Virtual Reality Technologies: Analysis of their Application in Electronics Engineering Career Programs.

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Abstract: Many problems have arisen in traditional electronics engineering education because of the Coronavirus lockdown. Although these problems have not been solved yet, this paper analyzes the use of virtual reality (VR) technologies as a possible teaching resource to solve them. Even though VR devices are relatively new in the field of teaching, this analysis makes use of numerous research projects, weighing up its positive effects and its drawbacks. Summarizing the results, it is clear that hybrid learning (by means of conventional and virtual reality systems) presents some advantages to traditional learning. However, more research has to be done in order to evince these new devices as an improvement in engineering education.

***Index Terms* - education, engineering, teaching, virtual reality.**

I.INTRODUCTION

In the early 2020s, a virus called SARS-CoV-2 made most countries in the world decide to implement strict social containment measures, such as the closure of educational institutions. The United Nations Educational, Scientific and Cultural Organization (UNESCO) states that, because of the pandemic, during April 2020, 92.32% of the schools were completely or partially closed [1] and the use of computers as a tool for education at different levels has been mandatory since then [2].

Since education has been carried out through online lessons, highly complex career programs like electronic engineering have found a number of problems. As a result of the lack of access to face-to-face interaction in the development of practical or laboratory assignments, students have failed to acquire important competencies like teamwork, communication, project management, self-learning, and leadership. Considering this, it is not possible to teach remotely everything an engineering student needs to graduate using current methods. This is where virtual reality comes in as a tool for engineering education. Virtual Reality (VR) is defined, based on the article of University of North Carolina at Chapel Hill, as an experience in which the user is immersed in a responsive virtual world [3].

This paper is in line with one of the Sustainable Development Goals (SDGs) [4], adopted by the United Nations in 2015, which is ensuring *Quality Education*. Achieving inclusive and quality education for all emphasizes the belief that education is one of the most powerful and proven tools for attaining sustainable development. This research searches for the improvement of education through the implementation of VR technologies.

The aim of this paper is to analyze the effectiveness of VR in electronics engineering career programs. To achieve this aim, this paper is organized as follows. Section II describes the present issues in the current lockdown in an electronic engineering educational context. Section III states the reasons for the use of VR in engineering career programs. Section IV analyzes the VR at present, in this part the educational and economic constraints to implement VR technologies are presented, and after that you can find a brief description of three different, and very popular, VR systems. Finally, section V will show some examples of their uses and their results in education. After introducing current examples of the use of these technologies in education, the conclusion presents the main ideas to round up the discussion about the implementation of VR in engineering career programs.

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II. EFFECTS OF THE LOCKDOWN ON STUDENTS OF ELECTRONICS ENGINEERING

The lockdown, due to SARS-CoV-2, brought complications to electronics engineering students. Numerous reports of colleges show the impact of COVID 19 on university students, revealing the increase of stress level, feelings of anxiety and depression in students [5]. In general, according to a study carried out by the ChangZhi Medical College, when faced with public health problems, the mental health of university students suffers greatly, and they require the attention, assistance, and support of society, families, and colleges, this is related to the fact that about 24.9% of the students have experienced anxiety due to this COVID-19 outbreak [6]. Moreover, numerous students are getting lower grades as well as more failed tests than before [7].

According to our own experience as students of electronics engineering during the pandemic and the experience of our classmates, there are three principal problems that can be the reasons for the issues described before.

The first, and most important issue is that students have to do most of their non-theoretical tasks in a simulation software. It is known that the practice in the real world is very different from the simulation software because the electronics uses or relies on an ideal mathematical system. In other words, the use of simulation software does not guarantee the same learning experience as the one that comes from using real circuits.

Secondly, students lack supervision while doing their practical assignments or prototypes of circuits. This leads not only to inefficient learning experiences but also to dangerous ones since undergraduates do not count with all the safety measures in their home.

The last problem is that these simulated practices are very far from the real job of an electronics engineer. Taking these problems into account, VR technologies arise as a way to improve engineering students' learning processes without breaking lockdown rules.

III. REASONS TO USE VIRTUAL REALITY IN ENGINEERING CAREER PROGRAMS

This section tackles the issues mentioned in Section II, namely, electronics engineering students doing most of their non-theoretical tasks in a simulation software, lacking supervision during practical assignments and the difference between simulated practices and the real job. To address these demands, some studies have shown evidence of better learning responses using virtual tools. For example, Koretsky [8] compared the use of physical and virtual laboratories and stated that "student responses showed statistically significant increases in categories of Experimental Design, Critical Thinking, and Ambiguity in the virtual laboratories" [8, p. 1]. The paper also mentions that "In a virtual laboratory, students do not interact with real equipment to obtain data, but rather with computer simulations of laboratory or industrial process equipment" [8, p. 2]. This helps the students work with the equipment that is used in the work environment and do it with more confidence because they cannot break the instruments that is a common fear among students because they have never used that equipment before.

Another reason that supports the use of VR is the cognitive load. According to the cognitive load theory, cognitive load is the combined measure of mental energy invested in the working memory during learning [9, p. 12]. Cognitive load is divided into three categories: intrinsic, extraneous, and germane cognitive load. These cognitive categories are defined the following way [10]:

- Intrinsic cognitive load is the cumulative effort connected with the complexity of the topic.
- Extraneous cognitive load is associated with the instructional design and depends on the method by which material is being offered to the student.
- Germane cognitive load is defined as the collective effort required to create an everlasting pool of knowledge.

As reported by Chitkara University [10], a virtual reality-based learning environment (VLE) can enhance educational design by combining it with technology design, reducing extraneous cognitive load while also reducing germane cognitive load indirectly.

Another paper published by Salzman et. al. [11] presented a VR software project for teaching physics. This project consists of virtual world such as Newton's World and Maxwell's World, where students have the possibility of experiencing Maxwell and Newton's Laws in a multisensory environment. This paper shows how VR can easily present very complex concepts, like the abstract idea that a punctual charge can generate an infinite electric field, so the students can understand this concept. When VR is not used, the common way of presenting Maxwell and Newton's Law is through equations and graphics that sometimes are not very clear for the students that are exposed to those concepts for the first time.

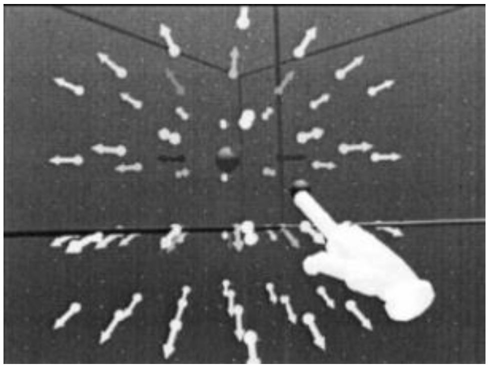

Fig. 1. Student manipulating a source charge in Maxwell's World

The claim that virtual reality models, such as Maxwell's World, help understand complex topics can be backed up by two studies. In the first one, Schnabel and Kvan state [12] that:

> This study has demonstrated, despite the fact that 2D representation of 3D space is the predominant medium to understand and communicate spatial arrangements, that designers' understanding of complex volumes and their spatial relationships is enhanced within a VR setting [12, p. 10].

VR technologies make the visualization of concepts through 3D representation possible, which are easier to understand than 2D representations in complex cases.

Since Newton's World and Maxwell's World comprise main topics which are taught in electronics engineering career programs, it is evident that, by using this technology, the teaching and learning processes will be more valuable. Moreover, they can be used to explain other invisible phenomena, such as the behavior of electromagnetic fields, light propagation, among others.

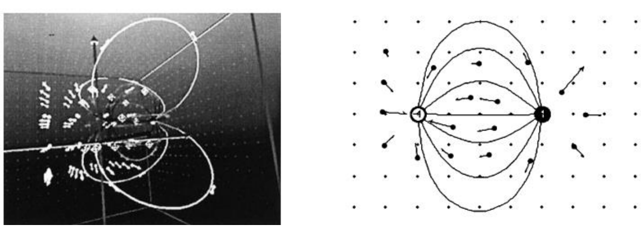

Fig. 2. 3D virtual representation (Left) and 2D traditional taught model (Right) of a dipole.

In the second one, Kollöffel and de Jong [13] study the acquisition of conceptual understanding using virtual methods. These authors point out that:

> Results showed that students in the virtual lab condition scored significantly higher on conceptual understanding and on procedural skills. In particular, students in this condition scored higher on solving complex problems [13, p. 1].

Both challenging conceptual and operational challenges yielded this finding.

Taking all this into account, it can be observed that there is a minimal amount of evidence showing that using VR-based learning environment (VLE) is superior to using only traditional methods. However, this evidence is enough to consider VLE as a possible solution to the problems mentioned before.

IV. ANALYSIS OF VIRTUAL REALITY

In this section, the educational and economic constraints on VR and some current popular VR tools are presented. One of the objectives of this section is to analyze the considerations that should be taken into account before the implementation of some kind of VR technologies in education. The other topic of this section is the description of three of the most popular VR technologies that are used in education today. These are: Virtual Reality Headsets, Augmented Reality and Cave Automatic Virtual Environment.

A. Educational and Economic Constraints

Since VR is a new technology in the education field, there have been some problems that may hold back its advance. One of the substantial obstacles is the cost of implementing VR systems [14], which can be divided into two main problems.

The first one is related to the high cost of the devices. Since VR is a relatively new technology and there is not much demand in the education field, its price might keep stable and high for years.

The second one is the cost of the training courses that personnel and teachers need to pay. If these people want to use these technologies to its maximal potential, it is necessary to improve their command. For example, RobotLAB is a company that works with schools to support the integration of technology in teaching and learning. However, since their teacher training courses are year-long, the time and the cost of training need to be considered.

As Noureddine Elmqadde [15] states:

> An effective adoption of augmented reality and virtual reality in education and learning will not happen until some technical and social issues are resolved and education programs are more adapted so as to take full advantage of the potential of these technologies [15, p. 2].

The solution to these problems is that all the members of the education should work together. In this way, as time goes, by these technologies will be commonly used in educational contexts.

B. Current Popular Virtual Reality Tools

- Virtual Reality Headsets (VRH)

Also called Head-Mounted Displays [3], VRH are the most well-known VR devices since they are used in the industry of videogames. Their most important fact is the visual cancelation of external distractions. Since they are superior to other devices, they give the user a feeling of immersion. The main disadvantage of VRH is that they can be only used by one person at a time. The average lowest price of them is around US$70.

Fig. 3. Child wearing a virtual reality headset.

- Augmented Reality (AR)

Augmented reality (AR) [16] is an interactive experience of a real-world environment in which computer-generated perceptual information enhances the things into reality. Its main advantage is that most devices with a camera support AR. However, it does not give any sensation of immersion to the user. If the user has a device that supports this technology, its cost is free, making it the most accessible of all systems.

Fig 4. Thermal monitoring with augmented reality.

- Cave Automatic Virtual Environment (CAVE)

A Cave Automatic Virtual Setting (abbreviated CAVE) [3] is a virtual reality environment in which projectors are directed between three to six of the walls of a room-sized cube. Its benefits are a high sensation of immersion and that it can be used by multiple users at a time. However, its cost is very high since it needs multiple image-generation systems.

Fig 5. U.S. army research lab's omni-directional treadmill with CAVE

The technologies presented here are the most common ones, but there are others with lower costs than can also work in some learning situations. The best option depends on the needs of the learning situation.

V. EXAMPLES OF IMPLEMENTATION OF VIRTUAL REALITY IN ENGINEERING CAREER PROGRAM.

The objectives of this section are to present and describe two examples of VR use in education, particularly, in electronics engineering education. The first example is about teaching robotic programming using low cost VRH. Robotics is one of the most important topics for the industry and it is for this reason that it is essential for electronics engineering students. The second example is about enhancing electronics engineering laboratory experiences with the implementation of a virtual reality-based learning environment (VLE) to help students learn how they must operate the oscilloscope and the function generator.

A. Teaching Robotic Programming Using Low Cost VRH

Every day there are more industries that use robots for tasks that are repetitive and relatively easy. This change in the industry makes more students interested in robotics, since they want to be ready for the near future.

As reported by the article of University of Alicante [17], when it comes to robotics classes, there are a few issues to consider from an educational standpoint, some of them are:

- Cost of robotic arms.
- Space required by robots.
- Safety problems due to inexperienced students.

Virtual reality can help solve these problems with a relatively low cost. There are many different methods to teach robotics using VR, but in this case the focus is over the system described in the research paper of the University of Alicante [17]. According to this article, the suggested approach comprises a bespoke simulator program designed specifically for robotic arms, as well as a low-cost virtual reality headset device connected to a smartphone that streams 3D rendered video from the computer and sends head orientation data to the simulator. Fig. 6 depicts the interconnection of various components.

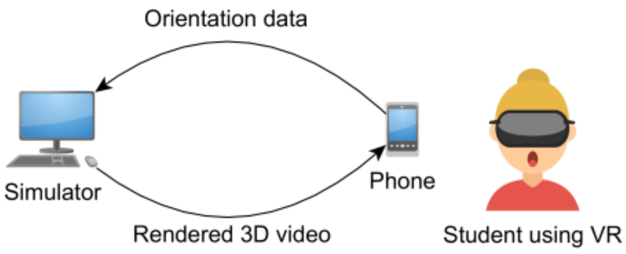

Fig. 6. Schema of the proposed method

In robotics, simulation allows users to create, visualize, monitor, and execute safety checks as well as path planning. As a result, users may build and test robotic cell settings in simulated situations using a custom-made software simulation for robotic arms. The simulation program was created to be as near to genuine industrial robotic simulation software as feasible in terms of capabilities, so students may have a better understanding of how robotics works in real-world settings. The comparison of the simulation on VRH and the real world can be seen on Fig. 7.

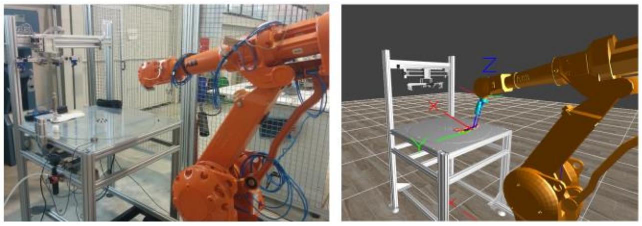

Fig. 7. Real and simulated robotic cell

The principal characteristic of this example of VRH implementation in education relies on the very low cost of the virtual reality headset. These headsets provide the image and the sound of the virtual world to the user. They also send the orientation and position information of who is using it to the computer. However, due to the fact that the price of one VRH is around US$100, it is expensive to provide one to each student, but Google developed a solution. This cardboard headset, a smartphone, and some lenses, recreate the VR experience in a cheaper way. These glasses are available in many models and for a very low price, for example, in Fig. 8 you can see a five-dollar pair of glasses.

Fig. 8. Google cardboard glasses.

B. Enhancing Electronics Engineering Laboratory Experiences

In the research about virtual reality, done by G. Singh, A. Mantri, O. Sharma, and R. Kaur of the Chitkara University, the implementation of a virtual reality-based learning environment (VLE) for enhancing electronics engineering laboratory experiences is described [10]. In this case, VR helps students learn how they must operate the oscilloscope and the function generator. The VLE allows the student to engage with 3D models rather than real ones, giving them confidence in their ability to manage the technology.

The VLE was created as a teaching tool to help students be ready to practice with current equipment in an analog electronics lab. The created VR system is an active learning tool based on learner-centered design, in which the student is actively involved in the learning process. Students can utilize a PC mouse to interact with 3D representations of laboratory apparatus (Fig. 9), which, when combined with the VR experience, will provide them with previous instruction and immersive experience in operating the hardware.

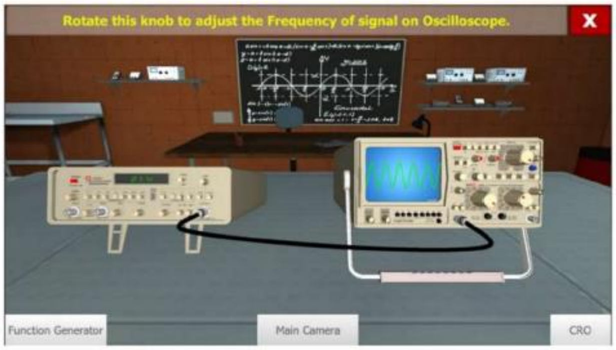

Fig. 9. User view of the VLE.

This VLE allows students to see the different signals created by the function generator and adjust the signal parameters in the VR environment by twisting the relevant knobs on 3D models.

The use of VR technology in engineering laboratories has a substantially favorable influence on student learning, according to an examination of its application on electrical engineering students. The explanation for these results is that when students used virtual reality, they were less concerned about equipment failure, which increased their confidence and lowered their cognitive load while operating real-world equipment. These results imply that the VR experience aids students in operating equipment, implying that the usage of VR technology in engineering laboratories has a favorable impact on student cognition [10].

VI. CONCLUSION

This paper provided an overview of the emerging virtual reality technology in the engineering education field. It is clear that, due to what has been discussed, VLE has some proven benefits. Though, since every system or technology has its own strengths and weaknesses, it is advisable to analyze when and how VR is going to be added to an engineering career program. To conclude, this research is in line with the "Quality Education" SDG because it presents and describes many different VR technologies that may help the students understand concepts easily, decreasing their cognitive load and their anxiety, and ensuring a high-quality engineering career path for them.

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