.04	-0.97
3	I try to do the most I can in the physics class	4.33	0.83	-0.71	-1.16	4.00	1.10	-1.10	1.11
	Behavioral engagement								
4	I enjoy the time I spend in the physics class	4.44	0.88	-2.11	5.71	4.11	0.82	-0.87	0.72
5	It is exciting when I make connections between ideas learned in the physics class	4.36	0.90	-1.80	4.24	4.28	1.16	-1.74	2.24
6	The content we see in the physics class is interesting	4.53	0.56	-0.63	-0.65	4.28	0.70	-0.45	-0.82
Disaffection									
	Emotional disaffection								
7	It is difficult to attend the physics class	1.75	1.20	1.55	1.43	2.06	1.39	1.17	0.04
8	I only do enough to pass the physics class	2.42	1.44	0.60	-0.93	2.28	1.28	1.01	0.13
9	I do not do much work outside the physics class	2.86	1.27	0.36	-0.71	2.64	1.15	0.53	0.08
	Behavioral disaffection								
10	The classes of the physics teacher are very boring	1.58	0.94	1.62	1.70	1.50	0.74	1.13	-0.14
11	The physics class stresses me	1.89	1.09	0.79	-0.82	2.78	1.40	-0.11	-1.63
12	Being in the physics class is a waste of time	1.03	0.17	6.00	36.00	1.14	0.35	2.18	2.91
M: mean, **SD**: standard deviation, **A**:asymmetry, **K**: kurtosis									

Table 3. Descriptive analysis of the responses obtained from the control group on the CEDS scale

Source: Own elaboration

Regarding detachment, the values obtained for both groups are very similar, with the highest value obtained for the statement "*I only do enough to pass in the physics class*," highlighting the need to implement strategies aimed at improving students' engagement through methodologies such as active learning.

As for the analysis of normality, skewness and kurtosis indices were used, and the majority of the values obtained are less than ±2, indicating a normal distribution of the data (George & Mallery, 2010, cited in Trógolo et al., 2019).

Augmented reality and active learning

After obtaining the initial academic commitment values from the students, the content was developed without the intervention of augmented reality in the control group, while in the experimental group, an active learning model was implemented using augmented reality as a didactic resource. This was done with the aim of promoting communication, reading, writing, problem-solving skills, and cooperative work through reading instructions, problem-solving, and communicating findings and conclusions.

Next, a pair of students are shown interacting with augmented reality elements in the interaction phase (Figure 2). This phase was incorporated into the classes of the experimental group using the Merge Miniverse platform, which uses the Merge Cube from ©Merge Labs Inc. as a marker. For this, students needed to have the free Merge Object Viewer application installed on their tablet or smartphone. The designs were incorporated as images on the Merge Cube or developed in Tinkercad, which is a free online 3D modeling tool that runs in a web browser.

Figure 2. Diagram of the experimental development.

Source: Own elaboration

Final academic commitment

Subsequently, as explained in the methodological approach, the final level of commitment of students from both groups was determined at the end of the August - December 2020 semester, after being instructed with different teaching approaches in the Physics I course. The results obtained are summarized in the following table.

		Beginning of the course				End of the course			
Engagement		**M**	**SD**	**A**	**K**	**M**	**SD**	**A**	**K**
	Emotional engagement								
1	I pay attention in my physics class	4.62	0.54	-1.01	0.00	3.86	1.02	-1.08	1.64
2	I study for my physics class	4.03	1.06	-1.16	1.37	3.72	0.94	-0.04	-0.97
3	I try to do the most I can in the physics class	4.46	0.64	-0.79	-0.34	4.00	1.10	-1.10	1.11
	Behavioral engagement								
4	I enjoy the time I spend in the physics class	4.44	0.88	-1.98	4.84	4.11	0.82	-0.87	0.72
5	It is exciting when I make connections between ideas learned in the physics class	4.44	0.82	-1.29	0.77	4.28	1.16	-1.74	2.24
6	The content we see in the physics class is interesting	4.59	0.68	-1.41	0.74	4.28	0.70	-0.45	-0.82
Disaffection									
	Emotional disaffection								
7	It is difficult to attend the physics class	2.23	1.44	0.63	-1.16	2.06	1.39	1.17	0.04
8	I only do enough to pass the physics class	2.44	1.23	0.33	-0.91	2.28	1.28	1.01	0.13
9	I do not do much work outside the physics class	2.15	1.16	0.54	-0.76	2.64	1.15	0.53	0.08
	Behavioral disaffection								
10	The classes of the physics teacher are very boring	1.23	0.43	1.33	-0.25	1.50	0.74	1.13	-0.14
11	The physics class stresses me	2.46	1.70	0.54	-1.47	2.78	1.40	-0.11	-1.63
12	Being in the physics class is a waste of time	1.13	0.47	3.68	12.76	1.14	0.35	2.18	2.91
M: mean, **SD**: standard deviation, **A**:asymmetry, **K**: kurtosis									

Table 4. Descriptive analysis (mean and standard deviation) of the responses obtained to the CEDS scale.

Source: Own elaboration

Similarly, most of the values obtained for the skewness and kurtosis index are below ±2, confirming a normal distribution of the data.

Regarding commitment, as in the initial survey, higher values of commitment were obtained compared to detachment overall. However, upon further analysis of the means for each item, an increase in the values for emotional commitment is observed in the experimental group at the end of the semester, after following an active learning approach. Specifically, for the statements "*I pay attention in the physics class*" and "*I study for the physics class*," this difference has been shown to be statistically significant when analyzed using a paired samples t-test ($p = 0.04$ in both cases). In contrast, in the control group, a significant decrease ($p = 0.01$) was observed in the mean of students' responses for the statement "*I pay attention in the physics class*" after following a teaching approach without augmented reality intervention.

The above results are consistent with what was observed in the experimental group, where an increase in values ($p = 0.01$) was also evident for the statement "*It is exciting when I make connections between the ideas learned in the physics class*," corresponding to behavioral commitment, and a decrease in values ($p = 0.02$) for the statement "*Physics class with the professor is very boring*," related to behavioral detachment. In contrast, in the control group, an increase ($p = 0.01$) was revealed in the mean value for the statement "*Physics class stresses me out*," which belongs to behavioral detachment.

Based on the above, it can be summarized that the greatest benefits obtained from the application of augmented reality and active learning as a teaching strategy in the experimental group were an increase in emotional and behavioral commitment, coupled with a slight decrease in behavioral detachment. These aspects were not observed to the same extent in the control group.

CONCLUSIONS

Augmented reality possesses characteristics that position it as an effective alternative for promoting student motivation and engagement in the teaching and learning process. This is partly due to students' familiarity with this technology outside the classroom, making its incorporation into the classroom only require strategic content planning and a smart device such as a mobile phone. In this study, the design of a didactic strategy that included the use of augmented reality and its subsequent implementation in the Physics I course created an active learning environment in high school physics classes. The benefits of this intervention, assessed in terms of students' emotional and behavioral engagement and detachment, revealed that students who used augmented reality in class had greater benefits in the emotional dimension of academic engagement than in the behavioral dimension under this approach.

These findings suggest that augmented reality can have a positive impact on students' emotional connection to academic content, which is essential for their engagement and motivation. Furthermore, the incorporation of augmented reality in the classroom can contribute to creating a more active and participatory learning environment, where students can interact more dynamically with concepts and enhance their understanding.

In conclusion, this study supports the idea that augmented reality can be an effective tool for promoting students' emotional engagement in the academic context. It is important to highlight the need for careful and strategic planning for its implementation, as well as appropriate teacher training to fully harness its educational potential. In future research, further exploration of the effects of augmented reality on other dimensions of academic engagement and in different knowledge areas is recommended.

CREDITS

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