NEW AUTOMOTIVE AND AERONAUTICAL MODELS AND DESIGN OF DIGITAL TWINS TO SUPPORT LEARNING IN TEC21 EDUCATIONAL MODEL

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ABSTRACT
One of the takeaways from distance learning during the COVID-19 lockdown was that virtual labs and mixed-reality lessons needed to be attractively designed. The MxRP simulator based on replicating processes of an ERP system of a virtual car assembly company, models based on Meccano, were used. Surveys were carried out with students and teachers to improve virtual and augmented reality practices. As a strategy to bring the lessons to the intramural education of the Tecnologico, or Academic Extension, models of their own cars and planes were designed to take advantage of our student's creativity. The prototypes of these models will be built by 3D printing and machining through a magnet-based clamping model to replicate the same experience in both augmented and virtual reality of the assemblies. New and models previously built by our students for automotive and aeronautical competitions will be also digitized, creating digital twins for learning. The paper shows the context, planning of process of design, prototyping, and construction of these models, with the help of students and professors of the research group. The collaboration of schools of Industrial Design, Industrial Engineering, Mechanics, and Mechatronics for creating and manufacturing these models. Technological advances lead us to replicate professions through virtual and augmented reality, as well as the creation of digital twins to increase the quality, efficiency, and manufacturing of a product.

Keywords: Digital twins, professional education, higher education, educational innovation

1 INTRODUCTION
The application of virtual and augmented reality in education has had a great boom in recent years. These new technologies have gradually displaced traditional methods [1]. But the use of these technologies does not guarantee the attention of the students. The support of didactic techniques such as gamification should be considered, to be better accepted by the new generations of students [2].
On the other hand, the use of digital twins (digital replicas of physical models) allows for a richer learning experience and with the benefits that each of these types of models and their respective means of implementation. Digital models have the ease of manipulation without the fear of wear, damage, even breaking, this through immersive and safe means. The possibility of repetition and flexibility in times that VR offers are interesting characteristics to consider. All the above makes virtual reality a widely used medium in educational and entertainment environments [3]. For their part, physical models allow the use of more senses in the learning experience, a better understanding of proportions and characteristics of the object of study, among others. It is important to mention that both physical and virtual media complement each other and allow for a better and richer learning experience in groups of students with different cognitive abilities. As already mentioned, initially models built with Meccano were used for the virtual assembly plant [4]. In Figure 1 we can see an example of a Formula 1 vehicle made with Meccano and its digital twin, to be used in the virtual assembly factory. Due to the need to

request permits and pay for licenses for the use of commercial models, in addition to considering business models in the future, we intend to develop our own automotive and aeronautical models.

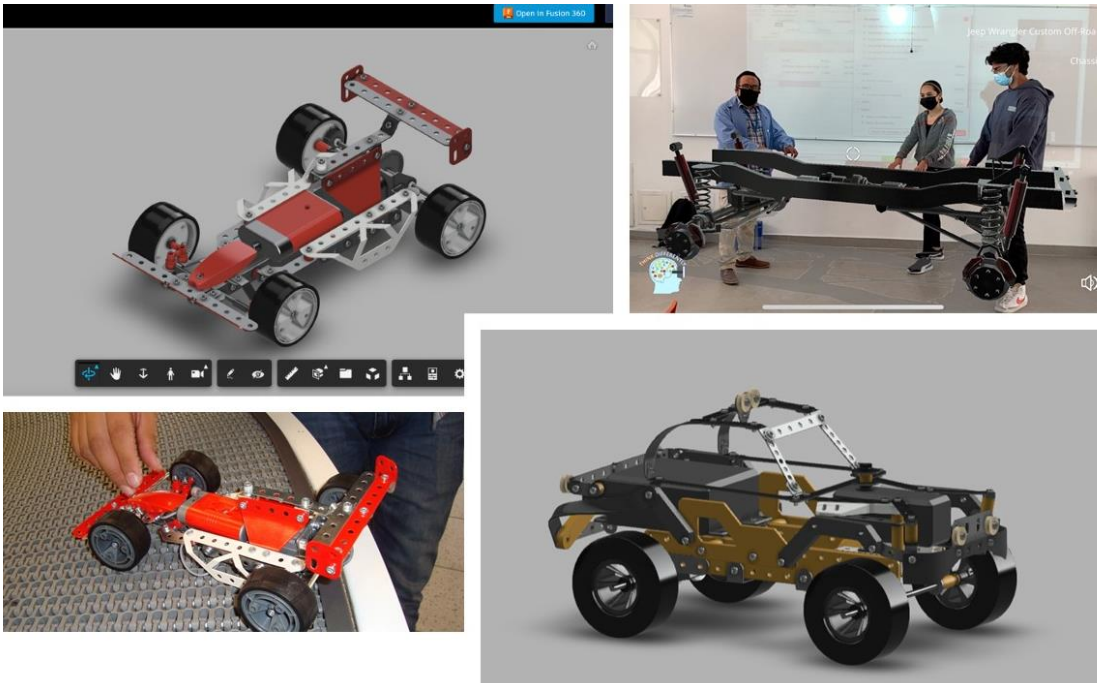

Figure 1. Formula 1 and Jeep car model built with Meccano and its digital twin

2 METHODOLOGIES

Before explaining the methodology behind this project, it is important to mention that this educational innovation proposal is supported by the Novus Fund for Educational Innovation. Novus is an initiative of the Institute for the Future of Education that seeks to reinforce the culture of evidence-based educational innovation among the professors of the Tecnológico de Monterrey, Mexico [5]. The main components of this proposal are described below, including the objectives, main deliverables, execution times, among others.

2.1 General aspects

The official name of the proposal is "Tec Assembly 21 Virtual design and scale construction of automotive and aeronautical concepts". The proposed thematic line is Preparation for the future and the duration of the project is 16 months (since February 2023 to June 2024).

On the other hand, the educational technology that is proposed is Mixed Reality, due to the possibility of considering physical and virtual models in the learning experience. In addition, it is considered that the most appropriate instructional strategy for the implementation of these resources should be Gamification. The academic level for its implementation is Bachelor, with second- and third-year students of Industrial Engineering and Product Design.

2.2 Educational innovation proposal

The educational need can be defined as follows: In the courses that have been determined, from the academic programmes of Product Design and Industrial Engineering, being able to see complete ERP processes run in laboratories or with the training partner (company). it is not entirely possible. This is due to the ability of laboratories and companies to receive visits from students (maximum 20), so emulating these processes in simulators with virtual and physical reality at scale allows us to have active learning by being able to manipulate parts and subsystems. and not a liability with only the explanation of the training partner.

On the other hand, the traditional way to develop skills is through laboratories (mini assembly lines), physical projects (models), video analysis and visits to industrial factories. Figure 2 shows examples of car assembly activities with Meccano.

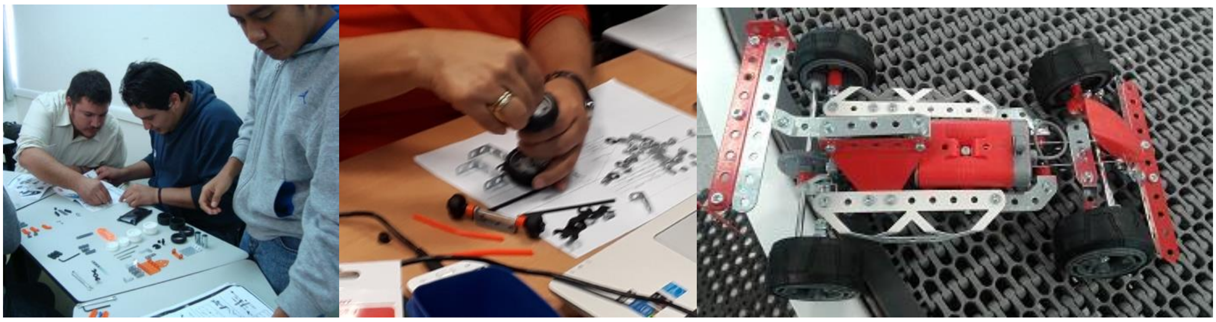

Figure 2. Examples of car assembly activities with Meccano

Based on the above, the general objective of the proposal is defined as developing virtual and physical educational models for the Tec21 virtual car assembly plant and a table game (board) for the development of skills related to the integration of systems and technologies. emerging in students of Industrial Engineering and Product Design. It is important to mention that the cars and planes will be integrated into a new virtual reality platform, project that started last year and will soon be ready for implementation.

It is considered that the innovation proposal, for its part, has the potential to be transferable since it could be implemented in other disciplines and/or levels, since it is the application of virtual/physical reality to recreate environments and dynamics that are impossible to live in the classroom, and even in visits to industrial plants. Although the initial proposal has a focus on Industrial Engineering and Product Design, due to the flexibility in terms of the focus of the activity, it may have applications in other careers such as Robotics and Digital Systems Engineering, Mechatronics Engineering, Mechanical Engineering, among others. It could also be used by graduate students in Engineering.

2.3 Administrative aspects

For the realization of this project there is a budget of $9,500 USD. This amount of money will be used for the payment of a product design student as On Campus Intern, for the development of models and manufacture of scale models. Also, for the purchase of materials for the manufacture of physical models, such as consumables for 3D printing, glues, paint, magnets, among others.

It is important to clarify that the team of teachers involved will not perceive any workload for carrying out the project. Only the On Campus Intern student will receive a monthly payment of USD 250 for each of the 12 months of work (four months per semester).

2.4 Justification of proposal

Because this proposal is an extension/expansion of two previous projects, related to virtual reality [6], augmented and physical reality [4], the educational technologies of 3D printing and mixed reality are the most convenient for the development of this innovation [7]. Figure 3 shows the initial design of the student interface of virtual assembly factory.

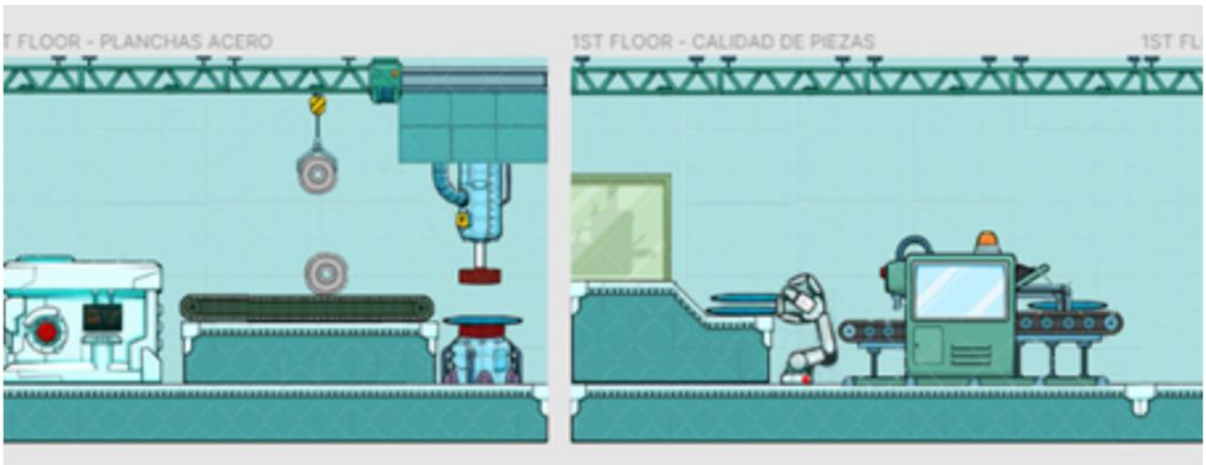

Figure 3. Initial design of the student interface of virtual assembly factory

Virtual and physical models of automotive and aeronautical concepts developed by the Institution are required in order not to depend on existing concepts patented by brands such as LEGO [8], [9], and Meccano [10].
The variables under study, for their part, are learning and problem solving, which to statistically demonstrate results, tests will be applied for the learning variable and the use of a rubric to identify development in problem solving.
Two knowledge exams focused on the practice (topic) of which we want to measure the use will be applied. The first prior to the automotive and aerospace design, the second after having carried out the design practice, to measure if there is learning and that it is statistically significant.
The hypothesis to be verified is the mean of the average of the qualifications obtained in the exams, which for the study will be called "knowledge gain"" is different between the two, being M1 before the PV and M2 after applying the PV, this is we can do by analysing the individual grades of M1 vs. M2 using a two-sample student's t-test in which we want to validate not only that they are different, but also that the mean of M2 is much higher.
For each subject, a specific practice of the virtual plant will be designed where the elements of the test (exam) are linked so that the student has a more detailed knowledge of each element and can, through experimentation, associate the theory in class with the practice offered by using the virtual plant [11], [12].
In the gamification aspect, we found that, in 2021, 70% of teachers saw an increase in student participation when using educational video games. Games, in any form, increase motivation through engagement. Nowhere is this more important than in education [13]. Other studies have found that gamified learning interventions have a positive impact on student learning, however, the impact of gamified learning interventions on student engagement varies depending on whether the student is motivated [14]. These data are relevant to our proposal as it is considered to impact a variety of disciplines and concentrations where student engagement can be increased and learning improved.
Finally, we believe that developing our own aeronautical automotive concepts (virtual and physical) will be a great contribution of added value because we will not depend on licenses and permits from companies such as Lego and Meccano. This will allow us to scale the proposal as required (continuing education) and at a given time (why not) consider marketing it. Another advantage is that these concepts will be adapted to the virtual Assembler and with the required specifications and scope.

2.5 General implementation proposal

The general implementation proposal, as already mentioned above, will consider from the months of February 2023 to June 2024, but considering only the academic periods included in that determined time. That is, the project will be carried out within the semesters February-June 2023, August-December 2023 and February-June 2024. The intensive periods of summer 2023 (July) and winter 2024 (January) will not be considered. This responds to the workloads of the teachers and students involved.
Figure 4 shows the most important aspects of the project and its distribution in the three semesters considered.

Figure 4. Initial design of the student interface of virtual assembly factory

As can be seen in Figure 4, the first semester will be used for preliminary research regarding which design parameters, components and systems, and production line that will be considered for the project. It is expected to achieve the design, 3D modeling and physical manufacturing of at least two cars and

two small aircraft. The intention of the first semester is to obtain the first car design. It will be an MCC (Micro Compact Car), due to the simplicity of its design.
Until the moment of writing this work, progress has been made in the recruitment of the second year student of Product Design who will serve as On Campus Intern; in the investigation of the components and systems to be considered in each type of car and airplane and the different types of assembly lines; as well as in the definition of the parameters to be considered for the design, manufacture and assembly of the models.
The second semester, for its part, will be used for the design of the two aeronautical models and the missing car, the incorporation of 3D models to the new virtual reality platform and the first implementation tests (this new VR platform is still under construction and is expected to be finished by April 2023). Regarding the gamification strategy, which is an important component of the complete learning experience, it will be defined based on previous experiences [2].
Finally, in the third semester, the activities will be carried out in different courses of Industrial Engineering and Product Design, the collection of qualitative and quantitative data, as well as the documentation and closure of the entire project. Publication of results in indexed journals and conference papers is also considered.

2.6 AI implementation in the creative process

In order not to occupy an existing design, teachers and students created our own automotive concept design, to work with the virtual assembly machine. Based on the Double Diamond Model of the British Design Council [15], this divergent process incorporates artificial intelligence in the generation of alternatives for the design of a two-seater car under the "microcar" segment, its two immediate references being the Renault Twizy and the Smart ForTwo. The model is graphically based on a simple diagram that depicts the divergent and convergent stages of the design process, giving the model the shape of a double diamond. The model is also called the 4D model because the name of each phase begins with a 'D': Discover, Define, Develop, and Deliver.
The way in which this principle is adapted to the development of the conceptual proposal of automotive design, lies in implementing artificial intelligence in the "Develop" phase. The discovery phase is given by the purpose of the investigation that corresponds to emulating the process of an assembly company in a virtual way. After an initial formal exploration through photos and sketches and once the automotive segment (Microcar) has been defined, we proceed to the Develop phase, where artificial intelligence is "fed" through "prompts" to generate a greater number of iterations in the process. as little time as possible, exploring the different alternatives that the algorithm produces than two different Artificial Intelligences: Midjourney and Deep Dream Generator. Before converging in the Delivery phase, the proposals are reviewed to obtain feedback from the design team, and thus, be able to determine a proposal that combines the requirements and appropriate parameters of the brief proposed in the first phase (Figure 5).

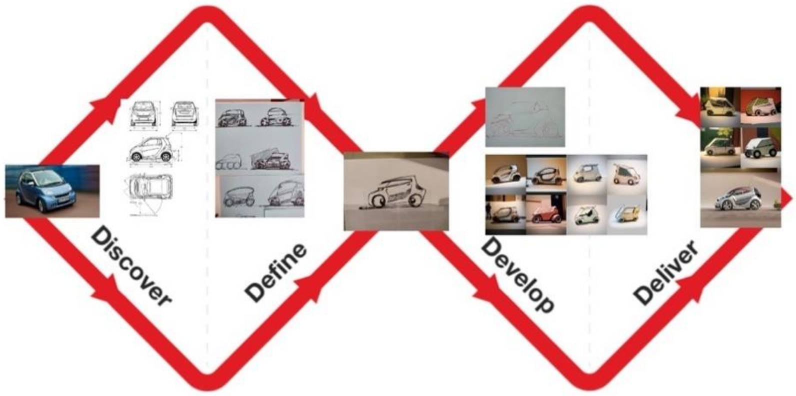

Figure 5. AI assisted double diamond model

3 CONCLUSIONS

Due to the timing of the project, there are currently no concrete results, but the authors consider it important to carry out this work to share the background, context, and implementation process of this educational innovation, to be developed at the Tecnologico de Monterrey Campus Queretaro. And precisely the Tecnologico de Monterrey, as a private system of universities in Mexico, is recognized as a pioneer in educational innovation in Latin America. The expectations we have, and based on similar experiences, is that the implementation of these new automotive and aeronautical models of our own will be well accepted by the Industrial Engineering and Product Design student population and will contribute to a better hybrid learning experience (digital and physical), with the support of virtual reality and the ingredient of gamification. It is also intended, as already mentioned, to eventually to share with others Campus of our university and commercialize the virtual assembly platform and the automotive and aeronautical models. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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