Bridge the Gap: Using Challenge-Based Learning to Connect University and Industry

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***Abstract*— Collaboration between universities and companies has become vital in training future professionals. However, on many occasions, this collaboration could be more agile and efficient to avoid a disconnect between the supply of trained professionals and the demand of the labor market. This situation is aggravated in the case of online training, where students are geographically delocalized and need the opportunity to interact directly with companies. To address this issue and ensure up-to-date and relevant student training, an innovative program that promotes collaboration between the university and various organizations in the Master in Industry 4.0 is presented. The proposal offers a new subject that uses learning based on challenges proposed and directed by leading companies in the sector. This allows students to apply their knowledge and gain insight into the industry in which they will work. Four calls have been carried out, and there are 14 challenges available, covering various industrial sectors and applications related to Industry 4.0/5.0. This paper presents the results of this program. Companies have obtained innovative and valuable solutions for their specific needs. In contrast, students have been able to apply their knowledge in real situations and gain valuable experience in the business world. Many students come from different geographical environments, especially from LATAM, and they value the subject and teaching staff positively. Due to the success of the program in Master in Industry 4.0, the same approach has been implemented in the university's master's program in the Internet of Things, with equally satisfactory results.**

Index Terms— Challenge-based learning, Industry 4.0/5.0, digital transformation, university-industry collaboration, online education, project-based learning.

I. Introduction

Artificial intelligence and advanced technologies, such as the Internet of Things (IoT), big data, and robotics, drive significant societal transformations. Globalization, technological advancements, and hyperconnectivity present challenges and opportunities shaping global politics. In this context, the concept of Industry 4.0 has evolved into Industry 5.0 [1], which focuses on value rather than technology, emphasizes sustainability, circular economy, and resilience, and emphasizes people and their interaction with machines and technology [2].

Industry's increasing digitization and specialization affect the demand for professional skills companies in the engineering and technical sectors [3]. These are highly valued by students seeking current and comprehensive training to enter a complex and demanding job market [4]. However, according to [5], 72 % of enterprises need help finding suitable professional profiles and perceive the educational system as slow to respond to training needs. As a result, there is often a mismatch between the educational supply and business demand, which impacts productivity and competitiveness [6].

Since education and professional specialization significantly influence employment [7], companies and universities must work together [8]. Companies seeking high levels of digitization and industry modernization demand professionals knowledgeable about the enablers associated with Industry 4.0/5.0 [9]. These specialized and rapidly evolving business contexts find university-company collaboration attractive because it allows them to attract well-trained professionals in the required disciplines and meet their needs quickly [10][11]. Similarly, the university benefits by gaining firsthand information on real projects, trends, and professional demands. If the university is agile and flexible, it can adapt its content and quickly offer what companies demand. Therefore, if the training offer is higher quality and more attractive, it will attract more students.

University-company collaborations have existed for some time [12]-[16], but they are often limited to agreements for traditional professional practice subjects, chairs, research projects with a commercial interest, and/or participation in job fairs. Furthermore, collaborations for the academic development of technical degrees or specific subjects are not common in online teaching due to challenges such as a lack of staff with professional and non-academic profiles, relocated students, bureaucracy, and a lack of defined common objectives in relation to university-industry [17].

This work presents a new subject in its online Master's program in Industry 4.0 to foster collaboration between the university and various organizations. The subject, "Professional projects for the digitization of companies in the context of Industry 4.0" [18], builds on previous content covered in the master's program, including robotics, smart manufacturing and 3D printing, big data and data analytics, cybersecurity, and electronic instrumentation. It aims to allow students to apply their knowledge and skills to real-world challenges and projects in collaboration with industry partners. It uses challenge-based learning [19], a teaching approach that engages students in problem-solving activities that are relevant and authentic. It allows students to gain practical experience, learn from industry professionals and gain insight into the industry in which they will work. It has been taught for four consecutive years, and the number of students (and their origin) and companies involved has increased yearly. Currently, there are 14 challenges available covering various industry sectors and applications related to Industry 4.0/5.0. The results of this program demonstrate that the subject matter is an effective way to

Fig. 1. Contextualization data of the type of students enrolling in this subject. a) sex, b) age, c) sector of origin, d) employment status and e) geographic location.

promote collaboration between companies and universities and address the gap between training supply and demand. Furthermore, the success of this program suggests that it could serve as a model for other universities seeking to foster collaboration with industry and provide students with practical, relevant, and engaging learning experiences.

II. CONTEXT

Nowadays, fully online degrees are gaining ground among students due to their flexibility and accessibility. This learning model allows people with busy schedules for work or family reasons to have the opportunity to study without having to travel to a specific location at a fixed time.

From the point of view of universities, this teaching model allows them to have a more significant number of students enrolled. However, it also poses a challenge for teachers since they must be able to adapt to the needs and characteristics of each student to guarantee their learning.

An example of the diversity of students found in a virtual classroom is Universidad Internacional de La Rioja's Master in Industry 4.0. Primary data on students is presented in Figure 1, reflecting various characteristics and needs. The number of students has not remained constant over the four academic years. In the first year, the course had 47 students. This number increased to 100 and 188 in the two subsequent years, respectively. Finally, the 2021/2022 academic year had 212 students.

In the first place, it can be observed that the students have different ages (Fig. 1.b), distributed in a more or less homogeneous way in all age groups. This means that you can find students aged 22 to over 45 in the same virtual classroom. In addition, it can be seen that the presence of women in this master's degree is less than 20% of the total (Fig. 1.a).

Regarding the employment situation of the students (Fig. 1.d), most of them combine their work with completing the master's degree, either in the public or private sector. However, the sector in which they work varies significantly (Fig. 1.c), which implies that teachers must adapt their teaching to meet the needs and expectations of students with different profiles.

Finally, it is essential to highlight that the students enrolled in this master's degree come from different parts of the world (Fig. 1.e). Although the university is Spanish, less than 40 % of the students are Spanish, and most come from Latin American countries such as Colombia, Ecuador, Argentina, Mexico, and Peru. This supposes an additional challenge for the professors and the university since they must adapt to such a heterogeneous student body's cultural differences, schedules, and concerns.

Therefore, it is essential to look for global educational solutions that are up-to-date and relevant to the industry in which these future professionals will work and that can be carried out with a simple Internet connection from anywhere in the world. In this sense, online education is presented as an effective and promising alternative to offer quality training adapted to the needs of an increasingly globalized society. In these educational contexts, promoting university-business collaboration is even more necessary to provide students with a more globalized and up-to-date education.

III. Description of the Subject "Professional Projects for the Digitalization of Companies in the Context of Industry 4.0"

The subject is compulsory and has a study load of 6 ECTS. It has been taught online since 2019 in the Master's Degree in Industry 4.0 of Universidad Internacional de La Rioja.

There are two key academic figures, as shown in Fig. 2: the coordinator and the teacher-tutor. The subject coordinator is a university teacher who performs management functions related to the subject: he/she contacts the companies, defines with the company the limits of the challenge they pose, coordinates the teacher-tutors, and assigns a challenge to each student. For their part, the main work activity of the teacher-tutors is in the company that proposes the challenge and, additionally, combines this task with a collaboration contract with the university, which acts as a guide or mentor in the subject. The latter is critical to the success of the project because they know the company and the proposed challenge, contextualize the problem in which they are experts, and guide students toward the solutions of most significant interest to the company.

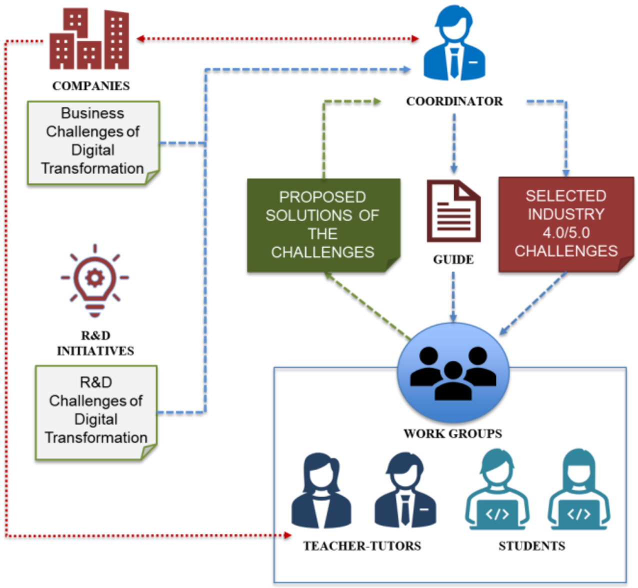

Fig. 2. General scheme of the university-company collaboration in the subject.

The main goal is for the students to carry out, with the support of a teacher-tutor, a work in which they propose and develop a solution to a real digital transformation challenge, putting into practice the knowledge acquired in other subjects of the master's degree. Teacher-tutors and students have a support guide that describes the methodology, deadlines, and evaluation regulations. shows the general scheme followed for the approach to the challenges proposed by companies and/or public or private entities, such as the technological innovation initiatives proposed by public entities, like the Government of Spain [20].

Table I. List of Current Challenges Presented

Company	Challenge proposed to the students
INCLISAL [21]	Improvement of a process in the company using a method based on Value String Mapping (VSM).
ECOTISA [22]	Adaptive Praxis. Incorporation of NFC and Blockchain to 3D immobilizers.
IZERTIS [23]	Automation of quality control of materials.
	Remote monitoring of industrial facilities.
	Automation of food production chain traceability.
SICAMAN [24]	Chicken farm automation.
	Hydroponic garden automation.
ATOS [25]	Integration of an energy efficiency system in corporate buildings.
	Low-Cost Predictive Maintenance for Industrial Machinery.
EUROCONTROL [26]	Real-time communication system for medical monitoring of patients transferred in ambulances.
	Efficiency measurement and preventive control in boilers.
	A platform for the maintenance of telecommunications sites through sensors.
BUSTAR (LIVESTOCK COOPERATIVE) [27]	Monitoring of cattle to help obtain animal health and welfare certificates.
CAF (RAIL ROADS) [28]	Digitization of heavy railway construction machinery for predictive maintenance.

Fig. 3. Recommended structure for proposing solutions to digital transformation challenges.

The challenges can be of two types:

1) Proposed by companies: Enterprises sign an agreement with the university and raise a dare or need in a specific industrial environment on digital transformation, focused on projects, substantial improvements, or specific changes in their key processes, such as the automation of a process that is currently carried out manually or the application of the IoT in the manufacture of a new product. A model provided by the university is used, where companies define the real problem they ask the students to solve. The challenges presented *(Table I*) are of this type.

2) Research and development (R&D): These are proposals identified by the students, the coordinator, or university researchers with active projects in the topic, development, and innovation in Industry 4.0/5.0 and digital transformation (for example, challenges of implementing new platforms, communication networks for IoT or new 3D printing methods).

Applying the knowledge acquired in the master's degree and from their own perspective of the problem, students are expected to develop specific and innovative solutions that integrate the necessary technological elements, considering their relationship with the rest of the processes and the staff involved.

All the proposed challenges will have the following characteristics:

- *Practical and applied character*. Students must propose solutions that are real and applied to the resolution of the problems or needs described in the statements of the challenges.
- *Professional format*. The proposals are presented in PowerPoint format with a clear and quick executive exposition, following the scheme presented in Fig. 3. The students are forced to capture and organize their knowledge in a summarized and company-oriented way.
- *Limited number of students per challenge.* Several students or groups can address the same challenge with a maximum limit of 10 students per challenge.
- *Tutoring by a specialist.* Each challenge is associated with a teacher-tutor specialized in the subject who partners with the student throughout the process.
- *Continuous work.* The work must be developed continuously, performing several intermediate tasks. Each task is analyzed by the teacher-tutor, who makes a critical assessment to correct possible errors or deficiencies.

A. Structure and content of student proposals

Fig. 3 describes the general scheme that is recommended to follow to propose solutions to the challenges. The proposed structure has been defined based on the experience of collaborating companies and the analysis of different proposals with common components and characteristics, such as [29]-[32]. Although this structure may vary, it contains the minimum elements necessary to define the approach of the proposed solution wholly and correctly. Each of the main parts is described below:

1) *Description of the challenge*. It contains general but sufficient information about the context, the objectives and needs to be met, the expected results, the processes and people involved, the infrastructure of technological resources, and their level of integration. The description of the process to be digitized by the company is especially important, clearly indicating the steps, people involved, resources, the time needed, tools used, and any other necessary elements the student should know.

2) *Maturity level and general approach*. The student must describe the level of digital maturity of the organization and a general approach of actions to be realized based on that level, using the tools and methods of diagnosing the levels of digital maturity and preparation for Industry 4.0 [33].

3) *Identification of technologies*. Students must conduct a technical analysis of the dares and identify the technologies necessary to approach them.

4) *Proposed solution*. Students present their solution to the challenge, which must include at least the following:

- *Methodology*. It describes which methodologies (for example, Design Thinking, Lean Manufacturing, Proof of Concept (PoC), or Scrum) and tools that are proposed to be applied, justifying their application.
- *Overview of the solution and future process.* A global description of the future digitized process is included. It is essential to identify the profiles of the people involved and the necessary resources with a view to its correct implementation.
- *Revised requirements, scope, and limitations.* As the project progresses, a multitude of new details and changes appear. For this reason, the scope and limitations must be reviewed when planning the solution.
- *Description of the proof of concept (if it exists).* In most of the challenges, it is essential to propose a limited scenario to test and assess the most important functionalities of the proposal. These tests must be done rigorously and follow a series of steps outlined by the PoC methodology [34]. The description of this process should include, at a minimum, objectives, a plan (time and resources), scope (which things will be tested and which will not), configuration (which parts will be simulated), and expected results.
- *Temporary plan.* The time needed to start up the project that solves the challenge must be planned, as well as the resources required (staff, material, subcontracting, etc.).
- *Human resources and training plan.* A recommendation on the crew necessary to accomplish the digitized process is included.
- *Economic plan.* This is one of the sections most valued by the company. Using the information above, a well-justified estimate of the costs, savings, and payback points should be obtained.

5) Conclusions. The student is expected to develop a brief and clear section that includes a good argumentation and justification for their proposal. In addition, he must indicate if all the objectives are achievable, describe if the proposed challenge is feasible, and if it completely solves the proposed dare.

B. Methodology

The student is expected to analyze the challenges from a broad and professional perspective, make decisions in a real scenario and propose global solutions to the challenge posed. For this, the methodology is developed in three phases.

Phase 1. Description, selection, and assignment process

In the first three weeks, students are introduced to the challenges and assigned. This phase is divided into three parts:

- *Publication and presentation (1st week).* The general guide of the subject and the statements of the challenges are published for the consultation of the students. The subject coordinator gives a session to present and describe the selection and assignment of challenges.
- *Challenge description sessions (2nd week).* Virtual face-to-face classes, in which the particularities of the proposals are described, are taught by the teacher-tutors. Students can raise questions and receive clarifications.
- *Application and challenge assignment process (3rd week).* When the challenges have been presented, a task is enabled on the virtual campus for students to submit their challenge requests through an ordered list in which they indicate their preferences. The coordinator reviews the requests and takes the assignment.

Phase 2. Development

Students must perform the work continuously with the advice of the teacher-tutor. To ensure this continuity, three deliveries are established (Fig. 3). In this way, the students present their partial approaches to the teacher-tutors, who assess the level of development to date and make proposals for improvement.

- *Initial delivery (4-5th weeks).* The student must review the description of the challenge, analyze the level of digital maturity of the company and describe the general approach proposed.
- *Intermediate delivery (6-8th weeks).* The student must identify technologies and, if necessary, review and correct the content of the initial delivery.
- *Final delivery (9-16th weeks).* The student must present the proposed final solution and, if necessary, correct the previously delivered content.

Phase 3. Final evaluation

As of the 17th week, the teacher-tutor reviews and assesses the final delivery and assigns the grade for the subject using the following criteria:

- *Participation (10 %).* The teacher-tutors value the continuous work and involvement of each student.
- *Project approach (20 %).* The focus of the digital transformation project and the justification of the level of maturity are valued.
- *Identification and justification of the technologies (30 %).* The quality of the proposal is assessed in terms of identification, organization, and justification of the technologies to be used.
- *Description of the proposed solution (40 %).* The quality of the proposed digitization solution is valued.

Suppose a student obtains fewer than 5 points out of 10 in the regular examination session. In that case, they have another three weeks to submit a new project report in the extraordinary exam session, being re-evaluated with the same criteria.

IV. Results Obtained and Problems Encountered

The challenges change and evolve each course. Since the implementation of the subject in March 2019, four promotions of the Master in Industry 4.0 have been developed, divided into three courses, as described in Table II. In that time, 547 students, 14 challenges and 8 different companies have simultaneously been part of the experience.

A. Learning outcomes

Integrating Industry 4.0/5.0 and digital transformation has recently transformed the business landscape. As a result, students need to be equipped with the necessary knowledge and skills to analyze and propose comprehensive solutions to the complex challenges posed by these advancements. In this regard, the methodology and procedures described in this study have proven to be highly effective in producing significant learning outcomes.

The main findings reveal that students exposed to this approach demonstrated improved analytical abilities, allowing them to identify the underlying problems of real-world business scenarios beyond technical considerations. Instead, they were able to employ a holistic approach, drawing on knowledge from various disciplines within the master's program to generate practical solutions.

Moreover, the proposed solutions were intended for application in real-world environments, enhancing students' professional skills and abilities. The approach allowed them to develop a more nuanced understanding of the complexities of digital transformation and Industry 4.0/5.0 and the importance of incorporating this knowledge into practical applications within the workplace.

Overall, the methodology and procedures employed in this study have demonstrated the significant impact of interdisciplinary collaboration and practical application in producing highly trained and adaptable graduates. The findings of this study have important implications for the future of education as institutions seek to prepare students for a rapidly evolving and complex business environment.

B. Valuation of students, companies, and university

To evaluate this subject, different indicators have been collected throughout the four courses it taught (Table II). From the company's point of view, their interest in participating in the program is verified because the number of companies and proposed challenges has increased yearly. Thus, in 2028/19, 4 companies participated (with 5 challenges in total), while in 2021/2022, the participation of

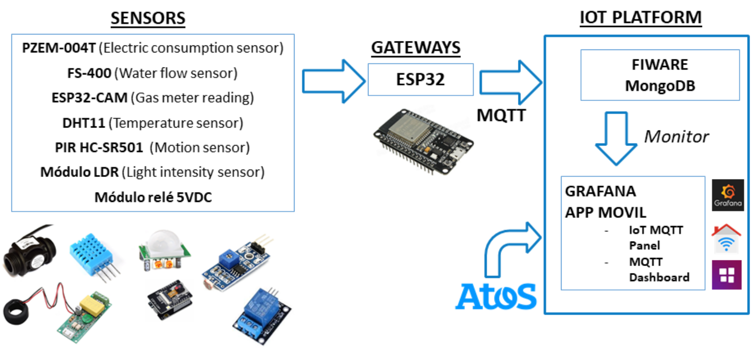

Fig. 4. Outline of the proposal made by the student to solve the challenge posed by ATOS.

8 companies (plus 3 students works in their own companies) was already available (with 14 challenges in total). This increase has gone hand in hand with an increase in the number of students enrolled in the subject (47 students in 2018/19 and 212 students in 2021/22) and in the number of academic degrees offered by this subject (in the last year, was offered in 2 masters). On the other hand, from the student's point of view, two important data can be discriminated against their grades, the level of abandonment of the subject, and their satisfaction with the assigned teacher-tutor. The average grade obtained by the students during the analyzed courses shows that it was at least 8.11 (10 maximum points). Although the first year, the percentage of students who passed the subject was high (78.70 %), the number of students who did not take it is also considered high (21.30 %). In the following courses, the percentage of students who passed the subject increased, and the percentage of students who did not take the course decreased in the same proportion. This parameter is associated with a greater experience of the teacher-tutors who perfected their proposals with the feedback received from the students. Finally, the grade the students gave to their teacher-tutor is highlighted, whose average value was never below 8.37 points (10 maximum).

Table II. MAIN EVALUATION INDICATORS OF THE PROPOSAL EVALUATED.

Indicator	Course* 2018/2019	Course* 2019/2020	Course* 2020/2021	Course* 2021/2022
Number of participating companies	4	6 (2 new)	8 (2 new)	8 *(+3 companies chosen by students)*
Total number of challenges	5	10	14	14
Students enrolled in the subject	47	100	188	212
Percentage of students approved	78.70 %	91.45 %	89.50 %	89.90 %
Percentage of students not present	21.30 %	11.00 %	10.35 %	12.80 %
Grade awarded to the subject (0-10)	8.67	8.80	8.11	8.65
Satisfaction note with the teacher-tutor (0-10)	9.00	8.44	8.37	8.4
Number of master's degrees in which the subject is taught	1	1	2	2

**Each course includes two promotions for each master's degree.*

Regarding the valuation of companies, there are no surveys because the low number of participants (8) does not allow for obtaining relevant statistical results. However, there is evidence that shows great satisfaction. Specifically, all the companies, except one, maintain challenges, and, in all cases, these dares have been modified and improved over time. This shows a significant commitment from the companies that positively value the usefulness of the collaboration achieved.

From the point of view of the university, the implementation of this subject and its ecosystem associated with other university degrees is being promoted, such as the Master's Degree in Internet of Things [35]. In the latter case, the subject is called "Professional Internet of Things projects for application in the company." It has been offered in two promotions as an elective to the traditional subject of external internships. In both cases, 80.95 % of the students enroll in this subject, and those who do not choose this option, mostly request validation based on their previous professional experience. This evidence is shown as another indicator of the quality of the proposal and the interest it arouses.

C. Problems detected

Implementing practical educational challenges effectively bridges the gap between theoretical learning and real-world application. However, this approach has limitations, which must be carefully considered to ensure its success.

One major obstacle to implementing practical challenges is the effort and dedication required to present the challenge effectively. From the company's perspective, challenges must be prepared well to ensure they have a positive impact. This requires a significant investment of time and effort to understand the methodology and structure of the proposed challenge. Initial promotions of the challenge may also lead to doubts or confusion due to a lack of clarity or relevant information. In such cases, the teacher-tutor must clarify the company's reality and the proposed challenge to ensure the students' success.

Another area for improvement is some companies' difficulty in providing staff to act as teacher-tutors. While attempts have been made to address this issue by engaging academic staff, coordination with the company and the time demands involved often make it a challenging and unsatisfactory experience for all parties involved. As a result, the quality of the student experience and the proposed solutions may need to be improved. Throughout the experience, we have tried to keep the same tutors in each company to ensure the continuity of the project. They have adapted the challenges according to their changing needs or deficiencies detected in previous courses.

Moreover, challenges that require confidentiality clauses cannot be executed in this subject due to the nature of the proposals being presented to students, who may present their candidacy to other parties. This further highlights the need for careful planning and execution of practical educational challenges.

From the university's perspective, quantifying the coordinator's high number of hours advising all the companies and helping them define their statements is an evident difficulty. In addition, hiring teacher-tutors can prove challenging due to variations in the number of students and personal interests, in addition to legal restrictions in labor matters. Furthermore, this experience has been carried out with a single coordinator. However, in subsequent years new coordinators have begun to be trained to implement this subject in other university degrees. There is still no data available on this aspect.

These limitations underscore the importance of careful planning and execution when incorporating practical challenges into education. However, despite the challenges, this approach remains an effective way to prepare students for the real-world challenges they will encounter in their careers.

D. *Example of challenge developed by a student*

Presented here is a successful case study that showcases the effectiveness of the approach implemented in this subject. The challenge, "Integration of an energy efficiency system in corporate buildings," proposed by ATOS, prompted a student to devise an innovative solution. The main objective of the project was to optimize the energy consumption of ATOS Group offices, using an open-source IoT platform based on unlicensed communications and managed centrally at a low cost.

The student began by familiarizing themselves with the installation and the company. This process revealed no centralized control or visualization of electricity, gas, and water consumption, leading to an estimated waste of 30%. Further, the cooling and heating systems and the water and gas meters were isolated and lacked integrated communication systems linked to IoT platforms.

To identify the digital maturity level of the company, the student employed the IMPULS method [36] and obtained an intermediate global maturity level (level 2), justifying the results. The PoC methodology was then utilized to perform the work, focusing on the problem areas and testing the proposed solutions to ensure they did not interfere with other business processes.

Based on the results, the student proposed a solution to monitor the building (Fig. 4), which involved the integration of several sensors that captured information and sent it to a Gateway (ESP32 with WIFI connection), utilizing the MQTT protocol. The FIWARE platform, through Docker, was used, along with the MongoDB database, displaying data in the Grafana mobile application and MQTT Dashboard.

The proposed solution included a 7-month implementation plan and resulted in an annual energy consumption cost savings of 70,000 € with a return on investment of 3 years. This case study is a testament to the effectiveness of the subject's approach. It highlights the immense potential for students to contribute innovative and practical solutions to real-world problems.

V. Conclusion

One of the key challenges in online degree programs where students are geographically dispersed and studying remotely is ensuring that the curriculum remains relevant and up-to-date and that students can gain practical experience and connect with industry professionals. While students may receive theoretical training in Industry 4.0/5.0 concepts, it is only through real-world case studies and challenges that they can genuinely integrate and apply their knowledge to form comprehensive technical solutions. In this context, teacher-tutors associated with companies are critical in providing students with the necessary support and guidance to tackle real-world professional challenges.

To address this challenge, an online ecosystem has been developed based on collaboration between universities and companies, providing mutual benefits to all stakeholders. Through this ecosystem, students receive practical training linked to the realities of the industry and can connect with companies to gain firsthand experience and feedback on their projects. Universities benefit by staying up-to-date with the latest trends and demands in the industry and can offer educational experiences that more closely reflect the realities of the workplace. Companies benefit by receiving feedback on innovative ideas and methods, which can enhance the quality of their processes.

However, a significant limitation of this approach is the inability of university staff, who may need to gain direct experience with a given company, to effectively mentor and support students in real-world projects. To overcome this limitation, it is essential that all stakeholders, particularly companies, are fully engaged and invested in these collaborative efforts to ensure their success. Overall, developing this type of online ecosystem represents a promising approach to addressing the challenges of online education and providing students with relevant, real-world experiences that prepare them for success in the workforce.

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