(06-019) - I already have the data; what do I do with it? Projects based on immersive reality in agricultural experimental fields.

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The COVID-19 confinement triggered immersive reality technologies within the educational context in Mexico and worldwide. This motivated governments and universities to develop virtual laboratories for distance learning. The educational model at Tecnológico de Monterrey requires the total immersion of students in industry and laboratories. In the context of Mexico, access to laboratories and industry was closed due to government confinement policies, which motivated the generation of solutions based on immersive reality.

At the CAETEC (Experimental Agricultural Center of the Tecnológico de Monterrey), taking advantage of the technologies of dairy extraction processes and the generation of data in its life cycle, which goes from the planting of corn to the shipment of milk, projects were generated. Data science and analytics, complemented with the design of immersive reality practices, were used to develop our students' remote learning practices in collaboration with the University of Mälardalen (Sweden) and the University of Mondragón (Vasco Country).

The present contribution describes the international collaboration between universities and the private sector to implement virtual laboratories. It describes the design and implementation of methodologies for managing multicultural and multidisciplinary projects.

Keywords: Educational_Innovation; Inmersive_Reality; Project_Management; Higuer_Education

Ya tengo los datos, ¿Qué hago con ellos? Proyectos basados en realidad inmersiva en campos experimentales agrícolas.

El confinamiento por COVID-19 fue el detonante para las tecnologías en realidad inmersiva dentro del contexto educativo a nivel mundial. Esto motivó a gobiernos y universidades a desarrollar laboratorios virtuales para el aprendizaje a distancia. El modelo educativo en el Tecnológico de Monterrey requiere la inmersión de los alumnos en la industria y laboratorios. En el contexto de México por las políticas gubernamentales de confinamiento, el tiempo que duró cerrados el acceso a laboratorios e industria motivó a genera soluciones basadas en la realidad inmersiva.

En el CAETEC (Centro Agrícola Experimental del Tecnológico de Monterrey), aprovechando las tecnologías de procesos de extracción de lácteo y la generación de datos en su ciclo de vida, que va desde la siembra del maíz hasta el embarque de leche, se generaron proyectos de analítica de datos para el aprendizaje remoto de nuestros alumnos, complementados con el diseño de prácticas de realidad inmersiva, en colaboración con la Universidad de Mälardalen y la Universidad de Mondragón.

La presente contribución describe la colaboración internacional entre las universidades y el sector privado para implementar laboratorios virtuales. De igual manera describe el

diseño y la implementación de metodologías para la gestión de los proyectos multiculturales y multidisciplinarios.

Palabras clave: Innovación_educativa; Realidad_Inmersiva; Gestión_de_Proyectos; Educación_Superior.

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1. Introduction

In the last years, Tecnologico de Monterrey through its new Tec 21 educational model, starting in 2019, has made a new opportunity for the rise and use of new and emergent technologies globally.

With these new technologies, we can implement and train the current student population via our partner CAETEC (Experimental Agricultural Field from Tecnologico de Monterrey) to analyze and identify new efficient solutions using current and previous data. Doing so increases the range of opportunities for the Institute and our partners to collaborate, share knowledge, and apply new technologies to controlled study grounds, allowing for the development of more complex projects regarding precise agriculture, data science, digital twins emulation, and better design of experiments using current milk production processes. Thus making room for other current and future projects.

A farm, whether agricultural or cattle, is an endless source of information. In the traditional way of working, knowledge is based on experience, not on processes, and if the daily operation is not automated, information flows freely but without rigor for research. The agricultural experimental field belonging to the Tecnologico de Monterrey began from Starting with the confinement caused by COVID-19; in Mexico, we had a long period without being able to use the facilities and laboratories of the Tecnologico de Monterrey, but at the same time, CAETEC was transformed into a data farm, whose process began in 2016. However, due to the lack of laboratories, it was accelerated to have a laboratory for the students of the Technological system, made up of more than 26 campuses and 54,762 students. The question is, I already have the data. What does Tec de Monterrey do with it?

Significant and large projects are often motivated by unplanned circumstances or situations that pose challenges, which motivate solutions based on creativity and innovation. The transformation of education and companies with distance learning and teleworking do not have returns. This journey involved developing technologies emerging in 2020, such as extended realities and data science.

In the same way, universities began to seek to develop virtual laboratories that would not detract from student learning, as well as links with the business sector to make a reality, in the case of Tecnologico de Monterrey, of the introduction of the new TEC21 educational model whose central axis is challenge, which is a problematic situation proposed by the training partner, who is the central figure because he is a character who does not belong to the Tecnologico, but who designs a challenge based on a genuine problematic situation that comes from his company.

In the academic world, networks between researchers and a spirit of collaboration to improve the quality of distance learning exponentially accelerated emerging methodologies. They motivated the increase in virtual and augmented reality lessons designed for academia and companies. These processes generated data, and the data now need to be given statistical treatment for them to have significance.

An example of a collaborative project where researchers and universities work on common objectives is the design of this project to process data from a living laboratory of the Tecnologico, an agricultural and livestock farm, for our students' learning. The expertise of the University of Mälardalen in the XR design as technology for learning and the research about the interaction between users and the robot to design the best academic and innovative educational lesson.

The data is generated in four significant areas, which are branched according to each stage of the process. Precision agriculture, in which information is generated from the seed, irrigation,

fertilization, harvest, and generation of silos, where the variables under analysis are focused on the increase of nitrogen in the diet, which is a variable that is highly correlated with increasing milk production.

The second area of study is focused on the cow barn, which has become a fully automated barn for 14 months since the milk extraction process is carried out through a voluntary system provided by the DeLaval company. The data generated allows the cows' diet to be optimized according to different variables and periods, the maximization of milk production, and the quality of life of the animals, to name a few.

The third area of data source comes from intensive agriculture: data obtained from greenhouses from the training partners' processes and seeds.

Moreover, the fourth large area comes from the information generated in the vineyards and fruit trees.

This project is focused on the second area. The academic target is for students from the School of Engineering and Sciences (EIC) as well as agricultural (IAG), food (IA), biotechnology (IBT), industrial (IIS), mechanical (IMA), and mechatronic (IMT) engineering. The project has been divided into two stages.

a. Development of a virtual reality lesson for distance learning of the milk extraction process using a voluntary system based on a robotic arm.
b. A simulator of the process from feeding the cow to its voluntary entry into the milk extraction room with the robot and its rest area.

The large amount of data that arise in the processes will feed both the virtual reality lesson and the simulator, which have three clear objectives.

a. The learning of students from Tecnologico de Monterrey and universities in agreement.
b. For disciplinary research and educational innovation.
c. To improve society through replicating good practices documented in practice and research.

The answer was to process and manage data for the learning of different training units, which in the TEC21 educational model are equivalent to a subject taught in one semester. These training units are five weeks long, but they cover the same number of hours as they would take in one semester.

With the data, concurrently, the need arose to use digital twins and emerging technologies to support learning from the data through virtual and augmented reality simulators and practices.

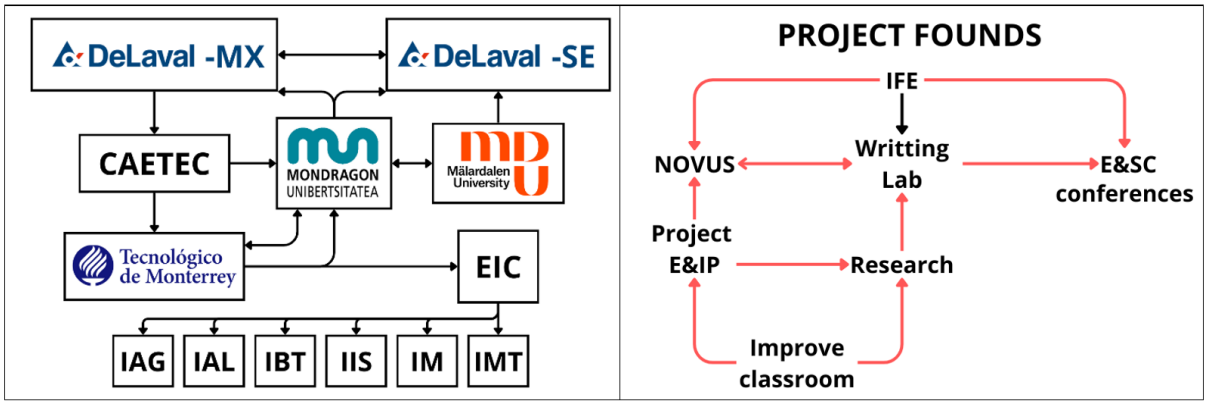
CAETEC, despite being the largest laboratory at Tecnologico de Monterrey, has different restrictions on bringing entire groups to its facilities. So, among the institutional projects, the present paper explains the making of a virtual plant for the experimental agricultural laboratory. One of the first modules is the robotic milk production process.

DeLaval manufactures the robots being used. The term robotic milking system refers not only to the use of an articulated hydraulic arm but also to the concept of global automation of a facility and the voluntary assistance of the cows to the robotic milking module, also known as VMS for its acronym in English: Voluntary Milking System.

This interdisciplinary project has allowed academic collaboration between three universities to achieve the established objectives where the University of Mondragón will work with the impact between users and robots, thinking in a future context that Mexican and other livestock farmers can replicate this technology. Latin America, the design of virtual reality lessons for training

DeLaval employees and students in the area of mechanical engineering, mechatronics, and digital systems, and finally, the Tecnologico de Monterrey that has designed the digital twin for the VMS system as well as virtual reality lessons (Figure 1).

Figure 1. Process to interaction between universities and the process to get the project's findings.



2. Methodology

The methodology followed in this research is to analyse the results obtained by using digital twins and ERP system simulators and follow the same process for the digitalization of the De Laval robot but in a multidisciplinary project between the University of Mälardalen, the University of Mondragon and the Tecnológico de Monterrey.

The research problem is to search for the best tool in emerging technologies to support the learning of different training units, taking advantage of the statistical information obtained both in precision agriculture of corn as a raw material in cow feed and the use of voluntary milking systems to generate sensitive information for decision making.

The variables studied are qualitative since they are focused on knowing the opinions of students and teachers when learning using accurate data with the support of digital twins.

The methodology used in this process as described below:

a. Describe the problematic situation through a collaborative intervention process between all parties, based on soft systems methodologies that provide an improved rich picture of the process, actors, stakeholders, and restrictions.
b. Correctly define the problem, avoiding confusion with symptoms through the Kepner and Tragoe methodology.
c. Collaboration between researchers and universities can be generated through experience and strengths under transparent processes, considering each university's and research center's regulations.
d. Projects are undertaken through creative phase methodologies, such as design thinking and thought engineering, to solve the problem in a viable and feasible way.
e. Establish both predictive and agile professional project management that allows remote collaborative processes with continuous reviews and improvements.
f. Design a data management system that provides the simulator and virtual reality lessons with valid information that is easy to process.

3. Development

Virtual reality is one of the most penetrating technologies in education and industry; recreating scenarios through digital twins is a differentiator in industries, and there is a high correlation between its use and the increase in quality indicators and productivity, which in turn are factors for increasing profits.

Through a digital twin that simulates the complete process from when the cow is in the stable, it goes to the station where the robot is, the milking process is carried out, the data is generated, and the cow returns to the stable; the simulator is ready to generate simulations with this information, based on accurate data for learning different topics such as:

- Experiment Design
- Forecasts for decision-making.
- Inferential Statistics.
- Statistical Engineering.
- Data science.
- Engineering in the robotic milking system.
- Integration of bioproductive processes

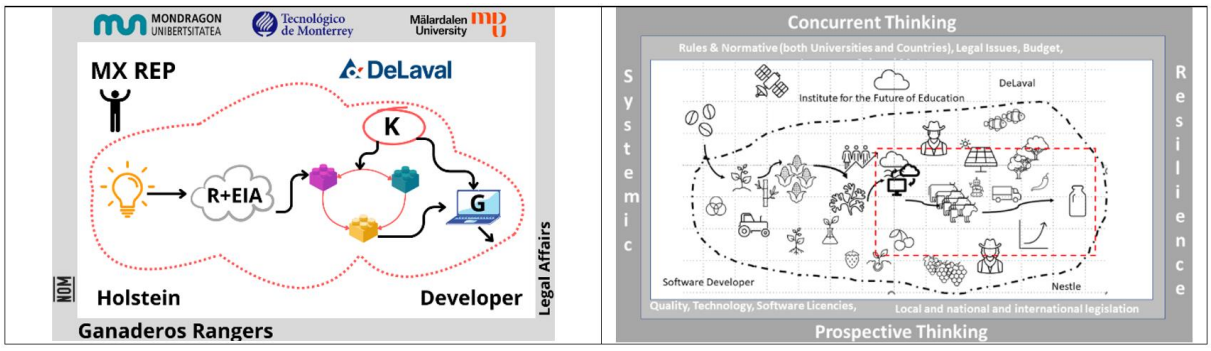
This digital twin also consists of virtual reality practices, where students can interact with the VMS system from their campus, which can be located in different states from where CAETEC is located, without the need to travel to CAETEC. Students who belong to the Tecnologico de Monterrey system can practice within the VR Zone, better known as Mostla.

CAETEC currently receives applications to be a training partner of training units, mainly from the Engineering and Science schools of the Tecnologico de Monterrey's different campuses, mainly from the Querétaro campus, specifically from the departments of Industrial Engineering, Mechatronics, Robotics, Agronomy, and Biotechnology. It also receives requests from other universities and research centers.

It has experimental fields for extensive agriculture (open sky), mainly of corn, where different precision agriculture technologies are applied. The main objective of planting corn is for it to become the basis of the cows' diet. They are of the Holstein breed, and the milk these cows produce is sold to one of the most important companies for human consumption.

Other activities of CAETEC are intensive agriculture (in greenhouses), vineyards, fruit trees, and cattle. Using the soft systems methodology proposed by González et al. 2022 and Checkland, P. B. (1989), the current situation of CAETEC was described. The current rich picture reflects how CAETEC operates from a systems point of view, and the problem has been defined. With this, the best solution proposal is the design of a digital system for the milking part (Figure 2).

Figure 2: Soft System Mapping explaining the CAETEC´s Problematic Situation



The problematic situation is that CAETEC does not have the infrastructure in human resources and facilities to receive large groups of students that want to learn about the milking process and cannot satisfy the demand for challenges requested by different teachers. So, service is not being provided for these requirements, being one of the objectives of CAETEC is to become a living laboratory for students of the Technological System; this also prevents it from serving as a reference and research for other educational centers and private researchers.

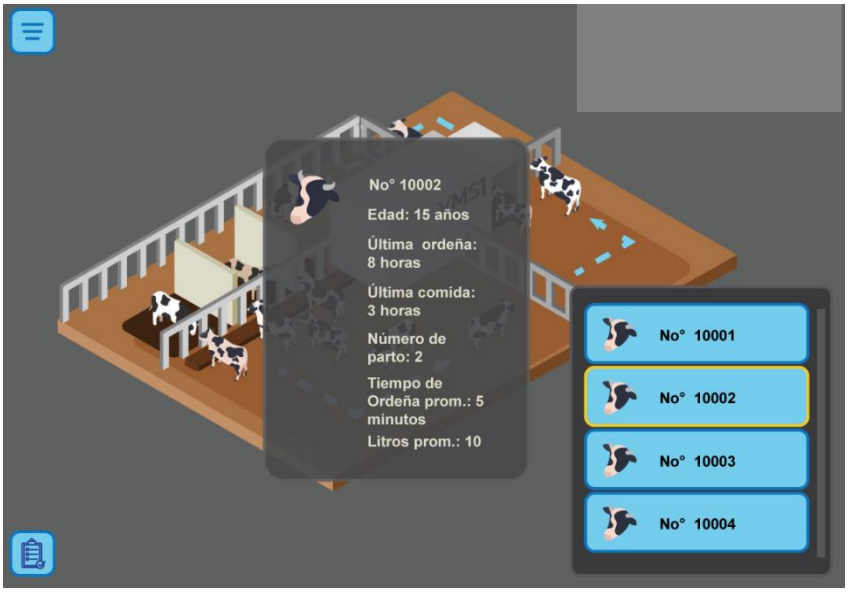
The problem definition, based on the Kepner and Tragoe (1981) methodology, the problem has been defined as follows: CAETEC needs to have the capacity in human resources and infrastructure to receive students who request to visit the VMS facilities to learn about its functioning and the daily performance, and this has occurred since the return to normality in classes derived from the confinement by COVID19 in the academic period that began in August 2022.

To solve this problem, a digital twin model of the milking robot was designed based on virtual reality and augmented reality technology for remote learning based in XR experiences, González et al. 2023 and Mirza and Matri 2023. The academy and the company worked together to ensure that said design meets the needs of the students' learning, as well as those of the company in terms of marketing its product and maintaining and using the robot by its employees.

The design we are working on consists of the following milestones: the digital twin will be an interactive solution for PC, and the milking process and the technology involved within the CAETEC will be explained. The application will guide the user step by step during the operation. Two development phases were defined for the interactive stable:

Phase 1: Interactive map of the stables where the general system of the milking area and the milk cycle is explained; here, the user interacts with the virtual world and the elements are mainly selected with the click of the mouse. The user will be able to select up to 10 elements in the scenario, for example, VMS, cows, feeding area, rest area, sensors, and doors, to name a few; the information of the selected elements (statistics and relevant information) will be displayed on the screen. The design of the solution also includes a dashboard with the operation's strategic KPIs. (Figure3)

Figure 3: Visualisation of the cow's milking process.



The user will also be able to view and analyse the cow control panel, where there is a list of cows and view data of research interest such as age, milking time, milk produced, last milking, and calving number. The user will be able to select all the components. The application will have a tutorial that guides the user to perform the following actions:

- Select all components of the interactive map.
- Select the cow panel.
- View the information on three different cows.

In the phase, a general panel has been designed where the general statistics of the entire stable will be displayed, accompanied by dashboards such as graphs of:

- Average milk production.
- Average milking time.
- Amount of food consumed per day.

Diet design (food generation). At this point, the user can modify the food formula by changing the percentages that make it up. For the cow simulation module, the system is designed for the user to manipulate the behaviour of the cows with the following commands:

- Send it to veterinarian service.
- Send to feeding.
- Send to milking.
- Send to rest.

For the virtual reality lesson, the design has been thinking about a prospective and concurrent approach since the lesson is being built in standard modules, to later derive the application for students (academic) and for the robot manufacturer in these lessons. We are explaining the maintenance and calibration process of the milking robot.

The application will guide the user step by step during the operation. Scopes: The design was made for HTC Vive headsets. Here, the user interacts with the virtual world and the elements mainly by selecting them with the control. There will be narration in Spanish and English; subtitles can be activated for this narration. In the same way, the design has considered deploying signage on those elements relevant to the learning process.

The simulator and VR lesson have been a work of many hours in a multidisciplinary and cultural project that started a year ago with the proposal to the Institute for the Future of Education through the Novus funds, where we won the competition to access financial funds to develop virtual reality lessons.

The first design phase was carried out through video calls, and in October 2023, there was a visit from the University of Mälardalen to intensively work on the design of the practices and the simulator. The second phase was to incorporate the vision of interaction between the management of the robot and the human from the University of Mondragon.

4. Results

The variables studied are mixed, quantitative, and qualitative since they are focused on knowing the opinions of students and teachers when learning using accurate data with the support of digital twins.

The study was conducted in three training units with two groups each, taught serially within the fifth semester of the Industrial Engineering curriculum.

- IN2004B Generation of Value with Data Analytics

- IN2005B Organizational Competitiveness Evaluation
- IN2006B Analysis of the Viability of Projects from a Systemic Perspective

The training partner was CAETEC. The objective of the three training units was to maximize milk production through the analysis of the data provided by the automatic milking system and make organizational improvements through the implementation of worth.

The study compared the results of this exercise in the same training units in 2021 and 2022 against the 2023 projects. In the IN2006 training unit, a milking process capacity exercise was carried out to evaluate projects. The data was used with a virtual reality test lesson, and the following results were obtained. The activity took place in the campus's VR Zone, Mostla. Teams of students used virtual reality lessons to learn the voluntary milking system.

The research protocol analyses four variables: two for using the Innovation Learning Activity (ILA) and two for traditional learning Table 1 shows the descriptive statistics for each variable.

μ_1: population mean of T before A

μ_2: population mean of T before C

Difference: μ_1 - μ_2

Equal variances are assumed for this analysis.

Table 1: Descriptive statistics of each variable

Variable	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
T before A	0	63.97	3.03	16.33	40.00	50.00	65.00	80.00	90.00
T After A	0	82.41	2.67	14.37	45.00	72.50	85.00	95.00	100.00
T before C	0	66.52	2.77	13.27	45.00	55.00	65.00	80.00	90.00
T After C	0	71.52	2.82	13.52	50.00	65.00	70.00	85.00	100.00

Before the ILA application, students applied for a knowledge test about the capacity line theme. The population in the 501 groups was 29 students, and the mean for 20 questions, the value for everyone, is five points, 63.97, under the minimum of 70 for approval of the test. Students performed the ILA first in the classroom and then in the Zone VR or Mostla Laboratory. The descriptive statistics show an increase in grade from 63.97 to 82.41. Figure 4 shows the boxplot between T before A and T after A variable.

Regarding the interface and interaction with the De Laval Robot, the result of a survey was applied to students, professors, and employees (size of sample 52) to answer the following 8 questions.

- Strongly disagree (value: 1)
- Disagree (value: 2)
- Neither agree nor disagree (value: 3)
- Agree (value: 4)
- Strongly agree (value: 5)

1. The robot enhances my work performance.
2. The robot helps me to be more productive.
3. The robot helps me to complete the task in a shorter time.
4. The robot is user-friendly.
5. I can use the robot without written instructions.
6. I trusted the robot would not harm me.
7. I am very confident in my ability to control the robot.
8. I can adjust the robot to help me carry out my tasks.

Figure 4: Boxplots between variables T before A and T after A

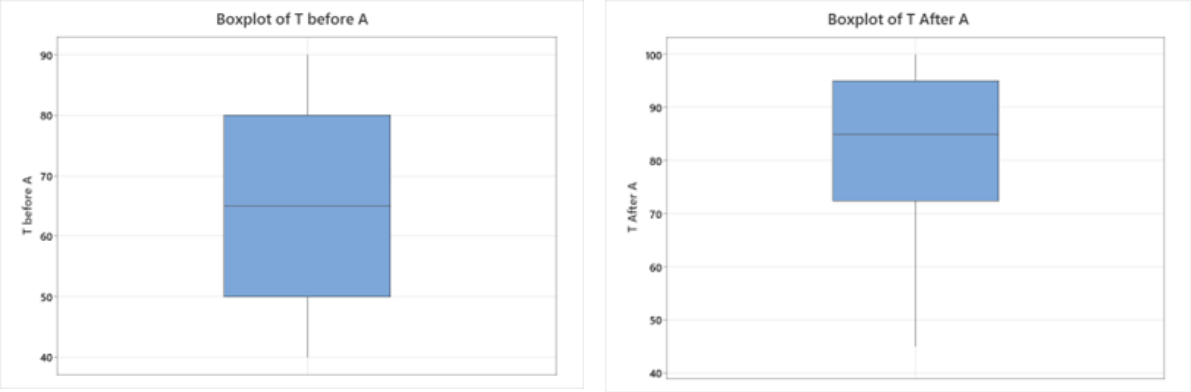
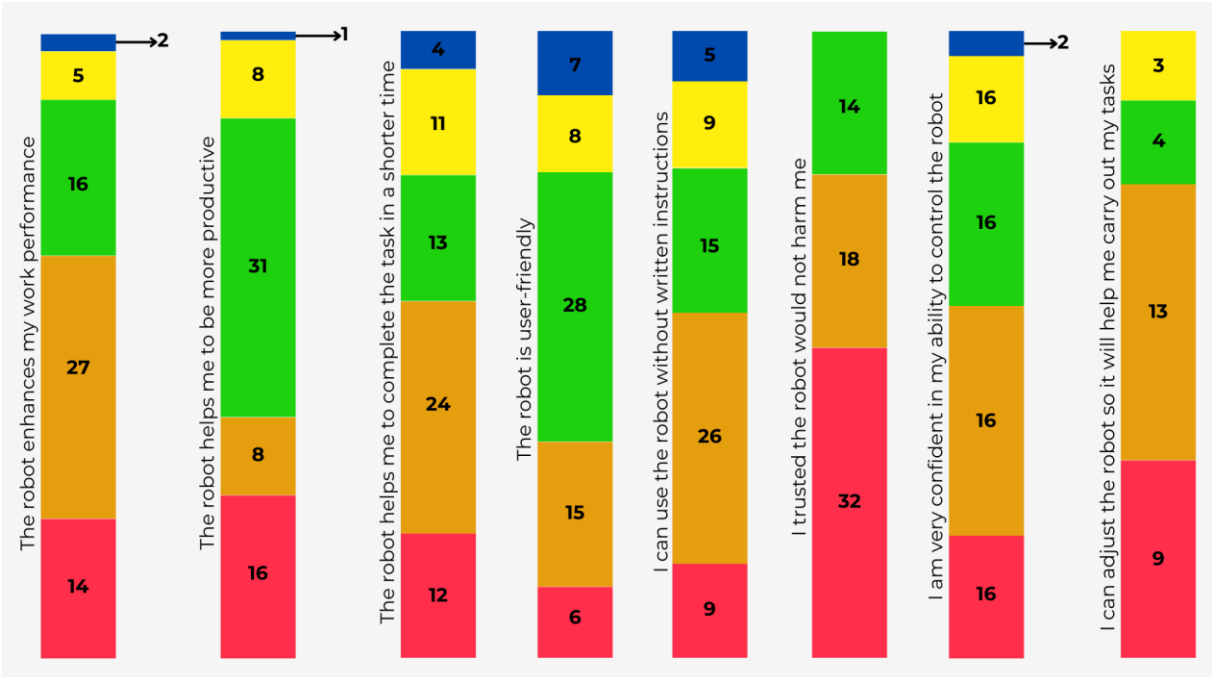


Figure 5: Hurox questionnaire applied to students, teachers and employees who use the De Laval robot.



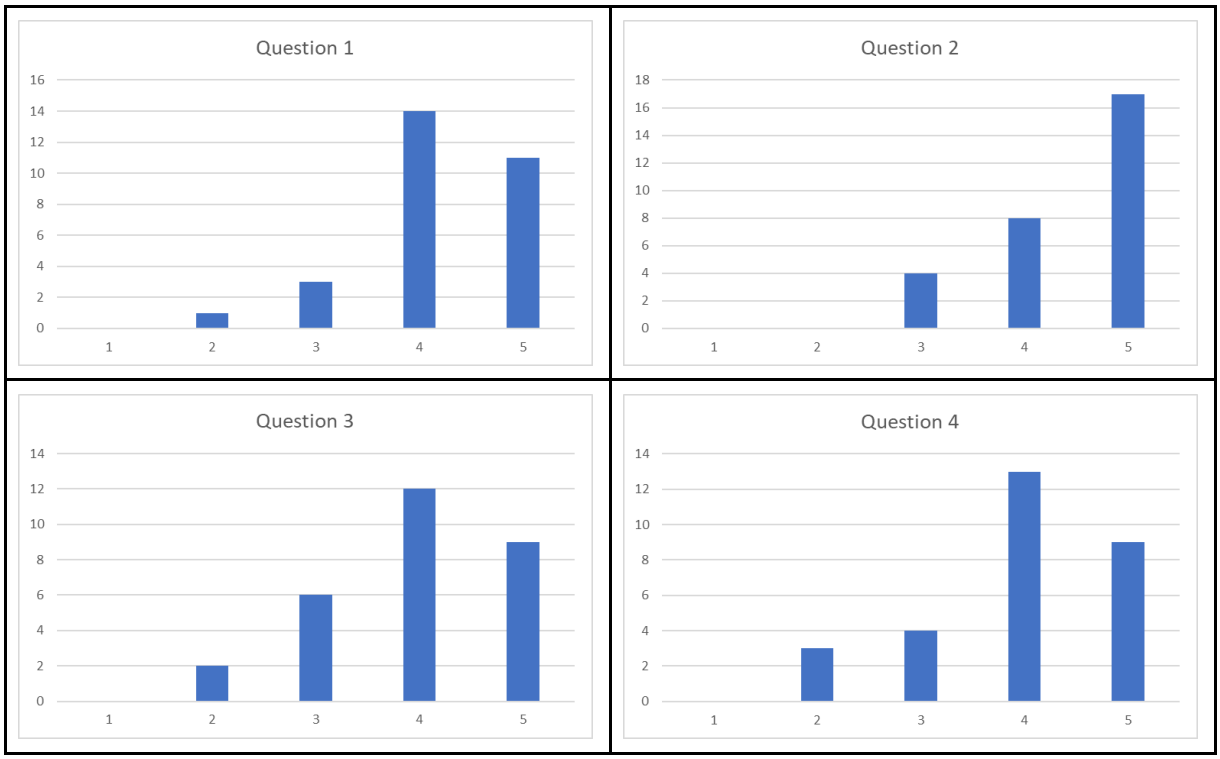
By applying the Hurox questionnaire proposed by the University of Mondragon, Apraizal et al. 2023 to measure the interaction between robot and humans, we can observe that users feel very comfortable using the robot, it is easier for them to use, CAETEC has managed to increase its productivity and quality, and above all everything, the information obtained about the milk milking process.

Regarding the qualitative variables, the students answered four questions using a Likert Scale, where the scale is:

- Strongly disagree (value: 1)
- Disagree (value: 2)
- Neither agree nor disagree (value: 3)
- Agree (value: 4)
- Strongly agree (value: 5)

1. Based on the virtual reality lesson you took, does using a digital twin improve your learning process?
2. When using the virtual reality lesson, did the data mean more than just numbers to you in your learning?
3. Based on the lesson carried out, would you like the learning of complex topics to be supported by virtual and augmented reality lessons?
4. Does the use of virtual reality lessons give significance to learning and database management?

Figure 6: Results to the questions, where the x-axis represents the scale and y-axis represents the number of students that answered the question.



5. Discussion

With these new topics, the importance of using this virtual reality tool in cooperation with the University of Mälardalen and Mondragon University, in partnership with the Institute for the Future of the Education (Novus) will allow greater cooperation efforts to improve an academic impetus between new technologies and real-life data exchange, thus making a complete scenario recreation with a more stable cloud data reservoir to improve amounts of uses in any day of the week without disrupting data input and at the same time allowing people from other places to see in real-time new files, data, and changes done to the machine. As such, making the current digital twin with total implementation via 3D laser and modal scanning as a first step via SolidWorks/Fusion 360 CAD software will allow us to share the CAETEC robot model between the Novus platforms, making small changes to the final model to start limiting the total movement of the machine considering current boundary conditions data input and outputs as to see where wrong data could happen, as such solving the wrong data to provide a final cooperative virtual reality project that will be repeated at any time and with any new data that may arise.

Collaboration with Mondragon University has been essential to applying research that helps to understand the behaviour of humans and robots. This discussion is applied in the simulator and the virtual reality lesson.

6. Conclusions

Digital twins are a more efficient and democratic gateway to knowledge. The construction of this design has allowed us to be at the forefront of the Tec21 educational model in terms of generating remote learning experiences. Today, we have designed during the last 3 years data analytic project analyzing the process from corn growing to delivery of milk to the customer. Still, this data are saved in the hard disk for CAETEC for the decision process now is necessary for the interact with the real data for students to understand the process and, researchers to find new and innovative process to increase the productivity, trough new methodologies and process.

The interaction and collaboration between academics from the three universities has also been an experience worth sharing. It has shown how different visions can converge in designing high-value learning activities through educational innovation supported by professional project management.

The project will be released in the classroom in July 2024 and can be fully implemented by the end of the school year (August 2024). Results and prototypes will be shown at the congress.

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