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Efficiency in the application of virtual reality in the teaching processes to generate competences in the university environment

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ABSTRACT

Technology is advancing rapidly and with it the way in which society develops; changing how we interact with new digital innovations. Based on this, the traditional teaching-learning model is changing radically under the current needs of the Knowledge Society. Consequently, generating a new model that envisages professional training based on competences. Its aim is to develop skills in students that help them face the challenges that arise in their professional life. This is done through the use of emerging technologies such as Virtual Reality (VR) which allows the students to acquire knowledge and generate skills in an experiential fashion. Students interact directly with different learning environments; thus, providing them with first-hand experiences that will stimulate their cognitive process; knowledge assimilation. It also promotes the development of competences. The present research project is part of a doctoral thesis. It is based on a quasi-experimental study with mixed methodology for data collection. This process involves the application of VR within the university teaching process. The objective is to establishing its impact, on both, its academic instruction and the development of competencies. The intervention will be applied to the Biology subject with students from the first year of the Dentistry career from the Catholic University of Cuenca (Ecuador). The use of this new learning method will be implemented from the beginning of their education.

CCS CONCEPTS

• **Applied computing**; • **Education**; • **Interactive learning environments**;

KEYWORDS

Virtual reality, competences, skills, university, teaching-learning

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1 CONTEXT AND MOTIVATION THAT DRIVES THE DISSERTATION RESEARCH

In the last decades the change in society has been exponential. Our habits change daily based on new technological trends that take over our customs, and transform our way of living. These break the barriers of time and space [31]. Every day we are digitally closer and our world turns minute by minute. However, the change in education is not keeping up with the real needs of the Knowledge Society.

In the last 10 years we have moved from chalkboards to whiteboards, and then to slide projectors, but the teaching- learning method remains the same. Most young people are born surrounded by technology with information at their fingertips. (Prensky et al. 2001) [32] mentioned that most young people are born surrounded by technology, with information at their fingertips. He categorized people into two groups; those born after 1995, called digital natives; and those born before 1995, called digital immigrants. It is important to understand that students who were born and raised in the digital era are characterized mainly by their high mastery of ICTs which they use naturally in their daily activities. Nevertheless, there is evidence that shows that young people can be skilled with the applications that are used in their leisure time, and not necessarily have the required digital skills or abilities to face their academic life and their professional development [2]. Therefore, it is imperative for the educational system to generate new learning methodologies that promote the development of these skills.

Therefore, this research is based on the application of Virtual Reality as a learning tool in the learning process of the Biology subject. The two main objectives are: to evaluate its effects on the assimilation of knowledge done by students, and to determine if the students develop transversal competences during this process. The use of technological tools such as VR as part of their professional development program will generate in student's new digital skills, which are an important addition to their university education. It is important to generate knowledge based on the current needs of the world of employment. It demands professionals with skills and competencies to transform and innovate a company; as well as their own professional lives. People who can change and address problems they may face.

With the advance of this technology some studies show that virtual simulation is as effective as the simulation in a real scenario

when learning. The use of VR has shown a significant improvement in student's performance [27]. This gives the opportunity to carry out more experiments without being exposed to any risk; it also allows remote interaction between the teacher and the students, which reduces the amount of contact hours or classroom classes. The latter one being extremely useful, given the current situation. Society is trying to adapt to the use of these new tools to face the challenges it encounters.

This article defines the objective of our research; first, by explaining the reasons why it was carried out; second, by describing the methodological design; third, by explaining the variables and the instruments used for data collection; fourth, by explaining the statistical analysis of the data; and finally, by presenting the advancements and conclusions obtained up to date.

2 STATE OF THE ART

The world is constantly evolving, adapting to new technological discoveries that surround us; thus, making them part of our lives, and changing the habits and the customs in the so called Information and Knowledge Society. Thanks to global connectivity that the Internet allows young people have, at their immediate disposal, information that allows them to answers their concerns. They are used to learning in an easy, practical and self-taught manner.

The profound social changes in recent years have established new relationships between: education and technology, education and knowledge; education and individuals and teachers and students. Based on this, it is essential for the education system, as well as academic institutions to take into account the needs of the working environment itself so as to prepare and train students regarding their needs and expectations [28].

However, formal education has not evolved enough to be at the forefront of these new learning needs. This issue has already been highlighted in the 1997 UNESCO report, which was prepared by the International Commission for Education for the 21st Century chaired by Jacques Delors. It states that: "Education systems must answer to the multiple challenges posed by the information society while continuously enriching knowledge and preparing people to exercise their citizenship which should be adapted to the present time [18].

In recent years' university education has transformed in an accelerated manner trying to solve these needs. An example of this is the adoption of a new learning model based on competencies which has been implemented both in the European Higher Education Area and in the Latin American one [26].

When talking about competences we will define them based on the final report of the TUNING project which was developed first in a European version and then in a Latin American version. More than 230 academics and people responsible for higher education took part. Competencies represent a dynamic combination of attributes regarding knowledge and its application, attitudes and responsibilities which describe the learning outcomes of a given program; or how students will be able to perform at the end of the educational process [14].

The TUNING project establishes two types of competences. The significant ones that refer to the acquisition of knowledge and skills from the student in the scientific branch in which their university education is; on the other hand, the transversal competences which are those that every professional must have in order to be able to solve the challenges and needs that arise from the working world.

Digital competences are an integral part of the transversal competences which are essential in the 21st century society given that we are surrounded by technology and it is necessary to know how to interact with it, so as to communicate and develop in this new information era. In this sense, in 2016 the European Commission developed the European Framework for Digital Competences for Citizens DigComp. It aims at identifying and validating the necessary components, that everyone should have, to survive the digital age. It also aims to promote a safe and critical use of all technologies [29] [30]; thus, establishing 21 digital skills that all individuals should have today. These are included in 5 areas: information and data literacy, communication and collaboration, digital content creation, security and problem solving [36] [20] [21].

The digital skills generated by the use of ICT (Information and Communication Technologies) and teaching-learning methods cannot be unrelated. Their integration is transcendental and necessary [22]. Ferrari et al. [6], synthesizes in three arguments the main reasons for this integration: (i) Benefits of ICT to improve the teaching-learning process; (ii) The need to acquire effective digital skills for the Information and Knowledge Society; and, (iii) Contribute to the fight and eradicate the digital breach so as to facilitate the participation of all citizens in this digital age.

Cabero et al. 1], indicate that one of the emerging ICT technologies of greatest momentum and importance regarding education is Virtual Reality (VR). Therefore, it can be said that teaching methodologies should be based on the use of new tools such as VR so as to assimilate knowledge in an experiential manner. By using VR as a component within the technological ecosystem of learning [9], students will be able to study different areas of science at the same time. This will produce a convergence of different topics that will complement different contents, methods and objectives [24].

2.1 Virtual Reality

The term "virtual reality" arises from the research carried out by J. Lanier, t. Nelson, M. Kruegger or J. Walker on how to improve the user's interaction with the computer interface by generating more natural and perceptive relationships. Therefore, a virtual environment outside the physical one was created. It uses devices which make it possible to interact in a real world created by a computer which allows the human mind to feel as if it were physically in that environment; thus, establishing that what matters is the appearance and what it seems to be linked to their connotations of the real world [3].

We could synthesize and say that Virtual Reality is a digital representation generated by a computer, which requires a headset that uses an electronic processing, and generates in the human mind the perception of being in the real world. People can interact in a natural manner, it can generate sensations and develop skills when using it. There are two main classifications of VR. The first one, consists of a reflection of our reality; this type of VR is created by using 360 degree images and videos, which means that the three-dimensional visualization capacity is lost (until 3D cameras are more developed), but the realism of the images is increased. The second one, consists of accessing a tridimensional world that has been entirely created by a computer; you can tell that what you

are visualizing is not real. This is due to the fact that the rendered images are evolving very fast [15]. From this type of VR, we can define deeper interactions or classifications that are given based on the user's interaction with the virtual world that is being operated.

VR is a tool that allows us to have 3D models or environments with a high level of precision. This tool has devices and computer systems that go beyond just visualizing these models; it allows us to interact with them in a completely different fashion than what we have seen before [16, 17] It is becoming increasingly popular in different educational environments; not just for being able to imitate a real world, or simulate historical events, but to also visit immersive environments such as the interior of the human body, so students can understand how it functions from inside. This allows the abstract, intangible or theoretical to become concrete, practical and palpable. This means to leave theory behind and enter the era of experiential learning [7].

Virtual reality establishes a first-hand constructivist learning where the student is the main actor within a given virtual world; hence, achieving a more profound learning process that generates better results than just listening or reading. Learning with this technology makes students the main focus for the process where experiences are received directly; remaining in the subconscious as an experiential memory [4].

3 HYPOTHESIS AND PROBLEM STATEMENT

Research on theories of learning, cognitive development and academic success of students, has confirmed that teaching through active learning and collaborative activities promote the intellectual engagement of students; becoming more efficient. [34]. When analyzing the pedagogical tools used by teachers today, it was stablished that these have not changed in recent years, and traditional teaching methodologies are still being used. This contradicts the reality of the students we have in the university classrooms; most of them were born in the information era. They are surrounded by technology, and they are eager to acquire knowledge in an experiential manner. The gap between the demands of our society, and the educational objectives shows the need to integrate emerging technologies into the teaching-learning process. This will allow the system to adapt to the present needs of the students while developing skills or abilities to work in the professional world.

Based on this, it can be said that virtual reality is a technology that allows learning in an experiential manner. VR has developed remarkably. It once was an exotic field for computer science, but nowadays is an important issue for the professionals of tomorrow. Virtual teams are being created all over the world and they use video and audio communication, as well as, social networks to interact and communicate in a collaborative fashion [19]; thus, becoming an alternative to generate in the students certain competences at the same time as they develop their learning in the classroom. They will be transported to new experiences such as simulations regarding the Biology subject. This will allow students to assimilate theory in a practical manner. Therefore, the following hypothesis is posed:

- H1: University students who use VR as a learning tool within their academic activities increase the development of their transversal and digital competencies.
- H2: Students who use VR within their academic activities increase their knowledge regarding the subject of Biology and have a good perception in relation to the use of this tool.

3.1 Research question

Within the areas of the sciences studied at university level Biology is a transcendental subject. it is transversal to all the careers from the health area; therefore, this research will be focused on the incorporation of VR into their learning. This research aims to answer the following question:

Is there a better assimilation of theoretical content from the Biology subject, as well as an increase in transversal and digital skills, through the use of the emerging VR technology in the classroom?

3.2 Research objectives/goals

The research aims to establish the effectiveness of virtual reality in education for which several objectives are established. These will help us evaluate its application regarding he generation of competences.

3.2.1 General objective of the investigation. Analyze if the use of Virtual Reality as a learning tool within the academic activities from the Biology subject in the Dentistry degree, increases the development of transversal and digital skills, and promotes the acquisition of the contents itself.

3.2.2 Specifics objectives of the investigation. Regarding the specific objectives, the following are proposed:

- To evaluate the effectiveness of the use of Virtual Reality (VR) in relation to the increase of transversal competences: instrumental, interpersonal and systemic competences.
- To assess the effectiveness of Virtual Reality (VR) in relation to the acquisition of the 5 areas of digital competence established by the DigComp framework.
- To evaluate and compare the academic performance in the Biology subject between the intervention and control groups.
- To know the perception students, have of the use of the VR tool.

4 RESEARCH APPROACH AND METHODS

The research is based on a quasi-experimental design with a non-equivalent control group. The study will be carried out with first year pre-formed groups given that a random selection it is not possible to do. It is important to mention that these students are divided into parallels based on the academic distributions of the Dentistry career at the Catholic University of Cuenca (Ecuador).

The method that will be applied is a mixed method; also called nested design. It uses quantitative data and a qualitative tandem approach embedding one into the other to provide new ideas or a more refined thinking [25].

For the measurement of the transversal and the digital competencies a pre- and a post-test will be used with a quantitative questionnaire. This instrument will be previously validated with the participation of experts under the triangulation modality [35]. The verification of knowledge acquisition will be validated with specific tools such as: a diagnostic test, a midterm exam, and a final

exam. Therefore, evaluating the acquisition of knowledge before, during, and at the end of the academic cycle.

On the other hand, to evaluate and determine the students' perception of the implementation of this new technology in the classroom a qualitative measurement tool will be established. This research will use Focus group which is a widely used technique for the analysis of group perception since it allows the researcher to evaluate the agreements and disagreements regarding the use of this technology. It is believed that this will make the participants feel comfortable when expressing their opinions with their peers; making them react based on their own criteria and that of the collective perception [33].

The sample size is around 136 students in each of the two studies; thus, the estimation of the sample is based on an expected 0.57 effect as a result of the intervention. The two studies will be carried out according to the G*Power application [5]. In relation to the qualitatively oriented sample, a diverse sample or one with maximum variation will be used given that this type of sample is used when the aim is to show different perspectives as well as to represent the complexity of the studied phenomenon [23].

4.1 Criteria

The study determines criteria for participation which guarantees its reliability; thus, establishing the following:

- Exclusion: Students who do not wish to participate in the study will not be part of it.
- Inclusion: The project will be carried out with students from the first semester from the Dentistry career.

4.2 Variables

An independent variable and two dependent variables are determined within the research. These three integrate the study so as to achieve precise results.

- Independent variable: Intervention RV. - Stimulus variable refers to the intervention groups with the VR tool in the Biology subject.
- Dependent variables and quantitative measurement instruments:
- Transversal competences
- Digital Competences
- Learning the subject
- Dependent variables and qualitative measuring instruments:
- Efficiency in the application of virtual reality in the teaching processes to generate competences in the university environment

5 RESULTS TO DATE AND THEIR VALIDITY

For the development of the research a Virtual Reality laboratory is required. For the implementation of the laboratory at the Catholic University of Cuenca (Ecuador) a project was developed. The University has financed the acquisition of such equipment and the construction of an adequate space for the research for the implementation of this technology into the teaching-learning processes in the different areas of the sciences Figure 1

The concept of virtual reality indicates that it is the generation of digital content for the recreation of virtual environments which

Figure 1: XRLab Laboratory

simulate the real world. It allows the user to acquire sensations so they can forget it is an imaginary world. VR varies according to the type of immersion and interaction that are based on two factors. The virtual reality equipment that is available, and the virtual environment software.

According to research there are two types of virtual reality:

- Immersive virtual reality 360 degrees. - Where the user can have the experience of moving and observing environments with minimal or no interaction. It requires a Smartphone and basic glasses such as Samsung Gear or Google Cardboard.
- Immersive virtual reality level 1.- The user has controls that emulate hands and can move in spaces; there is some interaction with the virtual world. In this type of immersion, the handling of graphics is high, but limited because the hardware is in the glasses, and does not require any additional equipment. For this immersion tools such as glasses Oculus Quest or Lenovo Mirage are necessary.
- Full immersion virtual reality level 2. - depending on the software employed the user is completely immersed in an imaginary virtual world. The user can explore different scenarios such as the interior of the human body; recreate each of its characteristics and interact with the available options. The user can manipulate the environment with their hands by using VR glasses that require an additional computer equipment with high graphic performance directly connected. This will generate all the graphic environments that the user visualizes, and it requires a machine such as Oculus Rift S, HTC Vive, or Play Station VR.

It is for this reason that the virtual reality laboratory has three types of glasses, so as to evaluate the interaction of the students based on different characteristics which are required for learning. The University has the following equipment: 11 cutting-edge devices (Oculus Rift S, Oculus Quest, Samsung Gear), and 11 portable computers with special characteristics for video games. Likewise, the construction of the laboratory and virtual software development center is about to be completed. This center will provide the necessary physical space and technology to carry out this research. It is worth mentioning that the equipment is portable; therefore, the laboratory is also mobile. This means research can be carried out in other branches of the University around Ecuador.

Since we are working through online classes; adjusting to the global emergency [10], a series of talks on the use of this new technology have been given to teachers. The aim is to try to collaborate to address this new methodology. An introduction to VR will be done in this new academic cycle with some groups of students. The

objective is to check the effects VR has when used through a video conference. The teacher uses VR glasses to submerge students in virtual environments.

Two existing software's from the Oculus platforms have been evaluated and will be used in the Biology subject. However, the research will be complemented with an additional software that is being developed by a multidisciplinary team from the University. This team is working for the new VR laboratory called XRLab. https://xrlab.ucacue.edu.ec.

6 DISSERTATION STATUS

A systematical theoretical review, and a technological observation of the latest advances of this technology are being carried out. An evaluation on how to implement the use of this tool in different educational levels, so as for it to be inclusive in the less favored sectors, is also being done.

7 CURRENT AND EXPECTED CONTRIBUTIONS

Based on the theoretical and practical research that is being carried out on the use of VR technology. This research project intends to create a significant change in the way teaching is done. Defining this change as an innovation within the process of changing teaching or learning activities which improves the performance of the students, while generating competencies during their university training. However, in order to consider the use of this technology as an educational innovation, this new learning methodology must meet specific criteria such as being effective and efficient. It must be sustainable in its development and it must produce transferable and applicable results beyond the initial context in which it was originally conceived [8]. Likewise, it must be able to evaluate the relationship of its application with the student's motivation, and their satisfaction levels when using the tool. The user's experience and the perceptions of their interaction in virtual environments must be evaluated as well. It is because of all the above mentioned that, a multidisciplinary technical team of professionals has been assembled as part of the new laboratory to develop the VR software that will be used in this research. The software will create the laboratory practices for the Biology class in a virtual environment. Thus, setting a precedent for the future development of new virtual applications based on different topics within their learning process.

Taking into account the current limitations due to the global pandemic, the application of virtual reality will be carried out this new cycle through online classes as the initial evaluation of this research. The teacher will enter the immersive environments and the screen will be shared through videoconference systems with the students. Students will be able to see the same thing as the teacher because of the use of animations and 360 degree scenarios. This will be considered part of the introduction of the use and advantages of VR. The perception students have of the use of VR through this online modality will be measured as well. In regards to the next cycle, when students have the opportunity to use VR individually in the classroom, a comparison between these two will be done.

8 CONCLUSIONS

As a conclusion, based on the literature review and the enriching experiences obtained from incorporating this emerging technology into the teaching process, it is fair to say that virtual reality is a very powerful tool that generates first-hand learning. By using VR students learn based on their emotions because they live the experience firsthand; hence, it helps them remember and understand the theoretical concepts, that up until now, were explained by using scale models or videos. Biology is the perfect example of how this technology can address current situations, e.g. working with cells or finding the cure for COVID19. Imagine being able to see how cells battle to defends themselves from viruses, or how a lung pumps less air when it has an infection. For those who are not experts in this area, understanding these complex systems is not easy; Therefore, using this tool which provides completely graphic and real scenarios will help the understanding of the subject, as well as the learning process.

Summarizing the conclusions are as follows:

- It is a technology that used at any level of immersion is useful for first-hand learning.
- It favors the comprehension in the learning process because it allows a visualization of the contents in an experiential fashion.
- When being able to work with cutting edge technology, the student feels motivated to use it and to live the experience.
- To generate a change regarding the application of this technology in education it is necessary to develop a VR software focused on developing the skills of each subject area.

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