Using Virtual Reality to Facing Didactic Obstacles in Engineering Education

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Abstract

Didactic obstacles have been a persistent challenge in the academic education of engineering students throughout time. Some of these obstacles are generated by the professors themselves when teaching complex or abstract subjects, while others are caused by the didactic materials used during the teaching-learning process. This leads to students not effectively comprehending the subjects being taught to them. For this reason, this article presents a theoretical proposal that suggests the use of virtual reality to address these obstacles, as this technology offers unique properties, such as the sense of immersion and presence, which can simultaneously stimulate various human senses in students. Through the development of this study, primarily based on a comprehensive review of indexed sources, results have been obtained that demonstrate the proposed technology is useful in addressing some of the main didactic obstacles present in the education of engineers.

Keywords

Didactic obstacles, virtual reality, engineering education

1. Introduction

First The teaching and learning process for engineering students is complex, as it involves several interconnected elements. Among these, the key factors include the subject matter under study, how it will be taught, and how it will be learned. The combination of these elements sometimes results in an unsuccessful process, giving rise to what are known as didactic obstacles and other types of barriers.

In the search for alternatives to address some of the didactic obstacles present in the teaching and learning process for engineering students, this research proposes the use of virtual reality (VR). This proposal is mainly based on the characteristics that this technology possesses, allowing it to stimulate various human senses through computer-generated three-dimensional simulations, stereophonic sounds, and interactive sensors. This makes it possible for the user to feel immersed and present in the simulation, which was previously impossible to achieve with conventional technologies such as blackboards or written text.

The inclusion of virtual reality as a didactic strategy to address didactic obstacles is also a response to the necessity created by the global COVID-19 pandemic. This crisis forced a transformation in teaching methods, pushing them towards greater technology usage, which, in turn, required enhanced digital skills. In most cases, this abrupt shift affected both teachers and students as they faced new paradigms in knowledge acquisition.

As [1] emphasizes, technological mediation in education represents a viable didactic academic alternative for innovating teaching systems and environments. The proposed approach aligns with the guidelines of international educational organizations, particularly those that stress the inclusion of digital technologies in educational processes. These technologies can serve as

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learning tools, communication mediums, learning environments, didactic support materials, or mediating channels in students' learning processes, as highlighted by [2].

2. Theoretical Framework

2.1. Obstacles in the teaching-learning process

In [3] it defines an obstacle as any event that hinders learning. In [4] emphasize that the obstacles students face are not solely due to cognitive reasons but can also arise from issues related to communication during the educational process. These authors also provide some examples of factors that can contribute to the emergence of these obstacles, such as when the teacher conveys a message in the classroom. The message itself may not possess the necessary characteristics to be understood, and the study materials may lack the necessary didactic structure. Finally, the student, influenced by their previous experiences and environment, can generate certain obstacles.

Several decades ago, [5] and [6] had characterized and defined obstacles within the teaching-learning process. They described them as knowledge that, in general, was satisfactory for a period because it was useful in solving specific problems, which made it stick in the minds of students. However, over time, it no longer proves suitable, as it is challenging to adapt to different contexts, especially when students encounter new problems in other areas of knowledge. This can lead to errors [7]. On the other hand, [8] suggests that an obstacle is knowledge that functions productively in some areas of knowledge while contributing to the manifestation of errors in others.

During his research, [6] found that the teaching-learning process was primarily conditioned by three types of obstacles (see Figure 1): ontogenetic obstacles generated by the neurophysiological limitations of the students, epistemological obstacles that arise from the discipline itself, and didactic obstacles that mainly depend on the teaching method. At the beginning of the year 2000, [9] added two more categories: cognitive obstacles related to the student's prior knowledge and contextual obstacles, which are centered on knowledge acquired from other disciplines and then emerge during the resolution of context-specific events in a particular discipline. Regarding Brousseau's classification, [10] also notes that, although he described these three categories separately, in reality, it can be challenging to determine whether a certain obstacle, for example, of an epistemological type, does not also have an ontogenetic character. Furthermore, as epistemological and ontogenetic obstacles always manifest within a didactic system, they could later configure themselves as didactic obstacles.

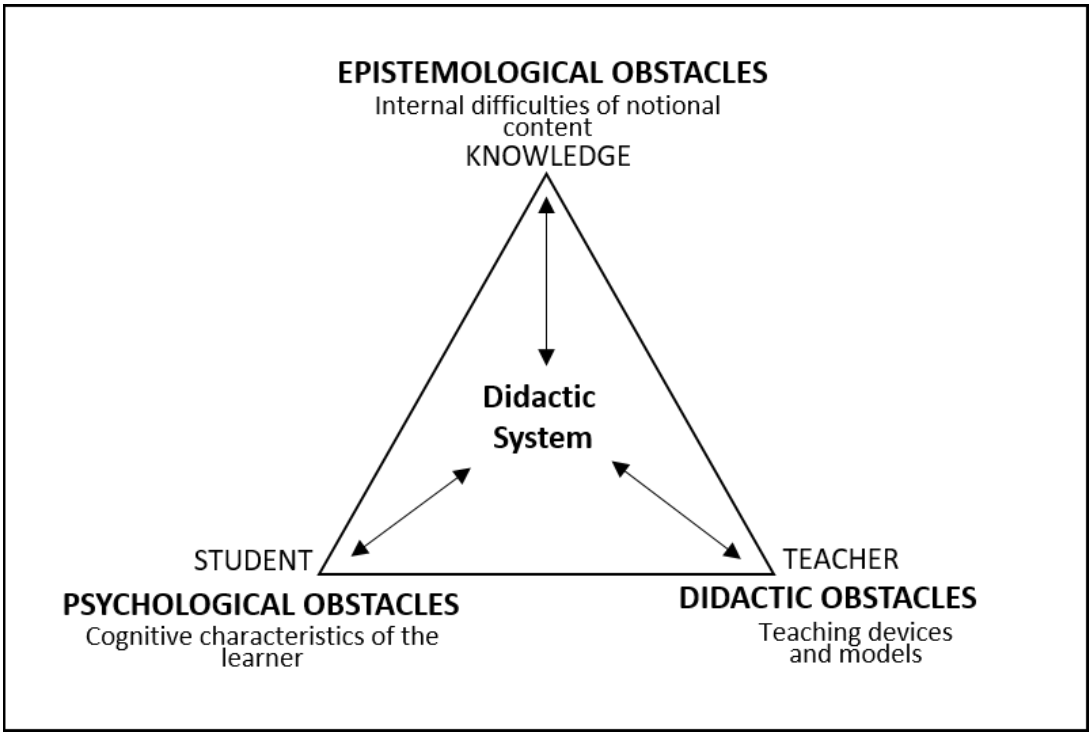

Figure 1: Didactic triangle, *Source*: Adaptation of Astolfi cited in [11]

In this research, Brousseau's classification was considered as the basis for a detailed analysis of the didactic obstacles that we sought to address through the use of VR, which are detailed below.

2.1.1 Didactic obstacles

For Brousseau, didactic obstacles appear to depend solely on a choice or an activity within the educational system. They form a system that, if modified, could help avoid such obstacles. On the other hand, the modification of the other obstacle systems (epistemological and ontogenetic) might not necessarily achieve the same result. Therefore, in this research, we delved into their study, leaving aside the other two types. To do this, we first considered the two categories of this type of obstacle:

a) *The teacher as a generator of didactic obstacles*

Didactic obstacles result from the didactic choices made by the teacher when establishing the teaching situation [9], [12] and [13]. For example, these obstacles can arise from following a specific methodology, employing certain teaching strategies during class, or using particular types of problems to illustrate the taught concepts. In [3], [14], [15], and [16] point out that this type of obstacle is often created by teachers at earlier school levels when they presented intuitive models that led to misconceptions in students.

Moreover, in [17] it is suggested that the didactic relationship can also generate obstacles. The gap between the student's knowledge and the teacher's knowledge can lead to their emergence. This can happen, for example, due to the use of inappropriate teaching methods, overuse of analogies, or partial approaches, which inevitably result in erroneous and incomplete knowledge. In [18] is emphasized that although didactic obstacles are specific to the decisions made by the teacher during the teaching process and are also a consequence of a particular pedagogical ideology, the educational system itself can also cause didactic obstacles, mainly due to how the curriculum is organized, finally, states that didactic obstacles can be avoidable through the development of alternative teaching methods and the use of technology [8].

b) *Didactic obstacles caused by didactic resources*

According to [2] and [19], the absence of didactics in the materials used for constructing the concepts to be taught also becomes an endless source of didactic obstacles, leading to inconsistent and less rigorous learning of a topic. In [20] the authors have, in their studies with teachers, found evidence that the presence of this type of obstacle can also be attributed to the strategies outlined in some of the textbooks they used during their professional training. In addition to this, [21] suggests that the use of inappropriate images in textbooks can be the main didactic obstacle to learning certain school subjects. Through their research, they conducted searches for didactic obstacles in elementary-level textbooks and found that these obstacles could generate three types of such obstacles. The first type arose because the drawings presented in the texts did not accurately reflect what was intended to be represented. The second was characterized by the fact that the drawings did not depict the dynamic nature of the objects as they were in reality. Finally, the third type of obstacle occurred because the drawings did not show the relationship that the object had with other elements in its surroundings.

Another author also provided a detailed analysis of didactic obstacles [10], primarily focusing on two aspects of knowledge construction. The first aspect is related to the use of specialized language from a particular branch of science. Differences between everyday language and the specialized language of a particular area of knowledge can create obstacles to knowledge construction. The second aspect is related to the contexts of exemplification and experimentation necessary for knowledge construction, which in [9] is defined as contextual obstacles. According to Heitele cited in [10], when a student begins to study a subject, they have already used terms and expressions in their daily activities to refer to events related to it, often without the precise sense that these terms acquire when formally studied in a classroom. These differences between everyday language and specialized language can also generate obstacles to knowledge construction [15], [22].

According to [23], some didactic obstacles can also arise when classroom experiments are not possible, when the topic is typically presented in a purely formal manner, or when the components of the topic are highly abstract. Furthermore, he suggests that these obstacles can be addressed by following a teaching strategy that replaces classroom experiments with computer simulations. He also recommends supporting formal arguments with graphical arguments or adopting an approach in the classroom that goes from less to greater complexity. To achieve this, he proposes the use of new didactic tools, such as real-time simulations.

Obstacles in the teaching of electrical engineering, in particular, identified factors that could also give rise to them through a detailed analysis of the curriculum and inquiries with teachers [24]. For example, this can happen when one of the subjects in the curriculum incorporates:

- *Concepts of an abstract or complex nature*, which, when trying to be taught through traditional methods, represent some difficulty for the teacher.
- *Exemplification of machines or real situations of an engineering situation*, using the blackboard, for example, when trying to explain the components of an electrical machine.
- *Situations of risk for students* are understood as those where there is a danger of injury, accident, or even death, caused by activities directly or indirectly related to the subject of study, for example, a visit to a power plant.
- *Risk situations for machinery and equipment when operated by students who do not have adequate training*.

Table 1 summarizes the main characteristics of the didactic obstacles:

Table 1
Didactic obstacles during the engineering education process. *Source: Own elaboration*

Obstacles caused by the teacher	Obstacles caused by didactic resources
By the teaching methodology or didactics used in a course.	Inadequate textbook images: a) The drawing is not a true reflection of what is to be represented. b) The drawing does not reflect the dynamic character of an object in reality. c) The drawing does not show the relationship that an object has with other elements of its environment.
By the use of intuitive models that create false conceptions.	Differences between the everyday language used by the student and the language of a specialty.
For the problems used to exemplify concepts.	When classroom experiments are not possible.
By the abuse of analogies and partial approximations.	When a subject has to be taught through the blackboard: a) Concepts of an abstract or complex nature. b) Exemplifications of machines or real contexts of an engineering situation.

2.1.2 Virtual reality and its properties

Jaron Lanier cited in [25], who is credited with first using the term virtual reality, defines this technology as a three-dimensional reality implemented with stereoscopic glasses and gloves, allowing people to interact with it. Therefore, virtual reality is an integration of human-machine interaction technologies with tactile, visual, and auditory behaviors. Its goal is to maximize the results of techniques and methods related to human perception and operation. Based on the previous definitions and for this research, virtual reality is understood as a computer-generated simulation intended to stimulate more than one human sense, enabling the highest level of interaction between the artificially created environment and the user, this is consistent with the definition given by the authors [26], who point out that virtual reality is a simulated environment created by a computer, which can be experienced through a headset or other devices that provide a fully immersive experience.

VR's stimulation of the human senses is mainly due to two of its emergent properties, immersion and presence [27], which are defined below:

a) *Immersion:* It is the perception that a user has of being physically present in a non-physical world. This perception is created through images, sounds, and other stimuli, which together provide a completely absorbing environment [28]. The term 'immersion' is used metaphorically, also defined as the state of consciousness in which a 'visitor' (in the words of Maurice Benayoun) or as Char Davies, cited in [29], calls it, an “immersant” alters their state of consciousness, transforming their physical self into the sensation of being surrounded by an artificial environment.

b) *Presence:* The sense of presence is a complex mental mechanism that is strongly linked to our emotional reasoning capacity, which causes a sense of psychological vulnerability in the user and a strong impact of symbols in the perception of a virtual world. Barfield et al. cited in [30], define presence as the sense of participating of "being there" in the virtual environment, which does not occur from the point of view of a mere observer, but one has the possibility of modifying, manipulating, traversing and interacting with the synthetic environment.

During the development of the research, three main categories into which current VR systems can be classified were found:

a) Desktop virtual reality systems, or non-immersive, within this category, are those systems with the ability to play multimedia content and computer simulations, which do not require computer equipment or specialized peripherals, so their integration is done only with a desktop computer, laptop, or mobile device, and equipment such as keyboards, mouse or touch screens. This category of VR has the disadvantage of not providing any sense of immersion for the user, as the contact with the physical environment is not lost at any time [31].
b) Semi-immersive virtual reality systems*, in this category, are classified as those systems that due to the technological devices used, such as monitors or large format screens capable of reproducing 3D content, partially deceive the user's brain, giving him the sensation of being immersed in the synthetic content presented, although in this category the user does not lose contact with his real environment [32].*
c) Immersive virtual reality systems*, this is undoubtedly the most important category on which the research of the last decade on this technology has revolved, being divided into two main categories, the first of which consists of a helmet or device mounted on the user's head, integrated by a pair of three-dimensional display screens, in which the synthetic 3D content created by computer can be reproduced, a helmet that is complemented with surround sounds, motion sensors and haptic devices, which allow the user to be completely isolated from the outside physical world, achieving high levels of immersion [33]. The second category is the so-called virtual reality caves, which are rooms in which the walls, floor, and ceiling surrounding the user have the ability to reproduce large format three-dimensional images of high quality, because of its size can provide a feeling of total immersion to a group of users at the same time, although only one of them can interact with the synthetic content, serving as a guide for others, these systems also have multiple peripheral devices to optimize its operation. Immersive Virtual Reality is considered for several reasons the best option for transmitting multisensory information, including the ability to almost completely* isolate the interference that the outside world could provide and thus allow the user to focus entirely on the information provided by the synthetic content.

3. Results

Finally, after the analysis of the information obtained, this section shows the correspondences that exist between the didactic obstacles and the virtual reality systems, which allows us to know that only two of the three categories analyzed fulfill the function of being able to address the main didactic obstacles present in engineering education (Table 1) since when contrasting these findings with the virtual reality systems, only the immersive and totally immersive systems complied with them.

Considering the above, it is possible to recommend the most suitable virtual reality system to address the didactic obstacles present during engineering education, based on the aforementioned classification, considering only those systems that offer the levels of interaction and immersion that allow addressing the obstacles present in the teaching-learning process mentioned (Table 2).

Table 2
Relationship between virtual reality and didactic obstacles. *Source: Own elaboration*

Didactic obstacles	Semi-immersive virtual reality	Immersive virtual reality

Inadequate images in textbooks.	Yes	Yes
Concepts of an abstract or complex nature.	Yes	Yes
Exemplification of machinery or equipment.	Yes	Yes
Transfer from common language to specialty or scientific language	Yes	Yes
Experimentation is not possible.	Yes	Yes
There are risk situations for the student.	Yes	Yes
Machinery or equipment is put at risk if used improperly.	Yes	Yes

It was also found that since virtual reality offers a three-dimensional interactive environment, the didactic obstacles present in the use of 2D materials, textbooks, and drawings on the blackboard, as well as when dealing with subjects that are difficult to explain due to their complexity, such as a production process or the construction of a building, can be easily addressed with this technology, without putting the students, equipment or machinery at risk.

4. Conclusions

The correct selection of a virtual reality system based on its emerging properties of immersion and presence, results in this technology becoming a useful didactic resource for engineering education, which should be taken into account when it is required to implement such technology in the educational environment, which will not only allow students to face the didactic obstacles present during their training, mainly when such obstacles are caused by causes such as inadequate teaching materials, concepts of an abstract or complex nature, or when it is necessary to exemplify machinery or equipment, as well as when it is not possible to experiment in a laboratory either because it is not available, or because the equipment is out of service, or when there are risk situations for students or machinery, or when it is necessary to exemplify machinery or equipment, as well as when it is not possible to experiment in a laboratory either because it is not available, or because the equipment is out of service, or when there are situations of risk for the student or the machinery due to incorrect use of the same, such obstacles may also arise in situations where it is necessary to visit facilities or industrial processes and the educational institutions do not have sufficient resources to do so repeatedly, or when it is required to exemplify machinery or equipment through the use of the blackboard.

It can also be concluded that after the analysis carried out, it was found that although two categories of virtual reality could be adopted in educational environments to successfully address most of the didactic obstacles present in the training of engineers, it is necessary to consider that both categories have their characteristics and different infrastructure requirements, so that the resources necessary for their implementation may not yet be available to all educational institutions, which could limit the massification of this technology at present.

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