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Challenge-Based Learning and Scrum as Enablers of 4.0 Technologies in Engineering Education

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Abstract: Incorporating Industry 4.0 technologies in higher education is crucial for preparing future engineers in a digitalized industrial environment. A challenge-based educational model and the agile Scrum methodology were implemented to move in this direction, combined with the use of Industry 4.0 technologies. New physical and virtual laboratories were enabled with Industry 4.0 hardware/software equipment. The engineering academic programs at the second-largest university in Chile were modified, and all the academic staff involved were trained. Based on conducting challenges that Industry 4.0 technologies can address, this study presents the results of implementing a new educational model and students' response to freely adopting new technology, such as artificial intelligence (AI), the Internet of Things (IoT), and collaborative robotics. The results showed a high rate of acceptance and use of 4.0 technologies by the students, so the proposed methodology could be extrapolated to other engineering programs worldwide.

Keywords: challenge-based learning; Scrum; Industry 4.0; engineering education

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1. Introduction

1.1. Context

In the last decade, Industry 4.0 has emerged as a fundamental paradigm for the modernization and digitalization of production systems, characterized by the integration of advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), virtual reality (VR), and augmented reality (AR), among others. This industrial revolution is significantly transforming all industrial sectors, including higher education.

Thus, universities face the challenge of adapting to these new technologies both in their organizational form and, of course, in the academic training of their students. It is essential that universities not only limit themselves to acquiring technology but also promote a culture of innovation and constant adaptation in their academic and student bodies. On the other hand, the labor market increasingly values competences such as solving non-standard problems using the latest technologies and developing innovative solutions [1]. To achieve all these objectives, a comprehensive approach ranges from strategic planning to practical execution in the classroom and laboratories.

In this sense, the implementation strategy presented in this article is based on six fundamental pillars: (1) adoption of the challenge-based learning methodology and the agile Scrum methodology; (2) selection and acquisition of Industry 4.0 technologies; (3) adaptation of infrastructure to create physical laboratories; (4) development of virtual laboratories; (5) modification of the degree curricula; and (6) training of the teaching staff.

These pillars were built through consultations with national and international experts from both academia and leading companies in Industry 4.0 technology. It is crucial to highlight that these pillars are not static; they must continually evolve based on technological advances and labor market demands. The implementation of these pillars included the adaptation of physical spaces, design, manufacturing, and installation of furniture specially

developed for the use of technology. In addition, a new technological department called the National Unit of Industry 4.0 Laboratories (NUIL) was created, composed of engineers who are experts in various Industry 4.0 technologies. The mission of the NUIL was to coordinate and manage the technological and human resources necessary to successfully integrate these technologies in academic training. It links specialized academics and technology, unifying joint projects and ensuring that students have access to real and current industry problems.

One of the most relevant aspects of implementing this initiative was training academics. To achieve successful implementation, the teaching staff were previously trained in 4.0 technologies, challenge-based learning, and agile project methodologies (Scrum).

The central objective of this article is to provide evidence on the implementation of Industry 4.0 technologies in a higher education institution (taking as a case study the second largest university in Chile) and evaluate the adoption of advanced technologies by engineering students, especially in their ability to solve real industry problems. The implementation of 4.0 technologies involves adopting new tools and a profound change in the educational mentality.

1.2. Technological Approach in Engineering Education

Various methods have been developed to enhance engineering education since engineering was formalized during the 17th century. In this sense, in engineering education, learning and teaching encompass various styles that acknowledge the diverse ways in which students learn. This approach—that in engineering education is strongly influenced by the positivist paradigm, with the educator significantly predominating and less space for the student to self-construct knowledge [2]—includes visual and auditory learning, reflective and active learning, logical and intuitive reasoning, memorization and visualization, drawing analogies, and constructing mathematical models [3]. In addition, teaching happens through the interaction of instructional tools and students' efforts to gain knowledge, principles, or skills [4], where technology is most relevant. In this sense, when implementing CBL, educators act as facilitators based on a constructivist educational approach [5].

From a technological perspective, the latest information and communication technologies (ICT) have become fundamental to university teaching, catering to students' diverse motivations and academic competencies. While ICTs do not replace educators, they serve as a potent resource. Their incorporation entails new platforms and capabilities for recording, storing, and disseminating knowledge, thereby enabling the development of new content, study methodologies, and assessment methods. Consequently, innovative initiatives have emerged, and in recent years, engineering educators have embraced the challenge of reforming engineering education by leveraging new technological tools and techniques to significantly enhance the teaching–learning process [6].

On the other hand, according to some regulatory frameworks that are commonly used as referents internationally, such as ABET (Accreditation Board for Engineering and Technology) and CDIO (a framework for engineering fundamentals focused on conceiving, designing, implementing, and operating), technological training plays a fundamental role. ABET [7] states that engineering training should consider integrating management systems into diverse technological environments, including computer-based technology. CDIO emphasizes, as one of its main objectives, understanding the importance and strategic impact of technological development in society [8]. From an institutional perspective, organizations guiding education policy have mentioned technology the most, emphasizing the importance of technology in an education context [9].

Nowadays, the field of engineering is experiencing rapid technological advancements, which necessitate updates to educational programs and the skills and knowledge provided to students. In the 21st century, societal well-being heavily depends on technological accessibility, with engineers as mentors. As a result, educational models need to expand their focus to include "Engineering Education for Industry 4.0" or "Education 4.0", driven

by the use of a wide range of interconnected innovative technologies such as AI, robotics, additive manufacturing, cloud computing, and big data [10].

Accordingly, the fourth industrial revolution will demand the development of new engineering programs to equip students with the ability to understand the requirements for technological solutions in various contexts [11]. In this sense, enablers for Education 4.0 must consider emerging technologies, new learning methods, and the current social dynamics to ensure adequate implementations based on appropriate learning environments that will prepare students for future scenarios [12]. In other words, Education 4.0 will help provide skilled labor in the future for Industry 4.0 [13]. Moving beyond Industry 4.0 to Industry 5.0—focused on utilizing innovation and research to facilitate a transition to a sustainable, human-centric, and resilient industry—experiences such as human–agent/machine/robot/computer interaction arise as strategies for lifelong learning and transdisciplinary education [14].

2. Materials and Methods

The convergence between engineering education and the technological advances of Industry 4.0 is redefining the skills needed by future engineers. This context demands an educational transformation in line with the challenges of a highly digitalized and connected industrial environment. Thus, Industry 4.0 requires a structured methodological approach to be effectively incorporated into academic training.

The use of Industry 4.0 technology was evaluated by analyzing the technological solutions presented by engineering students to real problems. In this sense, students were challenged with real issues from the industry, which required the use of Industry 3.0 or Industry 4.0 technologies. The evaluation of the technological solutions was binary: they used 4.0 technology, or they did not use it. This information was segmented according to the engineering program, gender, and technology. The results measured the effectiveness of technology integration and identified areas of improvement in the teaching processes and the management of technological resources within the university under study.

The adoption of challenge-based learning, together with the use of agile methodologies and 4.0 technology, allowed students to find technological solutions to the challenges posed by the industries from which the problems were obtained in a systematic, orderly, and modern way. Experiencing the pressure and demands of the working world first-hand was one of the points highlighted by the students, as they understood that they are being prepared to face challenges similar to those they will encounter in their future professional lives.

The methodology used in this research has been designed and implemented in a higher education institution, taking as a case study an important Chilean university, to transition towards a pedagogical model that efficiently integrates the digital and technological skills of the fourth industrial revolution.

In the initial stage, the needs and capabilities of the educational institution were evaluated, as well as the alignment of the academic programs with the demands of Industry 4.0. Strategic objectives were established, and action plans were designed to achieve adequate technological integration, considering aspects such as infrastructure, degree curricula, and collaboration with the industry. The result of this stage materialized in 6 fundamental pillars, detailed below.

2.1. Pillar 1: Adoption of the Challenge-Based Learning Methodology and the Agile Scrum Methodology

To enrich the methodology for inserting Industry 4.0 in engineering education, the present study incorporated elements of challenge-based learning (CBL) inspired by Apple's challenge-based learning [15], the Tec21 model of the Tecnológico de Monterrey in Mexico [16] and the Ethazi model of Tknika in the Basque Country [17], and the agile Scrum methodology to promote a practical and flexible approach in engineering education. This approach develops students' skills by resolving real problems and promoting autonomy,

teamwork, and adaptability in a dynamic environment. The interaction between professors and national and international researchers allowed them to adapt a challenge-based learning model to the educational institution under study: the new CBL4.0 model (Figure 1). This adaptation was possible since the fundamental model allows it, which is one of its qualities [15].



Figure 1. CBL4.0 model (adapted from Sánchez and Meijide [17]) based on Pillar 1 (adoption of the challenge-based learning methodology and the agile Scrum methodology).

Figure 1 shows the CBL4.0 model, separated into four blocks (colors), totaling ten stages. Thus, the CBL4.0 process was developed through a series of stages organized into the four blocks mentioned. Each stage addressed a crucial aspect of the teaching–learning process, which allowed students to face real and complex challenges while advancing in developing essential skills for the 21st century. This model also integrated the agile Scrum methodology in the "Development" block through iterative cycles.

2.1.1. Connection and Generation

The process began with team building and collaborative work, where teams were formed through dynamics that allowed for group cohesion, along with establishing roles and commitments through a flexible work format. Building trust and security among members was prioritized, aligning individual expectations with common goals. Then, in the next stage, the students were presented and connected to the challenge, a complex situation that allows for multiple approaches to a solution. The professor explained the challenge attractively and ensured the students fully understood the problem, providing essential information about the available resources, the time needed, the evaluation criteria, and the ways to receive feedback. In the next stage, the parameters were defined, and the necessary information was obtained to address the challenge posed. Through guiding questions, the students acquired the required knowledge, individually and collectively, through activities such as guided technical visits, classes, and reviews of relevant resources, allowing them to move forward in solving the proposed challenge.

2.1.2. Ideation

In this phase, students initially developed solutions individually, which fostered creativity and allowed for personalized learning assessment. These individual proposals were then presented to the team, where they were collectively evaluated and refined. The team selected the best alternative, which could be a combination of the different ideas contributed by the members, thus promoting a more robust and collaborative solution.

2.1.3. Development

The stage began with action planning, where the team was responsible for organizing all the tasks, resources, and times necessary to execute the project. This planning included a detailed risk analysis, which was reviewed, and feedback was provided by the professor, ensuring that all key aspects were considered before moving forward. Next, the students implemented the previously designed plan in this development stage. They worked on the selected solution using advanced infrastructure, such as the 4.0 laboratories at the university under study. During this phase, continuous monitoring was carried out to ensure the expected learning outcomes were achieved using the agile Scrum methodology. Finally, in the results presentation stage, the teams showed the physical solution to the challenge and reflected on the learning process, sharing the difficulties they faced and the personal discoveries that arose throughout the project.

2.1.4. Assessment and Reflection

In this assessment and reflection stage, the teams analyzed their final product using previously established rubrics. Then, they were subjected to three types of evaluation: hetero-evaluation by the professor, co-evaluation among peers, and personal self-evaluation. This process concluded with reflecting on the areas that need improvement and the learning achieved. During the reflection, documentation, and publication stage, the teams and the professors reflected on the entire process and documented the results.

2.2. Pillar 2: Selection and Acquisition of Industry 4.0 Technologies

The selection process for Industry 4.0 technologies for the university students who participated in this study was based on the experiences of the National Unit of Industry 4.0 Laboratories (hereafter the NUIL), as well as national and international professors and researchers, taking into account that the selected technologies were relevant to the academic field, encouraged interdisciplinary collaboration, were scalable and adaptable to projects of different magnitude, and were kept up to date with technological advances.

AI applications were defined using versatile programming environments with specialized libraries that allowed the creation of AI models. To achieve this, it was essential to have platforms that offered capabilities to train and deploy models on a large scale, which would better reflect real problems. Another characteristic sought was that the AI tools were easy for inexperienced students and, therefore, did not require complex programming, thus facilitating the creation of models more straightforwardly.

Regarding IoT, development boards were used to create prototypes with various sensors and modules. In addition, platforms were available that efficiently managed IoT devices, collecting data in real-time and allowing the development of connected applications. Support for standard protocols was crucial to ensure interoperability between IoT devices and systems.

Regarding VR and AR, it was essential to use development software that facilitated the creation of applications compatible with various display devices, offering high-quality immersive experiences. Likewise, 3D design tools were essential to create interactive content that could be used in VR/AR environments, facilitating the creation of simulations and immersive experiences.

In collaborative robotics, robots designed to work safely alongside humans (cobots) were used, with accessible interfaces that allowed easy programming. Simulation platforms were also crucial for students to experiment in virtual environments before implementing

their solutions physically. In addition, using advanced sensors and adaptive controllers was essential to ensure safety and precision in collaborative operations.

Finally, 3D printing employed printers that were accessible and reliable for educational environments, allowing the creation of functional parts with different materials. Three-dimensional design tools were essential for students to create three-dimensional models ready for printing. It was also important to select printers compatible with multiple materials, expanding manufacturing and prototyping possibilities.

2.3. Pillar 3: Adaptation of Infrastructure to Create Physical Laboratories

The Industry 4.0 laboratories considered in this study were spaces designed to facilitate interaction between students, professors, engineers, and technicians, focusing on two fundamental axes: the CBL methodology and the use of advanced Industry 4.0 technologies; hence, the CBL 4.0 concept. These laboratories were organized around the idea of technological micro space, where each area allows the use of specific technology and, at the same time, interacts with other technologies and their environment. This integrative approach promotes an interdisciplinary learning ecosystem where students can apply practical and technological solutions to real problems.

The laboratories' design stands out for its flexibility and dynamism. The furniture and layout of the spaces are designed to adapt to different activities, from prototyping to simulating complex industrial processes. This adaptability is essential for supporting the CBL methodology, in which students face real-world challenges that require innovative and technological solutions.

From an architectural point of view, the laboratories followed a modern line that prioritized simplicity and transparency. Simplicity is manifested in a minimalist design, where each element has a clear function and contributes to the teaching and learning process. Transparency is reflected in the space's layout, which allows a clear line of sight to and from any point in the laboratory. These characteristics facilitated supervision and technical support by engineers and technicians, creating an environment where students can receive advice anytime.

2.4. Pillar 4: Development of Virtual Laboratories

The virtual lab is a resource created by the NUIL in conjunction with the IT departments of the university under study. This cloud-based resource allows students to access information associated with Industry 4.0 technologies and has been developed to offer university students a comprehensive environment where they can access educational resources and take assessments to train themselves in various technological skills. This interactive learning platform is structured around several key enablers that allow students to acquire fundamental technical knowledge.

The enablers include AI, IoT, VR/AR, collaborative robotics, and 3D printing. Each enabler provides students with access to relevant and up-to-date content, promoting the acquisition of skills that prepare them for the challenges of Industry 4.0. In addition, the virtual lab also teaches students about security aspects when using various hardware, ensuring that they understand best practices to work safely and efficiently in physical laboratories.

From the educational environment perspective, Microsoft Teams (version number 24257.205.3165.2029) and tools from the Office 365 suite were used as the primary teaching platform to facilitate content delivery and collaboration. For each subject, working groups were created in Teams, where study material on the technology enablers was shared in documentation and video format. In addition, Microsoft Planner (1.3.1) was incorporated into each group, allowing students to manage their projects and making it easier for educators to monitor progress continuously.

The general Teams chat was used as a critical communication channel, where professors left essential reminders and announcements for students. The platform is a project management tool and facilitates constant communication between educators and students. Professors tracked student activities and progress in Teams and each team's planners.

Professors were given training on Microsoft Teams management to ensure efficient platform use.

This virtual platform also offers a series of assessments designed to measure the knowledge and skills acquired from each enabler. These assessments have constant feedback to ensure effective learning. By completing the modules and passing the examinations, students can access the physical laboratories and use hardware technologies and all the physical devices that the 4.0 laboratories have (VR headsets, cobots, drones, and cameras for computer vision, among others). This approach ensures that students acquire technical knowledge and are well-prepared to work with advanced physical equipment (high-definition 3D printers, professional drones, and others).

2.5. Pillar 5: Modification of the Degree Curricula

Based on this study, five engineering degrees were modified to adapt their academic programs to the demands of Industry 4.0 and strengthen students' training in emerging technologies. These degrees correspond to Civil Engineering, Mining Engineering, Industrial Engineering, Computer Engineering, and Energy and Environmental Sustainability Engineering, which last five years and correspond to ten academic semesters.

The modifications specifically consider three subjects in each degree, distributed between the seventh, eighth, and ninth semesters. In each of these semesters, an essential subject was redesigned to include practical challenges representing a significant part of the course. In the seventh and eighth semesters, these subjects were developed for 18 weeks, of which 6 weeks were devoted to solving a challenge. Additionally, in the ninth semester, a subject focused on interaction with companies covered 18 weeks, but with a challenge that extended throughout the semester.

The selection process for these courses was performed through an exhaustive bibliographic review of the state of the art associated with Industry 4.0 and its application in higher education, considering each engineering specialty. This analysis was carried out by senior researchers, professors, and academic directors, who identified the most relevant courses to be modified. The proposal was then presented to a committee of representatives from the business sector to align the modifications with the current labor market needs. The proposal was then discussed with the directors of each degree program and professors from the different engineering areas, which allowed the modifications to be adjusted according to each specific academic reality.

Finally, the selection of the courses was ratified by the senior authorities of the College of Engineering of the university under study and by experts in degree curriculum, ensuring that the modifications aligned with each program's educational objectives and global trends in engineering and Industry 4.0. The aim was to adapt engineering programs to Industry 4.0 to significantly impact students' employability by equipping them with advanced skills in emerging technologies and innovative methodologies. By working on practical challenges and becoming familiar with AI, IoT, or collaborative robotics tools, students developed technical and soft skills that will position them as highly qualified professionals, ready to interact in digital transformation projects. This new knowledge is expected to improve their professional attractiveness to employers, increase their opportunities to access high-tech sectors, and boost their professional careers, allowing them to take on leadership roles in a labor market increasingly influenced by digitalization and industrial automation.

2.6. Pillar 6: Training of the Teaching Staff

The convergence between engineering education and the technological advances in Industry 4.0 profoundly redefines the skills needed for future engineers. In this context, teacher training plays a fundamental role in adopting new technologies and integrating innovative pedagogical methodologies that can prepare students for the challenges of the 21st century. In the present study, teacher training focused on effectively applying CBL4.0, helping professors transform traditional teaching into a more dynamic and interactive model, integrating active teaching strategies (active methodologies).

This training of the teaching staff allowed students to learn through practice, solving real-world challenges that require the use of the aforementioned technological enablers (AI, IoT, VR/AR, collaborative robotics, and 3D printing). During the training, teachers participated in practical workshops where they learned to structure their courses around challenges that reflected real industrial problems. They were taught to design compelling challenges, establish competency-based assessment criteria, and use collaborative tools to facilitate student teamwork. In addition, they were trained in using the agile Scrum methodology, which was integrated into CBL to encourage iterative development and review cycles, ensuring that students received constant feedback and could adjust their solutions in real-time.

The CBL-focused approach also involved educators developing new skills in project management and educational leadership, as they had to guide students through learning processes that were more autonomous and less structured than traditional models. While training included the incorporation of specific Industry 4.0 technologies in the classroom, these technologies were always within the framework of one of the challenges addressed by the students.

In the training process, the NUIL acted as essential technical support for those teachers who, although experts in their specific disciplinary areas, did not all come from the world of Industry 4.0, so they might need assistance in integrating these technologies into their classes. To this end, a team of engineers and specialists in advanced technologies facilitated access to Industry 4.0 tools and platforms, offered ongoing technical support, and helped the teaching staff to understand and apply emerging technologies in the educational context effectively. The NUIL thus became a strategic partner for the teaching staff, ensuring that all professors, regardless of their prior experience in technology, could adapt their courses to the demands of modern education and prepare students for the challenges of a digitalized industrial environment.

2.7. Evaluation and Validation Process

The assessment process in challenge-based learning was collaborative and multi-focused, involving all stakeholders: educators, students, and, in some cases, external experts and industry representatives. The assessment was not limited to final results but also encompassed the learning process. Throughout the challenge, various assessment instances were established where students generated evidence of their progress, reflected on their performance, and adjusted their work based on team goals and professional development.

The assessment process includes three fundamental approaches: self-assessment, where students analyze their learning; co-assessment, based on feedback between peers; and hetero-assessment, where the teaching team and external experts offer a critical evaluation of the work. Tools such as portfolios, logbooks, and field books help document progress and facilitate evaluating the process beyond the final product.

In the final stage of the challenge, the professor provided detailed feedback, highlighting the achievements and the areas of improvement that must be addressed in future challenges. In addition, formal evaluations included tests and portfolios, which were fundamental tools to demonstrate the students' effort and progress. The participation of external experts also enriched the process, providing a professional vision that complemented the evaluation. In this way, the evaluation process in the CBL integrates both the assessment of learning during the development of the challenge and the preparation to face professional standards.

The stages of the challenge-based learning model were validated through an educational process characterized by continuous and collaborative. Both educators and students and, in some cases, external experts actively participated in the evaluation and feedback, which allowed the process to be adjusted as the challenge progressed. To ensure that each model stage was aligned with the learning objectives, various aspects of the process were monitored through field books, logbooks, portfolios, and their corresponding rubrics. These

tools allowed the students' progress to be documented and provided essential evidence that guides pedagogical decisions.

Self-assessment, peer-assessment, and hetero-assessment were pillars of this process. Self-assessment allowed students to reflect on their progress; peer-assessment encouraged the exchange of feedback between peers; and hetero-assessment, in which professors and external experts participated, ensured that the work met industry standards. During the final phase of the challenge, detailed feedback from professors and experts closed the assessment cycle, helping identify achievements and improvement areas for future projects. This comprehensive and context-specific approach ensured that the stages of the model were validated effectively and based on student learning.

2.8. Execution Stage

In this stage, the projects given to the students could be solved using Industry 3.0 or Industry 4.0 technologies. The students autonomously decided to select the technology, which allowed assessing the degree of penetration of 4.0 technologies. This evaluation was carried out in parallel with three engineering programs separated by gender: Industrial Engineering (male 44 and female 15), Civil Engineering (male 20 and female 6), and Mining Engineering (male 19 and female 6). Non-parametric statistical tests were conducted to determine statistically significant differences between academic programs, gender, and technology [18]. The students, organized into teams, began to apply the knowledge acquired in the previous phases to solve specific problems, with the provision of the technological tools available in the physical and virtual laboratories of the institution.

It is relevant to highlight that all students must have passed the mandatory tests to verify their knowledge when using each 4.0 technology. This process ensured the growth of the technical and software skills students need to continue their learning process and later access the physical laboratories and their technology.

The teams had to plan the actions necessary to execute their projects, considering key aspects such as resource management, time, and risks. Planning became an essential activity, guided by the Scrum methodology—which allowed agile iterations and constant adaptations as the students progressed in solving the challenges. The 4.0 laboratories, designed to simulate real industrial environments, provided the ideal environment for the students to experiment and validate their solutions.

The projects' execution involved directly applying the aforementioned technologies (IoT, AI, VR/AR, collaborative robotics, and 3D printing) to complex industrial problems, working in an environment that simulated the conditions of the modern working world.

Continuous monitoring is another crucial component of this execution stage. The professors, supported by the NUIL, monitored the teams' progress, offering constant feedback to ensure that the project objectives were being met and that the students were developing the necessary technical and soft skills. Interaction with the NUIL's specialized engineers and technicians also allowed the students to solve specific technical problems that arose during the project's execution.

Finally, the stage culminated with the presentation of the results. The students were required to deliver a functional technological solution and reflect on the learning process. This reflection included identifying difficulties faced, personal discoveries, and possible improvements for future projects. This approach also prepared students to face the challenges of the working world while fostering a mindset of continuous improvement and constant adaptation, essential skills in Industry 4.0. These results are presented and analyzed below.

3. Results

3.1. Examples of Challenges Addressed by Students

3.1.1. Example 1—Concrete Asset Digitalization

A group of Civil Engineering students from a "Business Workshop" course developed a solution to optimize materials management in a concrete supplier company. The problem was the lack of real-time information on material dosing since the data were only generated

monthly, which made efficient resource management difficult. The proposal consisted of creating a digital interface that allowed operators to enter data for each mixture and use of materials simply and expeditiously. This information was stored in a cloud computing computer infrastructure and then processed and visualized through a dashboard accessible from a web server and a mobile application. Using technologies such as IoT, cloud computing, and Python programming, the platform provided the company management instant visibility into the material used, the types of concrete manufactured, the amount of material used, demand statistics, and associated revenue. Today, the company has adopted this solution, and the students continue to work on the details necessary to bring its asset digitization system to the entire production chain. A view of the app developed for concrete asset digitization is shown in Figure 2.

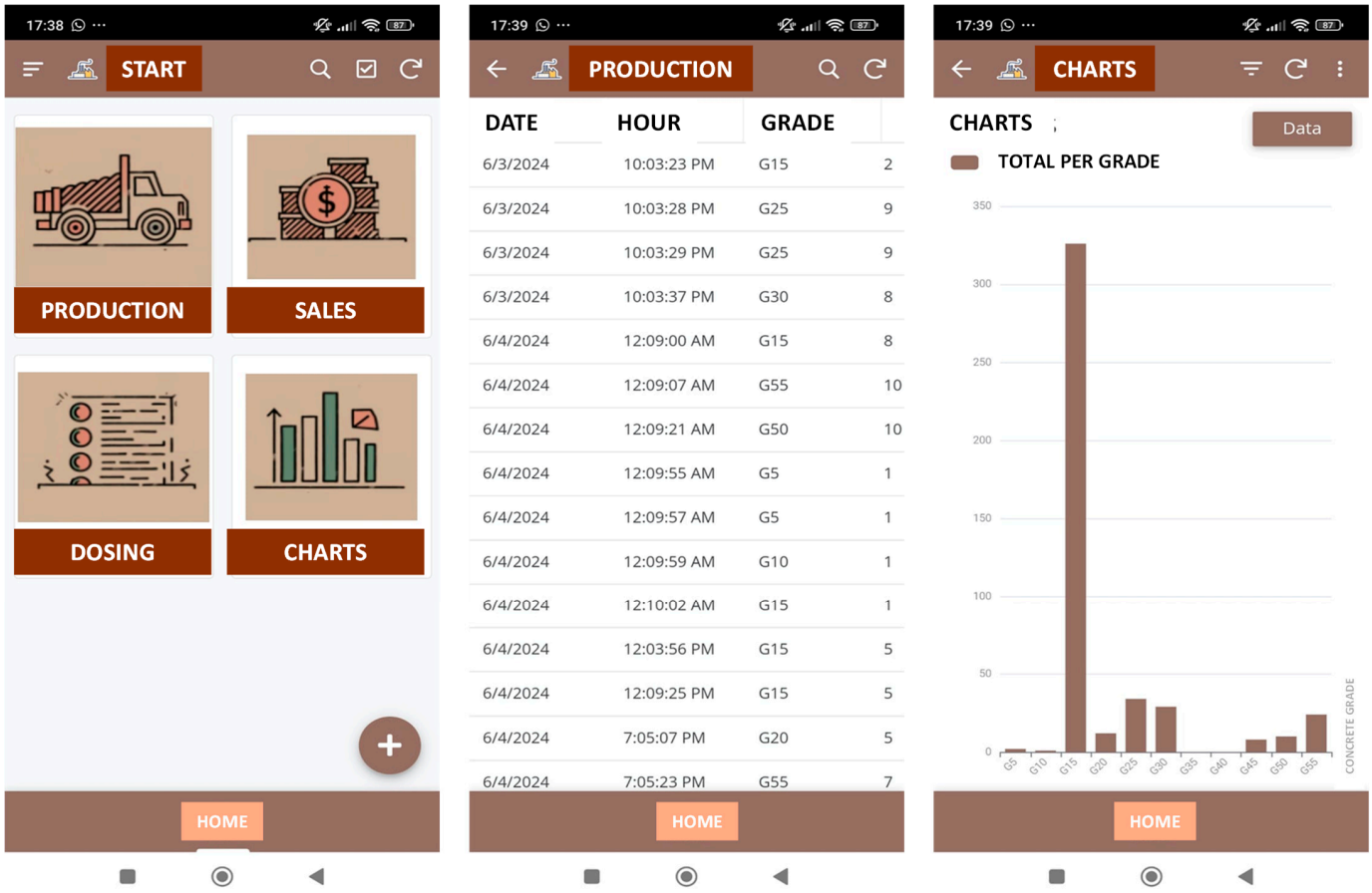


Figure 2. A view of the app developed for Example 1 on concrete asset digitization.

3.1.2. Example 2—Identification and Solving of Congestion in Vehicular Accesses

A second group of Civil Engineering students, in this case, participants in the "Advanced Topics in Construction" course, faced the challenge posed by a company in identifying and solving the congestion problems in its vehicular accesses. Using drones, the students photographed the accesses and the parking layout, and using AI, they could render the captured images in 3D without resorting to specialized topographical equipment. This methodology made it possible to identify the deficiencies in the use and vehicular flow within the facilities, which generated congestion. Based on these findings, the students proposed a new distribution of the parking lots and vehicular flow routes to mitigate the problem. The company recognized the solution's value and continued developing and collecting information, in collaboration with the Civil Engineering students, to continue perfecting the solution. Figure 3 shows the identification and solving of congestion in vehicular accesses of the company under study.



(**a**) (**b**)

Figure 3. Identification and solving of congestion problems in vehicular accesses: (**a**) 3D rendering of parking lot plan; (**b**) restructuring of layout and paths for vehicular flow.

3.1.3. Example 3—Accurate Positioning of North Magnetic for Solar Panel Installation

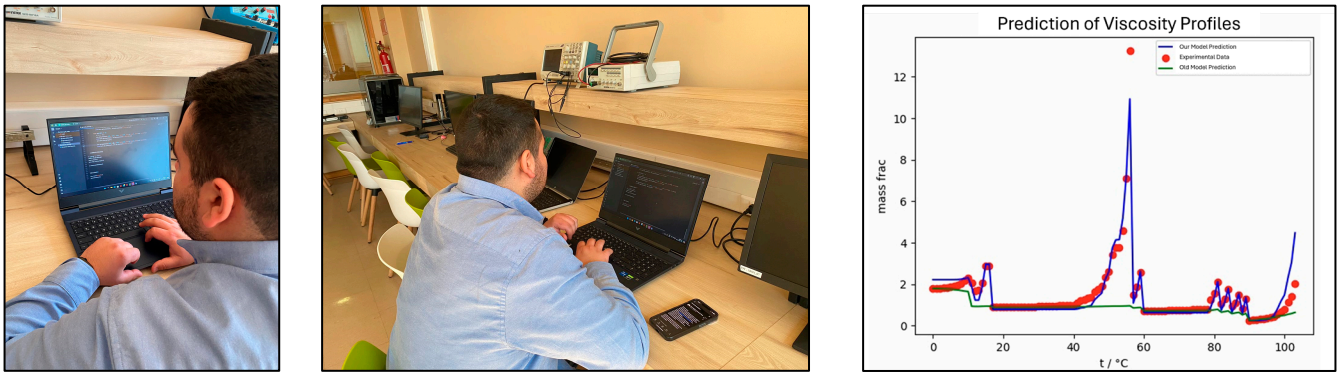
A third group of Industrial Engineering students, although from the same subject, "Business Workshop", addressed the challenge of identifying the magnetic north for positioning solar panels in a company dedicated to installing these devices. The company's usual process, which depended on a traditional technique with certain limitations in terms of repeatability, presented the challenge of improving efficiency during the installation of the panels through a more precise determination of the magnetic north. In this case, the students proposed a new methodology based on a prediction model of the aforementioned magnetic north. They then demonstrated how, using a collaborative robot, a solar panel could be positioned with high precision oriented to the magnetic north, thereby achieving an optimal location to maximize solar capture. The company, recognizing the potential of the new methodology developed by the students, decided to implement it and then proceed with the on-site verification of the accuracy of the prediction model. Figure 4 shows the simulated positioning towards magnetic north for a solar panel.



Figure 4. Simulated positioning towards magnetic north for a solar panel.

3.1.4. Example 4—Development of a Predictive Model to Determine the Viscosity of Complex Brines for the Lithium Industry Mining Using AI

A final example concerns Mining Engineering students who attended the "Business Workshop" course. In this case, the students addressed the challenge of developing a predictive model to determine the viscosity of complex brines, specifically in lithium nitrate ($LiNO_3$) solutions, as part of a challenge proposed by a company specialized in the lithium industry. The main objective was to improve the accuracy in predicting the rheological properties of brines using mathematical models and technological tools based on AI. The data used for the development of the model were provided by the mining company, which carried out the corresponding measurements. For their part, the students focused on analyzing these data and developing the predictive model requested by the company. In particular, they implemented exploratory analysis techniques and neural networks, using the programming language Python and specialized deep learning libraries to build a model that would allow them to predict the viscosity of solutions under different temperature conditions more accurately. Currently, the results of the trained model have shown a high correlation with the experimental data, which allowed for validation of its applicability in processes associated with the lithium industry. Subsequently, the mining company continued working with the students who participated in this challenge to strengthen the predictive capacity of the developed model and thus contribute to the optimization used in the lithium industry. Figure 5 shows a mining student developing part of the computer code for the predictive model raised by the mining company as a challenge.



(**a**) (**b**) (**c**)

Figure 5. (**a**,**b**) Mining student working on developing a predictive model to determine the viscosity of complex brines for the lithium industry mining using Python; (**c**) output of the prediction model developed (red dots represent the experimental data, green lines represent the current model prediction, and blue lines represent the deep learning model prediction).

3.2. Analysis of the Results Obtained

This work allowed for the gathering of evidence on implementing Industry 4.0 technologies in the training of engineering students. This implementation integrates agile Scrum methodologies and Industry 4.0 technologies in the context of real projects linked to the industry.

The methodology selected to implement the abovementioned was through industrial challenges proposed to students taking various engineering courses in the last terms of different engineering programs. In particular, to evaluate the penetration of technologies 4.0 in the engineering students' training, the chosen challenges were designed in such a way that students could solve them through 4.0 technologies (those widely described in this article) or 3.0 technologies (personal computers, conventional Internet, and, in general, any technology commonly used before the advent of Industry 4.0).

Under this freedom of selection, the present research has allowed for assessing how many students segmented by gender finally chose 4.0 technologies. This evaluation was carried out in parallel with three engineering programs: Industrial Engineering (IndEng),

Civil Engineering (CivEng), and Mining Engineering (MinEng). It should be noted that, in the case of Civil Engineering students, they had the opportunity to participate in a pilot experience during the term immediately preceding this activity, which is why they had more experience than the students from the other two programs. All this information is summarized in Table 1 on the use and non-use of Industry 4.0 technologies.

Table 1. Use and non-use of industry 4.0 technologies.

Degree Program	Use of Industry 4.0 Technology % (Number of Students)	No Use of Industry 4.0 Technology % (Number of Students)
IndEng		
Male	70 (31)	30 (13)
Female	60 (9)	40 (6)
Total	68 (40)	32 (19)
CivEng		
Male	80 (16)	20 (4)
Female	100 (6)	0 (0)
Total	85 (22)	15 (4)
MinEng		
Male	74 (14)	26 (5)
Female	100 (6)	0 (0)
Total	80 (25)	20 (5)

Table 1 shows the results separated by gender for each of the three selected engineering programs concerning the use and non-use of Industry 4.0 technologies. In the case of Industrial Engineering (IndEng), 68% of the total number of projects used 4.0 technologies. In Civil Engineering (CivEng), 85% of the total projects incorporated 4.0 technologies. In the case of Mining Engineering (MinEng), 80% of the total number of projects used 4.0 technologies. It is interesting to note that, in the case of Civil Engineering (CivEng) students who, as mentioned, had previous experience participating in a pilot application of 4.0 technologies, the percentage of students interested in Industry 4.0 technologies did not reach 100%, as might have been assumed. This finding could indicate that, despite how disruptive 4.0 technologies may seem, some students, even with previous experience in this type of technology, continue to choose less advanced technologies (3.0), such as personal computers and conventional Internet use (e.g., without AI tools or others).

Another aspect to be evaluated in this research was the type of technology used by the students. Now, it is necessary to specify that the students had less freedom in selecting this technology since the technology used was directly related to the type of challenge. This information on the technology used is summarized in Table 2, which is then explained. It is relevant to note that Table 2 only shows the three technologies with the highest preferences by students (AI, IoT, and Robotics).

As previously mentioned, Table 2 shows the results separated by gender for the three selected engineering courses about the type of Industry 4.0 technology used. This information comes from students who did use 4.0 technologies (Table 1). In Industrial Engineering (IndEng), there is a greater tendency for men and women to use IoT, with 60%, compared to 40% for AI. In Civil Engineering (CivEng), three types of technologies were used, where AI predominated with 54%, Robotics with 32%, and IoT with 14%, where the highest preference for AI was by female students, with 83%, while in the case of men, it was 44%. In the case of Mining Engineering (MinEng), 100% of male and female students used AI as a 4.0 technology to carry out their solution.

Table 2. Type of industry 4.0 technology used.

Degree Program	AI % (Number of Students)	IoT % (Number of Students)	Robotics % (Number of Students)
IndEng			
Male	70 (31)	30 (13)	0 (0)
Female	60 (9)	40 (6)	0 (0)
Total	68 (40)	32 (19)	0 (0)
CivEng			
Male	80 (16)	20 (4)	0 (0)
Female	100 (6)	0 (0)	37 (6)
Total	85 (22)	15 (4)	17 (1)
MinEng			
Male	74 (14)	26 (5)	32 (7)
Female	100 (6)	0 (0)	0 (0)
Total	80 (25)	20 (5)	0 (0)

The above results show a clear trend in each engineering area, evidencing how the preference and use of Industry 4.0 technologies vary according to the engineering specialty. In IndEng, the use of IoT is predominant, which suggests that students perceive this technology as fundamental to optimizing production processes. On the other hand, the high preference for AI in CivEng—especially among women—highlights the interest in applying algorithms and AI systems in the design and analysis of structures. Finally, the 100% adoption of AI in MinEng reflects the relevance of this technology in the exploration and exploitation of mining resources, promoting automation and advanced data analysis.

In addition, statistical tests were conducted to determine significant differences between academic programs, gender, and technology, with a significance level of $\alpha = 5\%$. First, a chi-square test was performed to assess a significant relationship between students' gender and using Industry 4.0 technologies, utilizing data from Table 1. The null hypothesis (H_0) states that there is no significant relationship between gender and the use of these technologies, while the alternative hypothesis (H_1) suggests that such a relationship exists. The test results ($\chi^2 = 0.0359$, df = 1, $p = 0.6571$) did not provide sufficient evidence to reject the null hypothesis. This indicates no statistically significant relationship between students' gender and using Industry 4.0 technologies. In other words, the findings suggest that there is no statistically significant evidence to conclude that gender influences the use of these technologies. To investigate other possible relationships, another chi-square test was performed to examine the association between students' academic programs and the type of 4.0 technologies used, based on the data in Table 1. The null hypothesis (H_0) states that there is no significant relationship between the academic program and the use of 4.0 technologies, while the alternative hypothesis (H_1) suggests that such a relationship does exist. The test results ($\chi^2 = 5.99$, df = 2, $p = 0.2021$) did not provide sufficient evidence to reject the null hypothesis. This suggests that no statistically significant relationship exists between students' academic programs and the type of 4.0 technologies used. Therefore, the academic program does not significantly influence the 4.0 technology students use.

Based on data from Table 2, another chi-square test was performed to evaluate whether there was a significant relationship between students' gender and their use of specific Industry 4.0 technologies (AI, IoT, and Robotics). The null hypothesis (H_0) states that no significant relationship exists between gender and the use of these specific technologies, while the alternative hypothesis (H_1) states that such a relationship exists. According to the test results ($\chi^2 = 5.99$, df = 2, and $p = 0.526$), the null hypothesis was not rejected. Therefore, no statistically significant relationship exists between students' gender and their use of specific Industry 4.0 technologies. This indicates that both male and female students have similar usage patterns of AI, IoT, and Robotics. Finally, a chi-square test was performed to determine if there is a significant relationship between students' academic programs and their use of specific Industry 4.0 technologies (AI, IoT, and Robotics), using the data in

Table 2. The null hypothesis (H_0) states that no significant relationship exists between the academic program and the use of these specific technologies. In contrast, the alternative hypothesis (H_1) suggests that there is such a relationship. The test results ($\chi^2 = 9.48$, df = 4, $p < 0.0001$) provided sufficient evidence to reject the null hypothesis. This indicates a statistically significant relationship between students' majors and their use of specific Industry 4.0 technologies, suggesting that the academic program significantly influences the use of specific technologies such as AI, IoT, and Robotics among the surveyed students.

4. Discussion

The results presented in this work provide an attractive approach regarding the adoption and use of Industry 4.0 technologies by engineering students through a challenge-based teaching tool (CBL4.0) and the integration of agile Scrum methodologies. The implementation carried out —based on six fundamental pillars considered in the present study—allowed a higher education institution to effectively incorporate the proposed methodology in real projects linked to the industry, and above all its applicability in an academic environment that can be expanded to other academic engineering programs. First, we can highlight the high level of adoption of Industry 4.0 technologies among students of the three engineering courses selected: Industrial Engineering (IndEng), Civil Engineering (CivEng), and Mining Engineering (MinEng). The results show an overall adoption of 68% in IndEng, 85% in CivEng, and 80% in MinEng. The difference in adoption between these engineering courses, with a higher proportion in the case of CivEng, could be influenced by the previous experience of students in this specialty with 4.0 technologies. As mentioned above, CivEng students participated in a pilot experience the previous semester, suggesting that familiarity with the technology may be a key factor for its effective integration into projects. However, although 85% of the adoption by CivEng students is high, it did not reach 100%.

On the other hand, it is expected to continue increasing as these types of technological immersion actions continue to be implemented in engineering students. Additionally, the gender-based assessment revealed differences in the adoption of 4.0 technologies. In the case of IndEng, 70% of men and 60% of women opted for these technologies, while in CivEng and MinEng, 100% of women chose 4.0 technologies, compared to 80% and 74% of men, respectively. These results suggest differences in adoption between genders, where female students in CivEng and MinEng showed a greater inclination towards using these technologies, which could indicate a greater motivation or interest in these technological fields by women.

Furthermore, analyzing the type of technology used allowed a deeper understanding of the students' preferences. In IndEng, men and women preferred IoT over AI, with 60% and 40%, respectively. In CivEng, AI was the most used technology, especially among women (83%), followed by Robotics and IoT. In MinEng, all students, regardless of gender, opted for AI. These results reflect that, although the type of challenge may have conditioned the choice of technology, there is a natural tendency towards certain technologies, such as AI, in the case of CivEng and MinEng. However, in the latter case, it is worth asking whether this strong tendency towards AI could be marked by the wide diffusion that this technology has had in recent years.

This analysis highlights the importance of prior experience and early exposure to Industry 4.0 technologies in encouraging their adoption. Furthermore, the use of innovative teaching approaches, such as the challenge-based approach (CBL4.0 combined with Scrum in the case of this research), together with continuous training in these technologies, seems to be essential to prepare students for the challenges of modern industry.

Finally, to learn from the professors' opinions, they were interviewed, and their views helped support the present study's findings. They emphasized that real experiences generated greater motivation in students, highlighting that practical engagement not only aids in better progress but also fosters a learning environment within teams. They pointed out that CBL4.0 promotes teamwork, enabling students to share responsibilities and viewpoints,

and encourages team decision-making—an essential professional skill. They also noted that CBL4.0 allows theoretical knowledge to be applied in real situations, making learning more relevant and motivating for students, promoting autonomous learning, and facilitating the acquisition of relevant skills, such as problem-solving and teamwork. Overall, professors underscored that implementing CBL4.0 enriched the learning experience and prepared students to face the challenges of today's labor market. The combination of motivation, practical application, and development of crucial competencies makes CBL4.0 a practical methodology for the comprehensive training of future engineers.

4.1. Comparison with Existing CBL Implementations

Piironen et al. [19] explored the implementation of CBL in embedded engineering as part of the CDIO Syllabus, emphasizing the relevance of having enough planning resources since the instructors of each course spend considerable time together outlining the main goals, synchronizing the course curricula and agreeing on the evaluation of the project work. To increase students' motivation and dedication to the project, they also recommend, as crucial aspects to consider, the challenging nature of the topic, the use of technological devices (e.g., robots), and competition against other project teams. Compared with our research, similarities are found concerning the amount of time teachers invest in preparing each session and the relevance of technological devices, along with a challenging topic within the academic experience. In contrast, an aspect not considered in our research that could be interesting to explore in future research is the incorporation of academic competitions between the different groups taught through CBL as a didactic technique.

On the other hand, Doulougeri et al. [20] worked on two educational resources to aid in conceptualizing, designing, and researching CBL for curriculum designers and professors. The first one consists of CBL design principles, offering advice on developing CBL courses, while the second one is a curriculum-mapping instrument designed to recognize gaps, superposition, and disarrangements in CBL implementation. Regarding our study, both educational resources were part of the research. First, they helped establish CBL design fundamentals to develop CBL-based courses in engineering, and second, they served as a curriculum-mapping tool to find gaps and differences in CBL applications compared with traditional classes.

Other studies have defined diverse disciplinary and transverse competencies for CBL implementations, where the following can be highlighted: (a) recognize and register the root cause of problems; (b) structure an activity program to implement proposals and optimize resources systematically; (c) evaluate choices to solve problems based on the knowledge and application of engineering tools, and (d) make proposals for solving problems related to the practice of engineering [21]. When comparing these findings with the CBL4.0 model shown in Figure 1, on which our research was based, it is possible to note certain similarities. In particular, the definition of parameters and obtaining of information is related to registering the root causes of the problems or the ideation of proposals that correspond to structuring the activities to implement the suggested proposals. Complementarily, implementing an action plan and its development is related to the alternatives proposed to solve problems based on practical engineering solutions, such as those associated with Industry 4.0, and addressed through our CBL4.0 proposal and its applied examples.

From the point of view of educational paradigms, the constructivist approach is characterized by educators acting as facilitators, encouraging students to develop and understand the role of engineers through solving challenges [5]. In this sense, CBL requires environments suitable for a student-centered constructivist learning organization, addressing real and open problems to complete the challenge, producing a solution based on concrete actions, and motivating students to analyze, design, develop, and execute the best solution to the challenge, along with defining educator's role in the process as a coach [22]. Concerning our study, the concepts underlying the constructive perspective on which CBL is based were evidenced in the mediating role of knowledge exercised by the teachers who implemented the CBL4.0 model presented in this research, putting the

student at the center of the teaching–learning process. Another relevant aspect was the solution of problems through concrete actions, evidenced in the challenges addressed by the students and presented in Section 3.1. (concrete asset digitalization; identification and solving of congestion in vehicular accesses; accurate positioning of north magnetic for solar panel installation; and development of a predictive model to determine the viscosity of complex brines for the lithium industry mining using AI).

Finally, Charosky et al. [23] confirmed that experiential learning experiences like challenge-based education combined with other teaching techniques (e.g., design thinking) successfully contribute to developing innovation competences, such as creativity, leadership, and entrepreneurship, along with teamwork, impact, personal and professional skills, and networking. In our study, where CBL and Scrum were combined, it was possible to develop some of the above skills, such as creativity, leadership, teamwork, and networking (the latter evidenced through the professional contacts generated between professors, students, and the companies participating in the challenges).

4.2. Complexities and Lessons Learned When Implementing CBL

Doulougeri et al. [24] documented several difficulties and lessons learned from implementing CBL, such as the need for effective CBL assessment methods, training for educators in CBL, providing instruction in transversal skills for students, and addressing students' struggles with ambiguity and uncertainty in open-ended challenges, among others.

Based on these previous findings, our research faced similar complexities from which some lessons can be learned. Firstly, when engineering has permanently based its assessment methods around equations and fundamentals of physics and mathematics, it is not easy to build assessment instruments focusing on challenges. Consequently, developing good assessments requires educators' time and appropriate preparation to count on suitable, objective, and transparent CBL evaluation rubrics, as found by Membrillo-Hernández et al. [25]. Hence, there is a second complexity regarding the importance of training educators in CBL, shifting their roles from lecturers to tutors in charge of monitoring the learning process, planning the sessions, selecting the challenges, and organizing the groups of students [19]. Another complexity was related to the need to strengthen transversal student skills, such as motivation, teamwork, and communication abilities. Finally, for engineering students accustomed to traditional teaching methods with a positivist approach focused mainly on the educator [2], it is not trivial to change their way of perceiving the teaching–learning processes, which, in the case of CBL, demands more attention to the need for narrowing down challenges and converting knowledge in practical solutions.

4.3. Implications for Practitioners

From a methodological point of view, this research raises new knowledge by providing a practical procedure that combines CBL and Scrum for teaching engineering. Although this study addresses a particular type of engineering student (i.e., industrial, civil, and mining), educators who teach other students may use the proposed methodology by adapting some of the challenges presented here.

Concerning contributions to practice, this research may become a consultation tool that allows engineering educators: (a) to have a first approach to the CBL and Scrum elements required to perform an innovative teaching process that helps students to become motivated; (b) to apply a CBL–Scrum integrated process into engineering education; and (c) to incorporate slight modifications to the presented methodology here to adapt it for use with students from other engineering specialties.

In summary, this research contributes to engineering educators with a methodology that can complement other teaching techniques, especially in handling complex and intricate engineering courses. In this sense, CBL–Scrum integration may promote a more dynamic teaching process than traditional engineering teaching methods, improving efficiency and providing flexibility in managing challenges like those presented throughout this research. Thus, this study establishes the basis for further research in engineering

education, with CBL–Scrum providing a flexible framework adjustable to other engineering courses as pivotal for improving engineering education.

5. Conclusions

Implementing 4.0 technologies in the educational field, specifically in engineering education, has proven to be a transformative process that requires a comprehensive and well-structured approach.

The results show that previous experience with Industry 4.0 technologies is crucial to their effective adoption. This finding is reflected in the high rate of students using these technologies, particularly in those programs where they already had previous experience. In addition, the evaluation by gender has revealed differences in adoption, highlighting a greater inclination on the part of women towards using these technologies, which highlights the importance of creating inclusive learning environments adapted to the needs of all students. The choice of the type of technology used by students also showed exciting trends, with a marked overall preference towards technologies such as AI and IoT. This finding suggests that, although the nature of the challenge influences the selection of technology, there are also innate preferences that could be exploited to maximize learning and innovation. However, it is reasonable to think that the higher choice for some of these technologies could also be influenced by the greater diffusion they receive, particularly AI.

It is important to note that, in addition to the adoption of technologies, the educational transformation towards Industry 4.0 requires a rethinking of the soft skills that must be developed in students. The ability to work in multidisciplinary teams, complex problem-solving, and critical thinking are essential skills that complement advanced technologies. Likewise, the continuing training of teachers should not only focus on the technical use of these technologies but also on pedagogically integrating them, promoting active and personalized learning.

In the future, the advancement of Industry 5.0—which combines 4.0 technologies with a more human-centered approach—is expected to generate new opportunities and challenges for both students and educational institutions. Education must continue to adapt to train technically trained professionals and people capable of leading the change towards a more sustainable and connected society.

In conclusion, integrating Industry 4.0 in higher education implies adopting new technological tools and a profound change in the educational mindset, preparing it for future challenges. The experience gained in this process provides a solid foundation for future implementations and improvements, ensuring students have the necessary skills to face a constantly evolving labor market driven by new technologies.

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References

1. Daniela, L.; Kalnina, D.; Strods, R. An Overview on Effectiveness of Technology Enhanced Learning (TEL). *Int. J. Knowl. Soc. Res.* **2017**, *8*, 79–91. [CrossRef]
2. Forcael, E.; Garcés, G.; Backhouse, P.; Bastías, E. How do we teach? A practical guide for engineering educators. *Int. J. Eng. Educ.* **2018**, *34*, 1451–1466.
3. Felder, R.M.; Silverman, L.K. Learning and teaching styles in engineering education. *Eng. Educ.* **1988**, *78*, 674–681.
4. Hohn, R.L. *Classroom Learning & Teaching*; Longman Publishers: New York, NY, USA, 1995; ISBN 9780801308796.
5. Lockwood, D. Challenge-Based Learning & STEAM Curriculum. *STEAM* **2023**, *5*, 1–7. [CrossRef]
6. Forcael, E.; Garcés, G.; Bastías, E.; Friz, M. Theory of Teaching Techniques Used in Civil Engineering Programs. *J. Prof. Issues Eng. Educ. Pract.* **2019**, *145*, 02518008. [CrossRef]
7. Accreditation Board for Engineering and Technology. *Criteria for Accrediting Engineering Programs, 2024–2025*; Accreditation Board for Engineering and Technology: Baltimore, MD, USA, 2023.
8. Crawley, E.F.; Malmqvist, J.; Östlund, S.; Brodeur, D.R.; Edström, K. The CDIO approach. In *Rethinking Engineering Education*; Springer: Cham, Germany, 2014; pp. 11–45.
9. McCarthy, A.M.; Maor, D.; McConney, A.; Cavanaugh, C. Digital transformation in education: Critical components for leaders of system change. *Soc. Sci. Humanit. Open* **2023**, *8*, 100479. [CrossRef]
10. Forcael, E.; Garcés, G.; Lantada, A.D. Convergence of Educational Paradigms into Engineering Education 5.0. In Proceedings of the 2023 World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC), Monterrey, Mexico, 23–27 October 2023; pp. 1–8.
11. Hadgraft, R.G.; Kolmos, A. Emerging learning environments in engineering education. *Australas. J. Eng. Educ.* **2020**, *25*, 3–16. [CrossRef]
12. Miranda, J.; Navarrete, C.; Noguez, J.; Molina-Espinosa, J.-M.; Ramírez-Montoya, M.-S.; Navarro-Tuch, S.A.; Bustamante-Bello, M.-R.; Rosas-Fernández, J.-B.; Molina, A. The core components of education 4.0 in higher education: Three case studies in engineering education. *Comput. Electr. Eng.* **2021**, *93*, 107278. [CrossRef]
13. Jamwal, A.; Agrawal, R.; Sharma, M.; Giallanza, A. Industry 4.0 Technologies for Manufacturing Sustainability: A Systematic Review and Future Research Directions. *Appl. Sci.* **2021**, *11*, 5725. [CrossRef]
14. Gürdür Broo, D.; Kaynak, O.; Sait, S.M. Rethinking engineering education at the age of Industry 5.0. *J. Ind. Inf. Integr.* **2022**, *25*, 100311. [CrossRef]
15. Nichols, M.H.; Cator, K. *Challenge Based Learning: Take Action and Make a Difference*; Apple, Inc.: Cupertino, CA, USA, 2008.
16. Mejorado, A.; Esparza, J. TEC21—A New Educational Model that Challenges the Student: A Small Approach. In Proceedings of the 12th Annual International Conference of Education, Research and Innovation, Sevilla, Spain, 11–13 November 2019; pp. 11077–11082.
17. Sánchez Márquez, M.I.; Meijide Bermúdez, M. Challenge-Based Learning in Vocational Training. *Supervision21* **2023**, *68*, 1–30. [CrossRef]
18. Makarova, E.; Aeschlimann, B.; Herzog, W. The Gender Gap in STEM Fields: The Impact of the Gender Stereotype of Math and Science on Secondary Students' Career Aspirations. *Front. Educ.* **2019**, *4*, 60. [CrossRef]
19. Piironen, A.; Ikonen, A.; Saurén, K.; Lankinen, P. Challenge based learning in engineering education. In Proceedings of the 5th International CDIO Conference, Singapore, 8–10 June 2009; CDIO Initiative: Singapore, 2009; pp. 1–9.
20. Doulougeri, K.; van den Beemt, A.; Vermunt, J.D.; Bots, M.; Bombaerts, G. Challenge-Based Learning in Engineering Education: Toward Mapping the Landscape and Guiding Educational Practice. In *The Emerald Handbook of Challenge Based Learning*; Vilalta-Perdomo, E., Membrillo-Hernández, J., Michel-Villarreal, R., Lakshmi, G., Martínez-Acosta, M., Eds.; Emerald Publishing Limited: Leeds, UK, 2022; pp. 35–68.
21. Cuevas-Ortuno, J.; Huegel, J.C. Serious Games or Challenge-based Learning—A comparative analysis of learning models in the teaching of lean manufacturing. In Proceedings of the 2020 IEEE Global Engineering Education Conference (EDUCON), Porto, Portugal, 27–30 April 2020; pp. 1542–1549.
22. Sukackė, V.; Guerra, A.O.P.d.C.; Ellinger, D.; Carlos, V.; Petronienė, S.; Gaižiūnienė, L.; Blanch, S.; Marbà-Tallada, A.; Brose, A. Towards Active Evidence-Based Learning in Engineering Education: A Systematic Literature Review of PBL, PjBL, and CBL. *Sustainability* **2022**, *14*, 13955. [CrossRef]
23. Charosky, G.; Hassi, L.; Papageorgiou, K.; Bragós, R. Developing innovation competences in engineering students: A comparison of two approaches. *Eur. J. Eng. Educ.* **2022**, *47*, 353–372. [CrossRef]

24. Doulougeri, K.; Vermunt, J.D.; Bombaerts, G.; Bots, M. Challenge-based learning implementation in engineering education: A systematic literature review. *J. Eng. Educ.* **2024**, *113*, 1076–1106. [CrossRef]
25. Membrillo-Hernández, J.; de Jesús Ramírez-Cadena, M.; Ramírez-Medrano, A.; García-Castelán, R.M.G.; García-García, R. Implementation of the challenge-based learning approach in Academic Engineering Programs. *Int. J. Interact. Des. Manuf.* **2021**, *15*, 287–298. [CrossRef]

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