25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
7-8 SEPTEMBER 2023, ELISAVA UNIVERSITY SCHOOL OF DESIGN AND ENGINEERING, BARCELONA, SPAIN

IMPROVEMENT OF THE LEARNING EXPERIENCE IN ENGINEERING COURSES THROUGH THREE SUCCESSFUL CASES OF IMPLEMENTATION OF EMERGING TECHNOLOGIES IN THE CLASSROOM

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ABSTRACT
The teaching-learning process has become, along with technological advancement, a dynamic process that adapts to the circumstances of the challenges that arise in the teaching-learning process, added to unpredictable environments for its development, have led the teachers to develop innovative ways of teaching inside and outside the classroom, as well as with flexible digital models that allow distance education. Whatever the innovation, it must enable the student to have a great experience in their learning process and meaningful learning. Given these circumstances, using technologies that help and facilitate students' learning paths has become more recurrent and essential. Technologies that, complemented with didactic techniques such as gamification, efficiently affect the teaching process, making it more productive in terms of the use of resources and the achievement of objectives such as skill development. This study presents an in-depth analysis of three successful cases of educational technology implementation within the teaching model of our university, which focuses on the student and favours the development of competencies. The applied technologies were: Virtual Reality, Simulation, and Telepresence. Once these technologies have been validated, their adoption is highly recommended to use them for the benefit of education at different levels and areas. The article results from different NOVUS projects, innovation for education, carried out at the Tecnologico de Monterrey, with proven successful results.

Keywords: Virtual reality, simulation, telepresence, technologies, education

1 INTRODUCTION
The challenge of any teacher in the classroom is to design better ways of learning, this is called educational innovation. Looking for students to maintain attention, have learning and develop skills generates motivation and creativity in the teacher. In the context of the teaching-learning process, the aim is to achieve the greatest impact in the development of knowledge and skills in the students, which is why the best didactic tools are sought for their use and implementation in the classroom, always seeking innovation. Technology in the classroom is an excellent tool to generate learning and develop skill, it can be used within gamification to generate more interest in students. Three trends in Education 4.0 related to educational innovation to be addressed are (i) students deciding the best method for learning, (ii) innovations in current learning tools, and (iii) use of digital tools and emerging ICTs (López et al., 2021).
The following paper summarizes three initiatives financed by the Institute for the Future of Education of the Tecnologico de Monterrey that have successfully developed transversal and disciplinary competencies of students in the School of Engineering and Sciences. MxREP, or Chencho Project, is an EPR simulator with virtual and augmented reality lessons. The design of an Interactive Virtual Environment for the training of operators is focused on developing skills in students through the total immersion that virtual reality gives and, finally, the Avatar Professor that allows the experience of having the best teacher in your classroom regardless of the distance. The professors of the Tecnologico de Monterrey seeking to carry out the best practices of the teaching-learning process have given themselves the task of using different technologies for the benefit of education, technologies such as

virtual reality, simulation, augmented reality and telepresence. Each of these technologies have given positive results for student learning.

2 METHODOLOGIES

2.1 Case Study: Chencho Project, an ERP Simulator with AR and VR activities

Chencho is an ERP simulator for learning industrial engineering concepts such as; Quality Control, Logistics, Design of Experiments, Production Planning, Project Management among others and is based on a gamification platform. This simulator was a response to the distance learning needs motivated by the confinement by Covid-19; it is based on manufacturing Meccano cars and is supported by virtual and augmented reality lessons. The first design was based on an SAP model, introduced in August 2020 during distance learning. It was based on solving a case (Figure 1). The first experimental run was carried out in the field of Problem-Solving Methodologies at the national level and online, with a group of 361 students in each of the 26 campuses of the Tecnologico de Monterrey. The first augmented reality lessons were made based on the traction system of a Formula 1 model, and the main case was based on a problem of tolerance sums in gear systems. Based on the learning activity design model proposed by González et al. (2021), through the design of experiments and design thinking, the environment was changed from similar to SAP screens to a gamification based on a robot, customized by the student. It competed with other robots to do the best manufacturing process, fulfilling all work orders and maximizing profits.

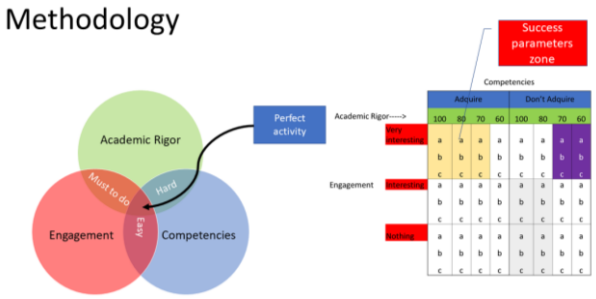

Figure 1. Methodology of the modification of the Chencho project

2.2 Case Study: Design of an Interactive Virtual Environment for the training of operators

The methodology of this research was of 2 phases: 1) The students were presented with a virtual environment in which they solved the expressed need of the problem, they had a week to develop it; furthermore, its objective was to analyse the skills developed of the students from the perspective of the solution presented through the 3D interactive virtual environment (Figure 2). Additionally, the first analysis was intended for students to be able to recognize the set of competencies they had developed and had a starting point for, once the presentation was made, to define the level of development of said competencies González et al. (2021). 2) The students were asked to answer a questionnaire about the skills developed and the level of said development, this work presents a qualitative analysis of how a sample of 37 students recognize the development of four competencies according to these levels, these levels vary from a basic level of a competency to a high level reached. To achieve this, all the students who took the project were asked to evaluate the level of development of the skills already described that they acknowledged having achieved during the project. The evaluation levels of each of the questions were: *Basic*, *Medium*, *High* and *Null*.

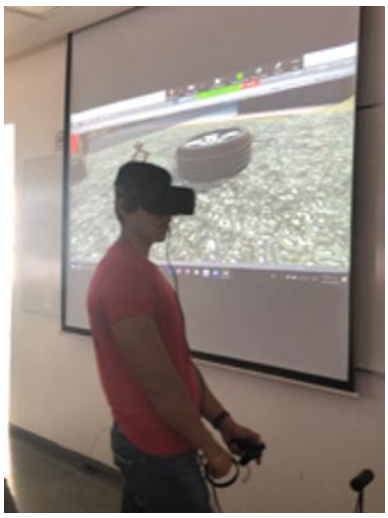

Figure 2. Demonstration of the use of the virtual environment

2.3 Case Study: AVATAR Professor

In 2017, a team of developers investigated evidence in publications where telepresence resulted in a different experience, furthermore, Tecnologico de Monterrey has distinguished itself by promoting educational innovation while facing the challenges of a multi-campus educational system (25 campuses). The holographic courses have been implemented on 11 campuses, two of them capable of transmitting and receiving, and nine receiving centres. The developers found that telepresence with a hologram made the students feel closer to the teacher more significantly than traditional videoconferences. With the hologram effect, the students saw their teacher in the anatomically correct size and could interact with him or her in real time, thus achieving telepresence. Pelet et al. (2017) described this phenomenon as a perceptual illusion of being present without feeling mediated by technology. This feeling can also be achieved with other media and contexts. However, the students reported feeling focused and immersed in the experience. This sensation is described in the literature as the state of flow. Flow is a psychological state characterized by an intrinsically pleasant, optimized experience. To recreate a face-to-face educational environment in distance learning lacking the physical presence of the professor, the developers created the Technological Ecosystem for the Telepresence with Hologram Effect Model (Figure 3).

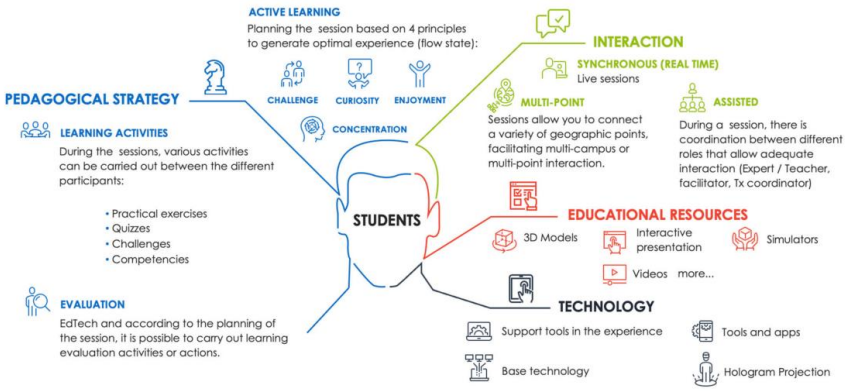

Figure 3. Technological Ecosystem for the Telepresence with Hologram Effect Model [5]

To understand and analyse the participants' perceptions, feelings, and opinions, Strauss and Corbin's representation was used, with the objective of linking empirical data with theory, in addition to Grounded Theory design (GT), which was a tool to analyse and understand the obtained data. The total population was 567 students from different campuses throughout México; this innovation encompasses seven courses, from which three were of Engineering, three of Business, and one Architecture. The study

took place during the semester of August-December of 2019. The students had an age range between 17 and 20 years, as such they were at different stages of their professional careers.
Moreover, an instrument was designed to collect data based on the research questions: 1) *How do students in telepresence-with-hologram courses evaluate the educational experience?* 2) *What characteristics of telepresence-with-hologram courses are meaningful to students?* It's worth mentioning that the questionnaire followed Glaser's guidelines for an open-question instrument prompting.

3 RESULTS

3.1 Case Study: Chencho Project, an ERP Simulator with AR and VR activities

The learning development for the students was good. However, the stress caused in the distance simulation, the interpretation of results, and preparing the case solution report represented a high stress for the students under the context of distance learning in total confinement in their houses.
The results obtained by this gamification in the classroom were surprising in the three study variables, *improvement of academic performance*, *student engagement*, and *development of skills*, and the results improved when virtual and augmented reality lessons were incorporated in which students they could analyse the MRP of materials of each product as well as quality problems by exploring the assemblies themselves without the need to assemble the Meccano physically. Figure 4.
Gamification by itself has significant benefits in education, such as a sense of competitiveness that makes the student addicted to the game and seek learning to improve their performance. This learning is to implement the industrial engineering techniques seen in class. During the simulation, it was observed that the students developed disciplinary learning and could simulate it until they found those parameters that maximize profits. The final reflections in the essay that summarized the experience of the simulator show the development of skills such as teamwork, the reasoning for complexity, and problem-solving.

Figure 4. Checho gamification

3.2 Case Study: Design of an Interactive Virtual Environment for the training of operators

Below the analysis of the results of the answers to each of the questions asked is presented:

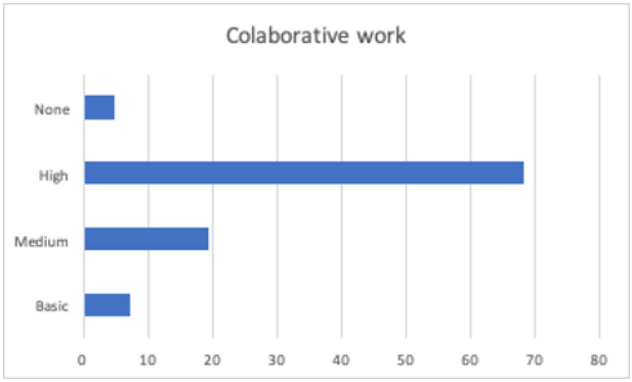

Figure 5. Analysis of the collaborative work competence

Figure 5 shows the results of the question, *What level of development of the collaborative work competence do you think you have reached as a result of your participation in this challenge?*, can be seen that a large majority of the students stated that they recognize a high development of the collaborative work competence, this means that the students recognize that the competence is fully developed and that they feel safe to demonstrate their knowledge and skills. Putting this competence into practice for the benefit of a problematic situation (González-Mendívil, Rodríguez-Paz, & Zamora-Hernández, 2022). Along with this, it is very important to point out that a little more than 80% of the student's state that they have a medium-high level.

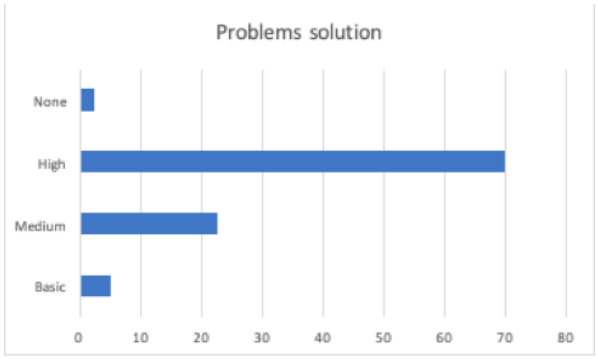

Figure 6. Analysis of the problem-solving competence

Figure 6, on the other hand, shows the question: What *level of development of the problem solving competence do you think you have reached as a result of your participation in this challenge?* and as in the previous case, most of the student's state that they feel that their competence is fully developed, since they are recognizing a high level of development of problem-solving competence.

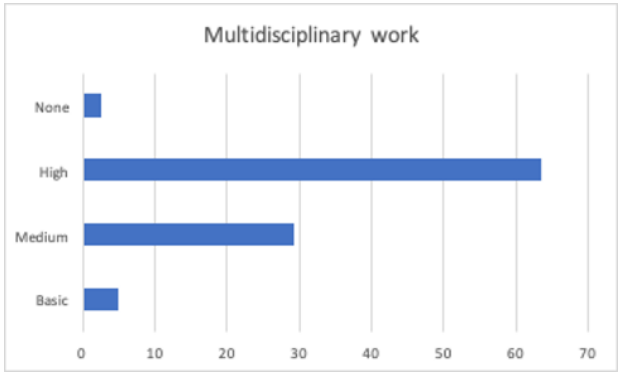

Figure 7. Analysis of the contribution of multidisciplinary work

Figure 7, presents the question *What level of contribution did the multidisciplinary work have to achieve the result of this project?*, in this analysis evidence is presented that most of the students consider that

the multidisciplinary work had a medium to high contribution to achieve the objective of the project with almost 93% evaluation.
In general, the results indicate that students recognize a high level of development of these competences, and this shows that this type of activity is an important approach to help not only students but also people in general to ensure that they have reached a certain level. level of competition (Rodriguez-Paz, González-Mendívil, Zamora-Hernández, & Sanchez, 2021).

3.3 Case Study: AVATAR Professor

Overall, in the telepresence courses the students have the opportunity to identify what excites them and appreciate the dynamic nature of the class, in addition to feeling comfort and amazement to the innovative tool that was developed. The educational experience of the telepresence courses with technological infrastructure gives the students a combined sense of innovation and comfort when seeing their teacher's life-size image, while providing an unique aspect of interaction from student of different campuses; on the other hand, for the professors it provides an opportunity for creating better learning conditions and interactions (Ramirez-Lopez, Castano, Aldape, & Tejeda, 2021).

4 CONCLUSIONS

In conclusion, the support of technological tools in a gamification process helps the students achieve more meaningful knowledge; it improves the collaborative work between students and is encouraged by using technology in learning. Moreover, it motivates students to learn as technology can make the learning process more attractive, as there is a flexible teaching process because of easy access to technological tools at a distance.

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