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RESEARCH ARTICLE

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Insights 4.0: Transformative learning in industrial engineering through problem-based learning and project-based learning

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Abstract

This paper describes a methodological study carried out between 2018 and 2022, at Rey Juan Carlos University, focused on the subject monitoring and control systems within a master's program in Industrial Engineering. The study proposes an innovative teaching strategy using problem-based learning and project-based learning methodologies. The projects undertaken are based on Internet of Things (IoT) systems aimed at enhancing **weather stations**, services and facilitating real-time decision-making. Inspired by our experience in the development of Industry 4.0 projects, we have designed a methodological strategy for this subject that focuses on providing students with the necessary knowledge and skills in the field of Control and Monitoring Systems and the IoT to develop real monitoring and control systems. The approach emphasizes interdisciplinary problem-solving, with students working collaboratively in stable teams. Throughout the 16-week course, tasks of increasing complexity are completed, resulting in the development of a complete system. The practical approach of the course and its relation to real applications motivates students, resulting in better performance. The acquired techniques and skills from the course are broadly applicable across engineering disciplines.

KEYWORDS

Industry 4.0, Internet of Things (IoT), learning environments, monitoring and control systems, problem-based learning, project-based learning, teamwork

1 | INTRODUCTION

Engineering projects at the culmination of an academic curriculum play a pivotal role in exposing students to real-world industry dynamics [4, 29]. While technical subjects endow students with proficiency in planning, calculating, and designing, it is imperative to extend this knowledge to multidisciplinary contexts that address multifaceted challenges. Industry feedback underscores the importance of elements such as testing, design reviews, release management, and teamwork within interdisciplinary frameworks [4, 28]. In the era of

Industry 4.0, characterized by collaborative technologies [13], the essence of teamwork becomes paramount.

To prepare students for collaborative careers in the evolving landscape of Industry 4.0, universities are increasingly adopting computer-supported collaborative learning (CSCL) approaches within engineering programs [5]. Aligned with the Bologna process, which seeks to create a unified higher education space in Europe [17, 20], collaborative learning (CL) emerges as a transformative teaching method in the European higher education area (EHEA) [9, 25]. CL facilitated by easily accessible software tools under free licenses, not only enhances engagement and teamwork but also fosters social relationships among students [14], thus aligning them with the demands of Industry 4.0, driven by digital technology [10, 15, 19, 23, 24].

This paper explores a proposal to bridge the gap between academia and industry by incorporating scheduled deliverables, peer-review processes, and open-source resources into engineering projects. Rooted in the collaborative nature of the industry, this methodology draws inspiration from the IEC 61160 design review standard, ensuring thorough evaluations and continuous project enhancements [11]. Students, guided by professors, embark on a structured journey, designing and implementing solutions on real hardware. Scientific and technical topics relevant to the study field are collaboratively prepared and presented, either onsite or virtually, using various tools to acquire knowledge and realize tangible projects applicable to Industry 4.0, with a special focus on IoT technologies [3, 6, 18].

The project is being developed in two stages: the first uses problem-based learning (PBL) for the implementation of a real-time monitoring system, and the second uses project-based learning (PrBL) to devise a final solution for a broader Industry 4.0 and IoT monitoring challenge. Previous studies have shown that integrating such collaborative tools not only motivates students, but also effectively addresses the course's learning objectives, equipping them with essential skills [6, 26]. In summary, engineering project courses that incorporate CL models and leverage emerging technologies create dynamic and engaging learning environments. Promoting CL based on PBL and PrBL models can better prepare engineering students for the constantly evolving landscape of Industry 4.0.

The paper is organized as follows; Section 2 provides a state-of-the-art, Section 3 provides the description of the project, Section 4 provides an in-depth overview of the project's contents and methods, Section 5 delves into the educational results, Section 6 provides an analysis of the results, and finally Section 7 concludes the paper by presenting key insights and implications for future research and practice.

2 | RELATED WORK

As engineering projects approach the culmination of the curriculum, they offer students valuable exposure to real-world industry aspects. Technical subjects provide skills in planning, calculating, and designing, but applying this knowledge in multidisciplinary contexts is equally crucial. Industry feedback highlights the significance of testing, design reviews, release management, and teamwork in an interdisciplinary context [4, 28, 29], especially within the collaborative nature of engineering, which becomes essential in the context of Industry 4.0 [13].

The integration of CSCL models in engineering courses, such as the classroom-based CSCL model, involves the use of software tools in educational settings. This fosters real-time collaboration and enriches course materials through peer-review processes [1, 8, 27]. These collaborative tools have been shown to be beneficial in teaching object-oriented design and using mobile devices to create engaging learning environments. However, there is a need for methodologies that motivate students in Industry 4.0 projects development. Open-source resources like Wikis, Moodle, and file hosting services further support collaborative efforts [21].

PrBL and PBL models actively engage students in engineering courses. PrBL-based model involves hands-on, extended activities, encouraging students to plan, design, and create tangible solutions for identified problems [2]. PBL, on the other hand, stands as a methodology that revolves around learning activities tailored to strategically solve specific problems, fostering autonomy, and teamwork. Its significance lies in nurturing students' problem-solving and critical-thinking skills and their ability to apply knowledge to novel situations [2, 3]. This methodology empowers students to acquire and integrate new knowledge, using problems as the starting point for learning, and reflection practices guided by examples could help bridge gaps between conceptions and scholarly discussions [7]. PrBL follows general steps while PBL learning provides specific steps. PrBL often involves tasks that solve real-world problems, while PBL uses scenarios and cases that are, perhaps, further from real life [26, 27]. Both models facilitate active learning, problem-solving skills, and knowledge transfer to new situations.

The growing prominence of tangible technologies, exemplified by the Arduino Educational Boards in computer science education, is underlined by the findings of Perenc [2]. Their innovative approach, integrating a dedicated Arduino board with a custom application programming interface (API) into programming classes, aimed to enhance student engagement and overall course appeal. The authors demonstrated the effectiveness of integrating tangible technology into programming education by providing hands-on experience and empowering students to pursue personal projects, such as video games, even without prior electronics knowledge. This aligns seamlessly with the contemporary educational landscape, emphasizing the symbiosis of PBL and PrBL with IoT tools to prepare students for Industry 4.0 challenges, aligning with the transformative demands of smart technologies and interconnected systems [22]. The integration of robotics and IoT in education, as illustrated by the interdisciplinary case study, presents a valuable contribution by offering practical, hands-on training to students from diverse disciplines. Through the application of these technologies in instructional design for language education, the study not only addresses challenges such as cross-disciplinary expertise and knowledge gaps but also provides a framework for future instructional design. The identified factors influencing designer perspectives contribute to the development of targeted training programs, enhancing the overall educational landscape by fostering innovative approaches that align with the evolving demands of Industry 4.0 [12, 26].

The incorporation of tangible technologies mirrors a broader trend in computer science education [16]. This trend emphasizes the diffusion of real-world applications to enrich the learning experience. Beyond mere technology integration. In fact, our proposal delves into the symbiotic relationship between PBL and PrBL with IoT tools, exploring their effectiveness, implementation, impact on learning outcomes, and application in specific contexts of Industry 4.0 and real time monitoring. The subsequent sections of this paper meticulously detail the contents, methods, and outcomes of the monitoring and control systems (MCS) course, offering valuable insights into how PBL and PrBL are seamlessly integrated into engineering education for Industry 4.0.

3 | THE MONITORING PROJECT

3.1 | The monitoring project and objectives

This course will offer a seamless integration of Industry 4.0 concepts, problem-based learning, and practical laboratory activities, enabling students to develop vital skills for the ever-evolving field of engineering. Throughout the course, students engage in diverse techniques that foster critical thinking, collaboration, and creativity—competencies highly sought after in the industry. This is a hands-on experience that allows them to apply theoretical knowledge in a real engineering context and prepares them for the challenges of Industry 4.0.

A starting project is proposed to student groups to develop a wireless weather station. The procedures and the methodology used are close to those required for the development of Industry 4.0 systems. This approach was confirmed to be appropriate when in 2018, the company Harting launched a commercial product, Harting MICA, “to implement Industrial Internet of Things (IoT) solutions” (https://www.harting.com/ES/es/mica), with the same architecture proposed for this course in 2017, and shown in 3.2. The use of open-source hardware and open development environments allows an easy and economically affordable implementation of the project. For this development, the CL approach has been used because it allows engineering students to learn from their colleagues and improve the skills necessary for teamwork. The students work together in small teams to solve, design, and develop MCSs using microprocessors and embedded systems. Data acquisition and storage and remote web-based monitoring are also required.

According to this, the learning objectives of this course are:

- To acquire skills for designing and developing MCSs based on IoT technologies/protocols and computer science tools to implement a final solution for a real system at Industry 4.0.
- Learn basic competencies in embedded system programming, based on both open-source hardware and commercial platforms.

3.2 | The monitoring project architecture

Figure 1 shows an example of the final architecture (objective) design (deliverable). It includes two sensor nodes, based on Arduino UNO and Nano boards, and a central node, based on a Raspberry Pi 3 board. The central node includes an SQL database and allows remote access for monitoring and data management. There are wireless communications among sensor nodes and the central node based on LoPy devices with LoRa protocol. All the hardware and software were developed by the students. The weather station is based on the Weather Meter Kit from Sparkfun (Sparkfun weather meter kit—https://www.sparkfun.com/products/15901), which includes a wind vane, a cup anemometer, and a tipping bucket rain gauge.

The Raspberri Pi central node runs a LAMP (Linux, Apache, MySQL, and PHP) server. This framework, comprising different computer tools, provides a robust foundation. The Arduino-based sensor nodes (clients) boards collect meteorological variables, forming a star network topology. The bidirectional communication between server and clients ensure real-time data reception, specifically meteorological variables from the weather station.

In Figure 2, a printed circuit board (PCBs) designed by the students for the sensor nodes is shown. The PCBs feature connectors for the Weather Meter Kit, a multisensorial board based on the Bosch BME280 integrated circuit, a real-time clock for accurate data timestamping, a LoPy board facilitating LoRa wireless communications, and an Arduino Nano board dedicated to data acquisition and control.

It is important to highlight the use of the LAMP server framework. The LAMP setup provides a robust and scalable server environment and facilitates seamless integration with IoT technologies. This strategic integration enhances the course's educational objectives by exposing students to industry-relevant tools and technologies, aligning their learning experiences with the demands of contemporary engineering practices.

To support the students in the implementation phase, they were provided with access to the necessary materials and tools so that the time spent on development and implementation did not take so long. For implementation, the resources of the Electronic Technology Laboratory of the Rey Juan Carlos University were used. The prototype was manufactured there using a micro milling machine. Later, the students decided by themselves to order a finished PCB. This indicates its high level of motivation. This has led to the implementation of a weather station at the Rey Juan Carlos University facilities, in a collaboration with the Electronic laboratory of our university, based on this architecture.

4 | CONTENTS AND METHODS

This section provides a concise overview of pivotal decisions taken in formulating the structure of the MCS course, which is mandatory for students

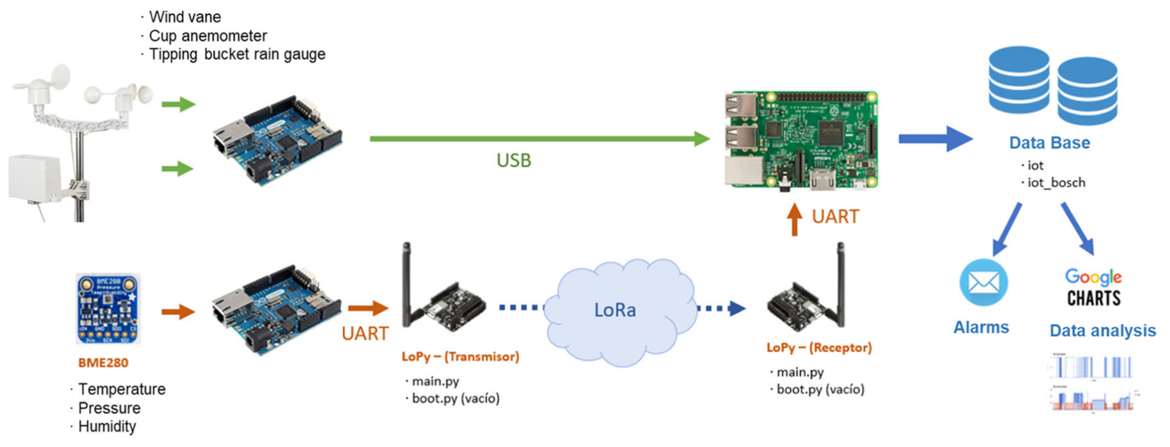


FIGURE 1 Implementation of the Internet of Things project with the final devices.

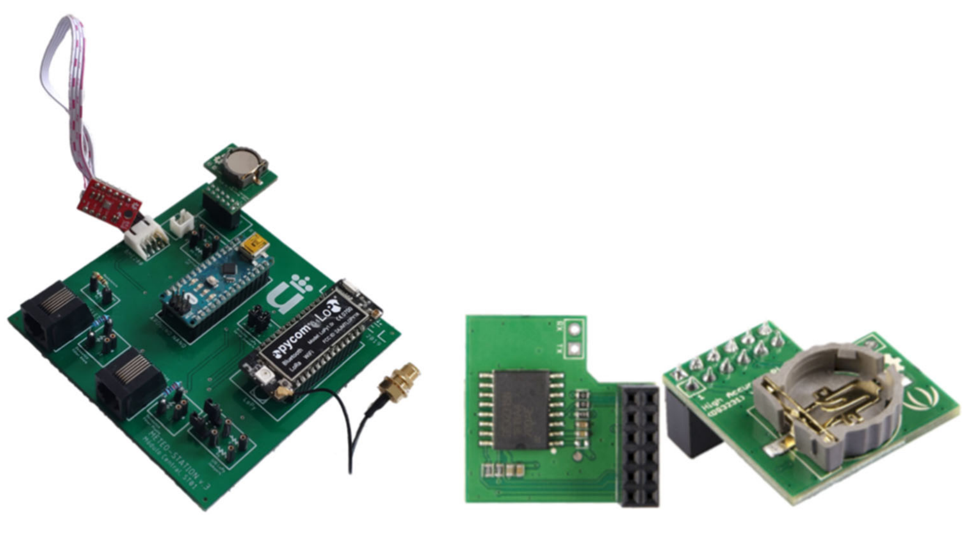


FIGURE 2 Circuits designed by students and used in the node sensor.

specializing in electronics within the master's degree in Industrial Engineering at Rey Juan Carlos University, spanning the academic years 2017–2018 to 2022–2023. The course, with a duration of one semester over 16 weeks, runs concurrently with other courses and carries a workload of six ECTS credits (European Credit Transfer System).

All students had actively participated in the continual evaluation of this methodology. The inaugural year (2017–2018) served as the control group, while subsequent years constituted the experimental groups up to 2023. As mentioned before, the course incorporates a team project challenge where both the control and experimental groups addressed a practical issue: the development of a wireless weather station. Over a 16-week period, students undertook the task of designing, implementing, and presenting their hardware-based solution, accompanied by a comprehensive report. For this timeline for the organization of the MCS, please see Table 1.

It is imperative to acknowledge that the LAMP platform, crucial for integrating the IoT component into the final project, was not incorporated in the 2017–2018 academic year. Subsequent iterations, however, introduced this framework, compatible with IoT devices, signifying an evolution in the course structure. Therefore, when alluding to the control group in the discourse, it is essential to clarify that this one deviates from conventional control groups due to the ongoing refinement of the course design, particularly with the assimilation of this IoT devices compatible framework featured in the final project.

4.1 | Contents and methodology

The contents of the course follow the methodology based on PBL and PrBL within one or several projects:

- Design and development of a real system: an approach to the design of a system to be developed by teams of students throughout the course. It will be finished with a fully functional demonstrator at the end of the course. It has a significant weight in the assessment.
- Master classes: explanation of basic concepts for Industry 4.0, organization of documentation and theoretical introductions to laboratories.
- Lab classes (IoT Project): progressive design and implementation of an IoT device based on different challenges. The project will be divided in IoT Project—Part 1 and IoT Project—Part 2.
- Hands-on seminars: general and useful tools are explained in short seminars, such as microcontroller programming or Git fundamentals for the control of software versions in a collaborative environment. These seminars are adapted yearly, according to the interests and the background of the students.
- Visits to real scenarios: Visits to different companies in the Industry 4.0 sector.

The course was divided into several content blocks. An overview of the specific contents of MCS and the number of sessions used during the course is provided in Table 1. These different blocks form a necessary background that is closely related to the objectives of the course project. For some blocks, external experts from both industry and academia in the fields of IoT, wireless communications, industrial buses, power systems, and electromagnetic compatibility are invited to give talks or lectures. This allows students to gain knowledge from people with direct experience in these topics.

Theoretical concepts and problems for both analysis and design are presented on a weekly basis. The students are required to solve them, either in class or during their own study time. To implement a problem-based learning methodology, the professor typically describes a methodology for analysing, designing, and implementing several basic exercises. The professor then assigns other exercises of greater complexity to help students gradually acquire independence in the development of these exercises.

The practical laboratory activities closely align with the general content shown in IoT Project—Part 1 and IoT Project—Part 2. Table 1 shows the schedule and content of each activity.

4.1.1 | Evaluation and practical sessions

Throughout the course, students actively engage in practical laboratory activities. The labs are designed to complement the content blocks and reinforce problem-solving skills. Students work in teams of 2–4 and assume different roles, such as design, implementation, verification, and documentation. For these sessions, the activities are:

1. *Oral presentations*: Each group presents their project orally, providing an opportunity to showcase their understanding and knowledge gained throughout the process. The oral presentation is a critical component of the assessment, allowing students to articulate their ideas, defend their approach, and demonstrate their comprehension of the subject matter.
2. *External evaluation*: Oral presentations are conducted in front of a panel of experts from the field of Industry 4.0 and IoT monitoring. This external evaluation ensures that the projects undergo scrutiny from

TABLE 1 Course overview: Project plan and course content for integrating real-world monitoring and system control concepts.

Content index (see Figure 2)	Description	Tools	Activity	Time
(1) and (2)	– Introduction – Organization of the documentation. Include monitoring and validation reports. Industry 4.0.	Moodle. Seminar	– Design of standard documentation to be used along the course for all the deliverables. – Reading documentation. – Auto-evaluation tests.	360′ + 60′ self-work
(3)	– Network operating systems, servers, and configuration. Databases for embedded and nonembedded servers. Conceptual description.	Moodle. Seminar	– Reading and study of documentation. – Software installation: OS, libraries, and software for LAMP (Linux, Apache, MySQL, and PHP) environment. – Auto-evaluation tests.	360′ + 120′ self-work
(3) and (4) Internet of Things (IoT) project (part 1)	Software installation (at the lab): – Database implementation for the IoT project. – Monitoring: variable measurement and data handshaking from clients and local server. – Data storage on the database. – Data representation and exploit using collaborative IOT ecosystem.	Moodle. Seminar. Examples	– Hardware development evaluation (design, components selection, and implementation). – Software evaluation (design, flow diagrams, and final implementation). – Auto-evaluation documents. – Evaluation and oral presentation. – Project demo, part 1.	640′ + 180′ self-work
(5)	– Concepts about wireless communication. Protocols. – Example of case study consists of a sensor node and a coordinator node using wireless communications.	Moodle. Seminar. Examples	– Reading documentation. – Auto-evaluation documents.	240′
(4)	1. Interruptions and peripherals. ISRs. 2. Timers. Serial communication. 3. Low power modes.	Moodle. Hands-on seminarExamples	4. Reading documentation. 5. On-line concept test.	120′
(3), (4), and (5) IoT project (part 2)	6. Basic weather station evaluation (pressure, temperature, and humidity) + LAMP with data exploitation and wireless communications.	Moodle. Seminar. Examples	7. Reading documentation. 8. Auto-evaluation documents. Delivery of Arduino code, SQL code, Raspberry code, flow diagrams, and documentation. 9. On-line concept test. 10. Project demo, part 2.	360′ + 60′ self work
Evaluation	Final exam.	Moodle.	11. Evaluation of concepts.	120′
Evaluation IoT project	Evaluation of two parts.	Moodle.	12. Final documentation delivery. 13. Oral presentation. 14. Demo of the complete weather station.	60′
Visit to industry 4.0 environments	Visits to companies where Industry 4.0 is being implemented.	-	-	240′

professionals who can assess the originality, depth, and practical relevance of the work.

4.1.2 | Enabling master thesis and industry visits

Upon completing the course, students can proceed with their final master thesis, applying the knowledge acquired. The course's focus on technology transfer and alignment with Industry 4.0 requirements has resulted in greater student motivation. Furthermore, students benefit from technical visits to companies implementing Industry 4.0 practices, providing valuable insights and potential internship opportunities.

5 | RESULTS

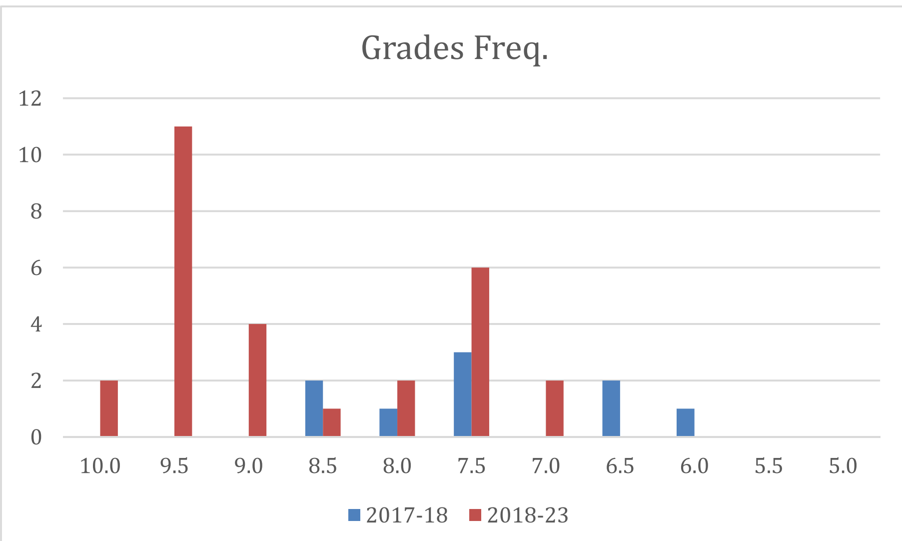
In this section, we will thoroughly discuss the evaluation results.

5.1 | Assessment

In this section, we present the evaluation results for the final stage of the subject, both at the individual student level and the group level. This assessment allows us to compare their academic outcomes with data from previous years, assessing the effectiveness of the implemented changes and new techniques in the course. The adoption of CL fostered increased cooperation among students, enhancing their teamwork and technical skills to achieve the set objectives. Additionally, the diverse perspectives and approaches taken by different student groups in developing the project contributed to a richer overall learning experience.

Figure 3 illustrates the progression of results taking the reference year (2017–2018) as a starting point. It represents the frequency of grades in both analyzed periods as an indicator of quality. For this purpose, it is assumed that students pass the subject with a grade above five points over 10, so that in both cases the results are satisfactory in 100% of the cases.

To establish the final grade, a common rubric was used that breaks down the evaluation, where phases for the IOT projects (parts 1 and 2, see schedule in Table 1) and Development of the Final Project account for 50% of the final grade. On the other hand, the deliverable documentation represents 20% and the theoretical evaluation a 30%. Overall, the final grades showed significant improvement, often achieving first-class rankings (>8.0). Although in each period the number of students enrolled fluctuates, the first group concentrates its results between 6 and 8.5 points with an average of 7.25 points, but the second group is distributed in values above 7, with an average of 8.7 points. This indicates a significant improvement in the results obtained by those students who have passed the subject.



Course	10,0	9,5	9,0	8,5	8,0	7,5	7,0	6,5	6,0	Average
2017-18				2	1	3		2	1	7,4
2018-23	2	11	4	1	2	6	2			8,7

FIGURE 3 Bar chart comparing the final marks of the last three courses. The course 2017–2018 corresponds with previous methodology without CL and deliverables courses 2019–2020 correspond with the period of application of the methodology explained in this paper.

The introduction of PBL, PrBL, peer review, and the revised structure of course content and deliverables contributed to a more effective teaching and learning process. Incremental learning facilitated the improvement of knowledge while expanding the course content. The greater involvement of the students meant an increase in grades of up to 1.11 points.

Table 2 provides a summary of the score evolution related to the IoT project and the final course.

5.2 | Evaluation method assessment

Additionally, student feedback was collected to assess the course's efficacy as an educational resource. Surveys, including a final course survey and the institutional Teaching Evaluation Questionnaire (TEQ), utilized a Likert scale to gauge students' opinions (Sparkfun weather meter kit, https://www.sparkfun.com/products/15901) where the different choices were: strongly disagree (SD, value = 1), disagree (*D*, value = 2), neither agree nor disagree (NAD, value = 3), agree (A, value = 4), and strongly agree (SA, value = 5).

TABLE 2 Score related to Internet of Things project and the final course.

Project score	Mean	Max	Min	σ
2017–2018	7.4	8.50	6.00	0.80
2018–2019	9.17	9.50	9.00	0.20
2019–2020	9.00	9.00	9.00	0.00
2020–2021	9.50	9.50	9.50	0.00
2021–2022	8.38	9.50	7.00	1.07
2022–2023	8.50	10.00	7.50	0.96

6 | DISCUSSION

The feedback showed that students who participated in the last year obtained a mean grade of 1.11 higher than in previous years. The improvement in grades can be attributed to enhanced detail in the written reports and demonstrations. Regular deliverables and self-evaluation led to more comprehensive designs and refined final project requirements. Collaboration and peer evaluation further motivated students to improve the quality of their work. Moreover, three students who completed the course secured internships in companies, a positive outcome facilitated by the organized visits during the course. Based on the data from Figure 4, several key conclusions can be drawn about the methodology and its effectiveness:

- *Interest in contents*: Over the years, there has been a consistent level of interest in the course contents, with an average score of around 4.6 out of 5. This indicates that the topics covered in the course are engaging and relevant to the students.

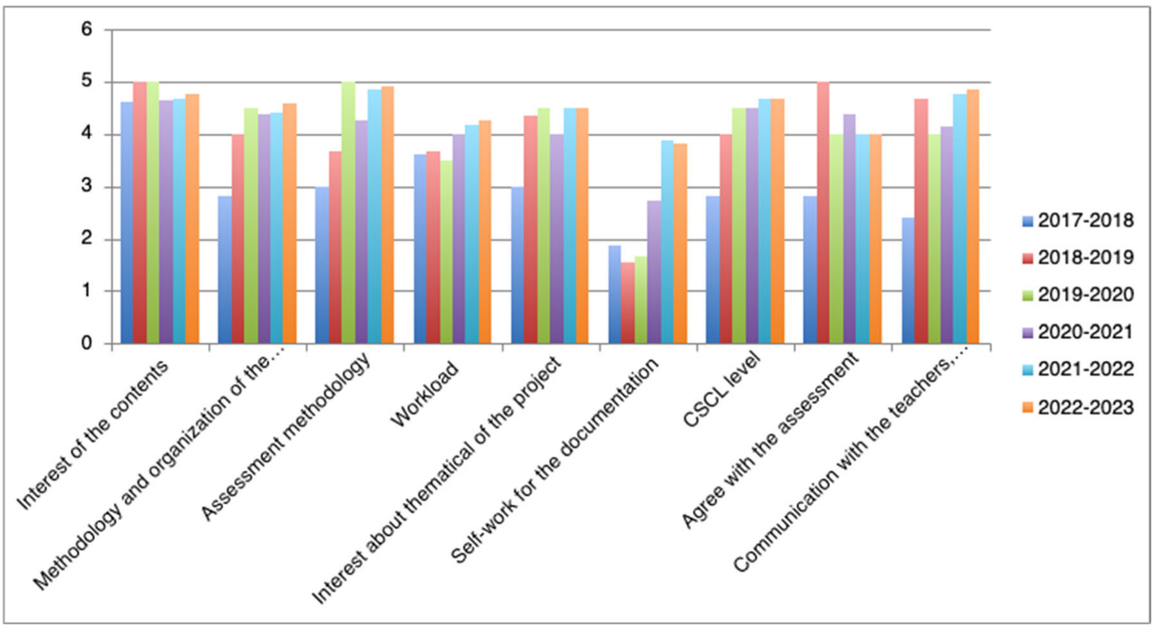


FIGURE 4 Bar chart comparing the evaluation method assessment. The course 2017 and 2018 corresponds with previous methodology without problem-based learning (PBL), project-based learning (PrBL), and deliverables. The courses 2019, 2020, 2021, and 2022 correspond with the methodology explained in this paper.

- *Methodology and organization*: The methodology and organization of the course, including laboratories and deliveries, have shown steady improvement, with average scores increasing from 2.8 to 4.58. This suggests that the changes and new techniques implemented in the course have positively impacted the learning experience.
- *Assessment methodology*: The evaluation process has been well-received by students, as indicated by increasing scores in this category over the years (from 3 to 4.92). The inclusion of CL and peer-review likely contributed to the positive perception of the assessment methods.
- *Workload*: The workload of the course has remained relatively consistent, with students finding it manageable over the years. Scores in this category range from 3.5 to 4.25, suggesting that students feel appropriately challenged without being overwhelmed.
- *Thematic interest*: The thematic relevance of the project has consistently scored high, with average ratings ranging from 3.5 to 4.5. This demonstrates that the chosen project topics align well with the interests of the students.
- *Self-work for documentation*: Students' engagement in self-work for documentation has been relatively high, with average scores ranging from 1.54 to 3.82. This indicates that students are actively involved in the documentation process, reflecting their commitment to the course.
- *PBL, PrBL*: The new updates of methodology has been well-implemented, with scores in this category ranging from 2.8 to 4.67. The course's emphasis on teamwork and collaboration seems to be effective in promoting a positive learning environment.
- *Agreement with assessment*: Students' agreement with the assessment process has shown a positive trend, with average scores increasing from 2.8 to 4. This suggests that students are satisfied with how their work is evaluated and the feedback provided.
- *Communication with teachers and deliveries*: Communication with teachers, deliveries, documentation, and readings has been well-received by students, with average scores ranging from 2.4 to 4.83. This indicates that students find the communication channels effective and helpful in supporting their learning.

Overall, the data indicates that the course has experienced notable improvements in various aspects, including methodology, assessment, and students' engagement. The integration of problem-based learning, CL, and practical activities seems to have positively impacted the students' learning experience, leading to higher grades and increased motivation. The positive trends observed over the years validate the effectiveness of the changes made to the course and affirm its relevance in preparing students for real-world engineering challenges.

Therefore, the integration of Industry 4.0 concepts, problem-based learning, and practical laboratory activities yielded positive results, evidenced by improved final grades and increased student motivation. The iterative evaluation process, coupled with student feedback, helped fine-tune the course methodology and enhance the overall learning experience. The continuous improvement and positive outcomes support the suitability of the implemented changes and highlight the effectiveness of the course in preparing students for real-world challenges in engineering.

7 | CONCLUSIONS

The guidelines provided by the European Higher Education Area (EEES) signify a paradigm shift in teaching methodology, emphasizing the student as the focal point of the learning process, with all other elements serving as supportive peripherals. The authors assert the significant advantages of this framework, including heightened student motivation, the promotion of teamwork, and the cultivation of creativity and individual work habits. In practical terms, implementing a course guided by these principles entails structuring knowledge around projects or practical problems, enabling students to directly witness the application of their studies. This approach facilitates more individualized monitoring of student progress and allows for the implementation of assessment methods complementary to objective tests.

In summary, the study has successfully introduced a practical and innovative methodology for the MCS course in the Master of Industrial Engineering. Focused on Industry 4.0 concepts, the course equips students with indispensable skills demanded by contemporary industries. Through the integration of problem-based learning and collaborative approaches, students actively participated in hands-on activities, project development, and practical seminars.

The course structure encompassed a blend of master classes, lab sessions, practical seminars, and visits to real-world scenarios, offering a comprehensive learning experience. External experts from both industry and academia were invited to share insights, enriching students' understanding of real-world applications.

Positive results were evident in the evaluation process, with students achieving higher grades compared to previous years. Regular deliverables, self-evaluation, and a peer-review process enhanced students' dedication and motivation. Exposure to diverse perspectives from student groups fostered a deeper understanding of the course materials.

The methodology's success is manifested in the development of functional and advanced IoT projects, such as a wireless weather station, conceived and implemented by the students. Student achievements transcended the course, with some securing internships in companies, a testament to the course's industry-oriented visits.

Overall, the teaching project adeptly aligns with the principles of the EEES while effectively addressing industry demands for Industry 4.0 competencies. By nurturing problem-solving, self-learning, teamwork, and technical skills, the course positions future engineers to confidently confront real-world challenges in an autonomous and effective manner.

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DATA AVAILABILITY STATEMENT

Research data are not shared.

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