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MIX REALITY, GAMIFICATION, AND SIMULATORS; THREE TYPES OF STRATEGIES TO INCREASE LEARNING IN THE TEC21 EDUCATIONAL MODEL

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ABSTRACT

During the pandemic, the use of remote laboratories helped maintain academic quality in the areas of Engineering and Science at universities around the world. At Tecnologico de Monterrey, we tried to go further using virtual, augmented, and immersive reality to give continuity to learning through the creation of digital twins during the confinement by COVID-19, and now that we have returned to strengthen the learning of complex lessons,

Using simulators replicating a manufacturing plant's operations allows students to better understand the transactions and generation of data formed by simulating the behavior during a determined period of demand. Gamifying the mixed reality lessons and simulators has allowed us to take learning to a high level of immersion on the part of the students. During distance learning, it was not easy to control the correct use of devices to avoid student distraction, now with the return to school, the use of these technologies allows not only an almost total immersion and increase in learning but also the development of graduation competencies not only of the students but also beyond the university.

A key element of learning in the TEC21 model is the challenge posed by a training partner, but one of the restrictions is the time they dedicate to us and the accessibility to their processes. Through these technologies, digital twins are being created that allow students immersive learning of the processes of the training partners and, for them, the current analysis of their processes and training of new personnel. This document reflects the learning by designing, developing, and implementing mixed reality lessons, simulators, and gamification from August 2020 to date for the development of student learning in the TEC21 model.

Keywords: Mixed reality, gamification, simulators, innovative education, higher education

1 INTRODUCTION

In the 70s, the material requirements planning system emerged, given the need in the manufacturing industry to plan the raw material required to satisfy customer orders. With the development of various applications for production planning, the ERP (Enterprise Requirement Planning) [2] systems were born in the 90s; These systems sought to integrate all the main functions that interact in a company to make production processes more efficient.

The constant variations in delivery times motivated the root causes of said deviations to be investigated; among the leading causes identified are an inadequate integration of supply and demand, incomplete lists of materials, poor capacity planning, and the lack of integration and development of suppliers. The latter generated an exponential development of techniques for production planning, purchasing, and handling of materials. The problem is that many of these techniques work in isolation; Therefore, it is imperative to adopt a holistic approach that allows the interaction of several elements to achieve a common goal. This is how the systematization of tools that allow production planning that simultaneously satisfies the specific needs of the different companies is achieved.

In recent years, gamification has been designed in the industrial engineering department to support the teaching-learning process in statistics, quality control, and operations management. Among the most distinctive approaches, we can mention the beer game, the Tec Motor Company simulator, and the Tec21 Car Assembler. See Figure 1.

Figure 1. Virtual Plant, Tec Motor and Beer Game playing for students

Since 2003, it has sought to design academic activities where knowledge of production planning, inventory control, design of experiments, quality, administration, and evaluation of projects, among others, can be reinforced and put into practice; Thus, the "Tec21 Car Assembler" was born under the STEM philosophy, [3] which was based on assembling scale cars using Meccano models [4].

2 METHODOLOGIES

In March 2021, due to the Covid-19 pandemic, the activity had to be redesigned to be used virtually, so the EON platform used augmented reality lessons with remarkable similarity to Meccano subassemblies, in order for the students to have an experience as similar as possible to physically doing the activity and visiting a car plant.

Based on the ERP (Enterprise Resource Planning) systems, the simulator was designed using systemic thinking to integrate the different activities of an assembly facility in a useful manufacturing process simulator. The students understood the importance of having a systemic vision that would allow them to understand the different flows in a productive entity and the interactions that must occur to improve, among other things, delivery times, availability of materials, and the general productivity of the company.

In 2018, the Tec21 car assembly plant was functional gamification [4], a physical simulation was implemented during the class. In each run, the aim was to enhance learning in a specific area. Using this concept, the simulator was developed with virtual and augmented reality support to make its use more attractive to students.

In the simulation, the concept of gamification is used in order to make it more attractive. When we play a board game, we are motivated to win; this sense of competition makes spending hours and hours in such an activity attractive. We engage students in the learning process by transforming methodologies and problem situations into fun challenges. The advantages of gamification [5] are the following:

- Make learning fun and interactive.
- Generates learning addiction
- It allows the student to see actual usefulness.
- Provides immediate feedback
- Gamification enhances the learning experience.

In this proposal, the most representative processes of a car assembly plant are replicated; It all starts with the customer, from which a purchase order is generated that reaches the materials buyers. When purchasing materials, the productivity index should be consulted because if the purchase order is for 40 cars, buying the spare parts kits for that product would be a mistake if the productivity index suggests buying more to counteract the production problems. Design and quality that may arise. Figure 2

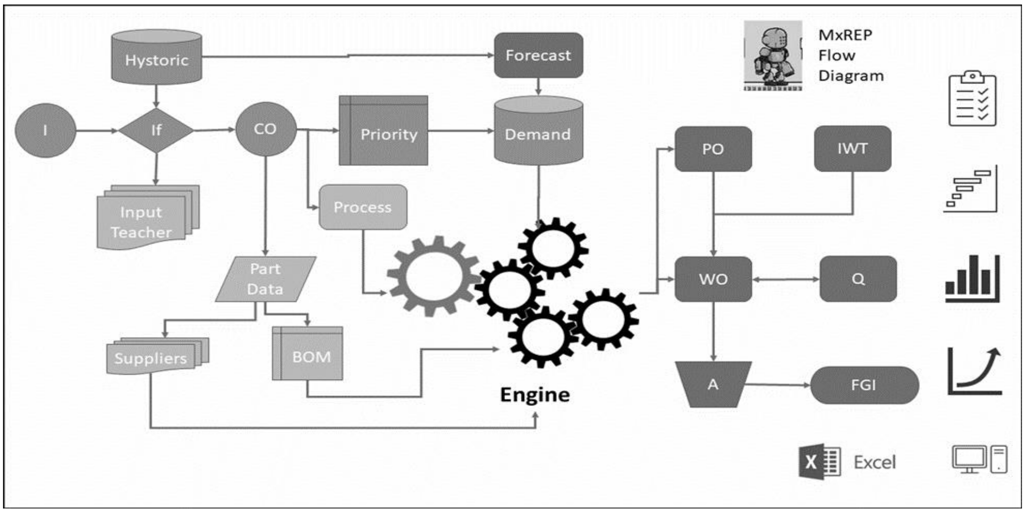

Figure 2. MxREP Flow Diagram

The simulation's programming is based on defining the processes involved clearly, mapping the flow of information, and delimiting it to the assembly of 5 different Meccano models, generating errors through probability distributions that substitute dice, hourglasses, perinolas, and other fun devices. Figure 2.
What is the advantage of this simulator compared to those already offered by other universities and system developers? The answer is that the simulator is wider than a single aspect of ERP. However, as shown in Figure 2, the simulator contemplates purchasing modules, customers, suppliers, demand, inventory management, product engineering, process, and quality, as well as logistics; which allows the simulator to belong to the spectrum, according to Deterding [6], of the concept known in English as “Gamification of learning,” which refers to “the use of game elements in contexts that are not games” or “the process to make activities more like a game” [7]. The simulator offers a game-based learning alternative, which, when implemented in education, has multiple benefits, such as improving student participation, increasing their motivation, and encouraging curiosity, as well as generating attractive and enjoyable learning environments for the student, among many others.
As already mentioned, other simulators are available on the market whose concept is similar to the MxREP. However, they are limited to a single module and do not have the possibility of augmented reality. Universities such as Harvard and MIT have solutions such as the "Beer Game," Flexsim for discrete event simulation, or "Fishbank" [8] to teach about resource management, to mention a few examples. While Harvard has the Operations Management Simulation: Balancing Process Capacity and the Global Supply Chain Management Simulation, however, as has been mentioned, only one aspect of the ERP is analysed, and it is not complete, in addition to the fact that it can be parameterized by the teacher and the game has a graphical interface that is very attractive to the student.
Lost, [9] designed by Professor Pacheco at Tecnologico de Monterrey is an excellent supply chain simulator, based in probability distribution to emulate the customer orders, the constraints of lost are the products, which are defined by the designer, and don't have the MRP o Bill of Material visibility, the supply chain is rigid, and don't have the possibility to make a supply chain configuration.
The Table 1, show the comparative analysis between educational supply chain simulators developed by universities and business companies [10] and [11].

Table 1. Comparative analysis between the simulators developed by universities and business

Features	Simulators						
	Fish MIT	Bank	Beer game MIT	SAP	The production dice game	Lost Tec de Monterrey	MxREP Tec de Monterrey

ERP	Resource Management System Thinking	Logistics, production planning, process control	Procurement Production planning	Inventory Production line, Workflow	Logistics and procurement	Since CO is placed to delivery FGI in site of customer
Gamification	X	X		X	X	X
Simulator	X		X		X	X
AR & VR	2D	2D				2D, 3D, AR & VR
Flexible	X		X	X		X

2 RESULTS

Recently, the implementation of the simulator was carried out in the class of Supply Chain . A test of previous knowledge was applied so that, once the run is finished, we can compare the results based on two variables: learning before (B MxREP) and after (A MxREP) running the simulation, all this through an analysis of experiments. A sample of 31 students was considered, and the data obtained by our survey is shown in Table 2:

Table 2. Descriptive statistics

Descriptive Statistics									
Variable	N	Mean	Standard error	Standard deviation	Minimum	Q1	Median	Q3	Maximum
A MxREV	31	58,60	1,63	9,06	37,59	51,86	59,82	66,9	79,91
D MxREV	31	92,90	0,876	4,878	87,5	90	100	97,5	100

The mean grades obtained before the activity in the simulator was 58.60 and the mean grades after the activity increased to 92.90. Furthermore, It can be seen a large difference between the maximum and minimum ratings obtained; before performing the activity the minimum grade was 37.59 and this value increased to 87.5.

A student's t-test with two paired samples was done to validate that there is a significant increase in student learning when using the simulator, that is, the research protocol has been followed.

The hypothesis to be checked is that the average of the grades obtained in the exams, which for the study will be called "knowledge gain", is different between the two exams.

H0: μ1=μ2 The application of the simulator does not make a significant difference in learning.

H1: μ1≠μ2 The application of the simulator makes a significant difference in learning.

where:

- μ1 is the population mean before the simulation.
- μ2 is the population mean after the simulation.

It is desired to reject the hypothesis Null H0, which will be able to demonstrate the veracity of H1 and validate the assumption that students improve their academic performance using the simulator in industrial engineering topics.

With the support of Minitab software, a student's t-test with two paired samples was done to validate that there is a significant increase in student learning when using the simulator, that is, the research protocol has been followed. The results are shown in Table 3.

Table 3. T Test

Test	
T value	P-value
-21.91	0.000

In addition to the results presented above, non-quantifiable differences in the performance of this activity could be observed. It was possible to see the clear participation of all the students, even in some of the teams there were discussions about what was the best strategy to obtain the greatest benefits. Despite the fact that their involvement was noted, it was observed that they treated this activity as if it were another one, that is, there was a lack of emotion, which arrived at the moment of explaining how they would do the same activity but through the simulator.

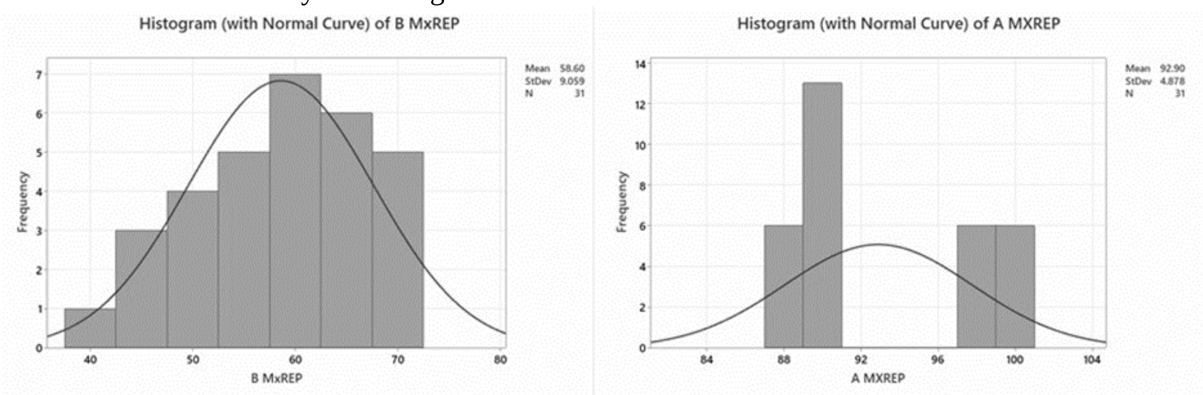

Figure 3. Boxplot before and after applying the simulator

3 CONCLUSIONS

The hypothesis regarding the use of simulators, in this case, the MxREP increased the learning in the logistics process was demonstrated. The variables under research were learning performance, engagement and competencies development, The use of simulators allow the student to emulate the reality under a controlled environment, and play different situations, from quality problems in the process and suppliers, until customs issues or last mile constraints. If a simulator does not get engaged with students immediately, we will lose interest in the learning process, but researchers don't necessarily lose the focus in that the activity is a medium to get an increase in the performance of the students, and the disciplinaries competencies development.

The advantage of MxREP is the flexibility to introduce any kind of product, the visualization of row material and the design of the whole supply chain of the product, the analysis start when the customer placed the CO and finish in the moment that is received the final product, we will measure every event in this process in order to improve the target.

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