An Advanced IoT-Centric Multi-Disciplinary Multi-Education Pilot Trial with Engineering Students

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Abstract

This work summarizes the findings from a multi-disciplinary multi-education pilot trial aimed at integrating the practical implementation of real-world use cases based on advanced Internet of Things (IoT) technologies in regular Engineering semester courses. Students from three different educations (BSc in Telecommunication Technologies and Services Engineering, BSc in Mechanical Engineering, and MSc in Telecommunication Engineering) with different skills and engineering maturity levels, cooperated to build functional prototypes of indoor/outdoor climate sensors targeting different reference application scenarios. The work sets the focus on the design and evaluation of the overall teaching activity based on the student self-development, as well as on the reviews from the different supervised sessions where both teachers and students were present. Quantitative results illustrate that more than 80% of the students found the exercise useful and representative of future professional engineering activities. Most of the students from all educations increased their knowledge in topics outside of their main competence areas. Interestingly, while 86% of the students reported to be prepared to face multi-disciplinary work after the activity, only 14% reported to be motivated towards multi-disciplinary work based on the current experience, being 38% of then not motivated at all. This implies an approximate 50% decrease in motivation after the activity. The root causes for the observed variation are analyzed and corrective measures are extrapolated to improve future editions of the multi-disciplinary multi-education activity.

Keywords: project-based learning; collaborative learning; multi-disciplinary education; multimodal learning; teaching perspectives

1. INTRODUCTION

In the realm of education, the integration of multi-disciplinary multi-education teaching activities presents a transformative approach that significantly enhances traditional teaching methods (Gorman, 1995). While traditional teaching, often characterized by a compartmentalized and subject-specific focus, benefits immensely from the incorporation of cross-disciplinary perspectives; this approach fosters a more holistic and interconnected understanding of knowledge, encouraging students to see beyond the confines of individual subjects (Borrego, 2008). Multi-disciplinary multi-education teaching activities also serve as a vital bridge to Problem-Based Learning (PBL), a student-centered pedagogy that emphasizes real-world problem solving and critical thinking. Unlike traditional teaching, which often relies on rote memorization and isolated learning, PBL engages students in active, collaborative exploration of complex issues, requiring them to apply knowledge from various disciplines in an integrated manner (Lehmann, 2008). By embedding multi-disciplinary activities within both traditional and PBL frameworks, educators can cultivate a more dynamic and engaging learning environment (Kolmos, 2008). This not only enhances student cognitive skills but also prepares them for the multifaceted challenges of the modern world.

At higher education level, multi-disciplinary PBL teaching activities can be further enriched by integrating students from diverse educational backgrounds and varying maturity levels (Ekundayo, 2021). Such an approach leverages the unique perspectives and skill sets of individuals from different academic disciplines, promoting innovative problem-solving and holistic understanding. It encourages socialization and peer-to-peer learning, where more mature or experienced students can mentor their less experienced counterparts, facilitating personal and professional growth for both groups (Gillies, 2003). Additionally, it helps students develop essential soft skills such as communication, teamwork, and adaptability, as they navigate the complexities of collaborating with individuals who have different approaches and thought processes.

Within this context, this article describes the design and evaluation of a multi-disciplinary multi-education PBL activity with university students, addressing a real-world engineering problem related to Internet of Things (IoT), where the main teaching innovation lies mainly in the simultaneous integration of the practical group work in different regular engineering semester courses.

2. METHODOLOGY

Different methods and tools were applied in the design and evaluation of the proposed pilot teaching activity.

2.1. Methods Applied in the Design of the Teaching Activity

The teaching activity was designed with the main consideration of letting students organize and do on their own as much as possible. Therefore, the following methods were applied:

- PBL: we consider student groups engaging in external research on identified learning issues to develop one or more solutions to problems or dilemmas presented in a realistic scenario. This was the main methodology, to guarantee the student-centered approach.
- Cooperative learning: we aim at promoting the spread of knowledge between group peers, evolving from different individual starting points towards final common learnings. Within this approach, active listening, critical thinking, and reflection are encouraged. Unsupervised groups are expected to offer a workspace where students feel secure to socialize and gain confidence.
- Supervised sessions: the main goal of this teacher-centered methodology was to monitor and evaluate the unsupervised student group work. Students received constructive feedback from the facilitators, based on short presentations of their developments and technical achievements.

2.2. Tools for Evaluation of the Teaching Activity

To evaluate the teaching activity at different progress stages, the following tools were considered:

- Anonymous online questionnaires: two questionnaires were used to gather the opinions and perceptions of the students. The initial questionnaire was collected before the start of the unsupervised group work, and the final questionnaire was collected during the last supervised workshop.
- Observations from the supervised sessions: relevant positive and negative organizational and technical aspects identified from the student presentations were logged in by the project facilitators.

3. RESULTING TEACHING ACTIVITY

The result teaching activity is organized in groups that merge engineering students from different educations and levels, facilitating a common space for spreading knowledge at the intersection of the different areas and competences, as depicted in Figure 1. The three educations and levels selected for this teaching trial were: 1st year MSc Telecommunication engineering

(MINGTELE), 3rd year BSc in Telecommunication Technologies and Services Engineering (GITELE), and 3rd year BSc in Mechanical Engineering (GIMECA). In total, 3 multi-education groups were formed. Table 1 summarizes the group compositions, number of students, and expected roles from the different students. The ambition was to create balanced groups that resemble multi-disciplinary engineering teams within a company. This was done with the aim of emulating professional industrial experience, something that, typically, university engineering educations lack (Waks, 2000).

Figure 1

Venn diagram for the resulting teaching activity, illustrating the overlapping of skills of the different educations and the potential multi-disciplinary competences to be acquired by the different groups of students.

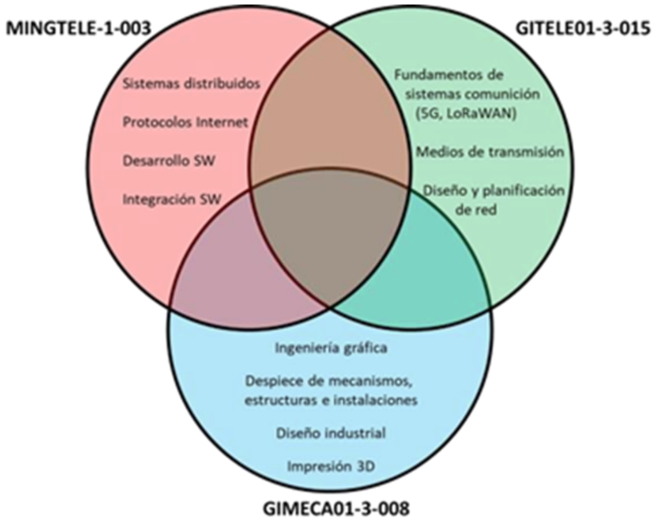


Table 1

Summary of student participation and expected roles within the activity.

	Total number of students participating in the activity	Number of students in a group	Expected role of the students within the group	Observations
MINGTELE	9	3	HW/SW integrators and programmers	Mandatory and graded activity
GITELE	3	1	Network technology advisors	Volunteer activity
GIMECA	9	3	Structural designers	Mandatory and graded activity
TOTAL	21	7		3 groups

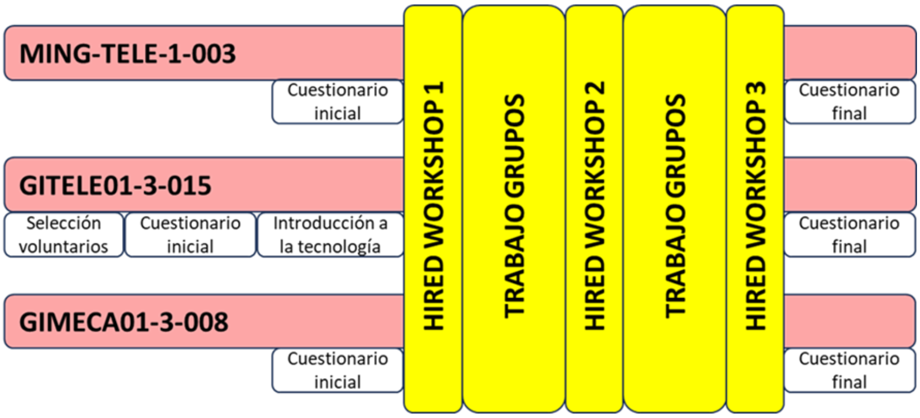
The overall structure of the activity is summarized in Figure 2, broken down into different technical work components (unsupervised work group and supervised workshops), and specific activities planned for the different group of students. The time span for the activity, defined between workshop 1 (W1) and workshop 3 (W3) was overall 2 months, having workshop 2 (W2) right in the middle. Each of the workshops had specific progress monitoring and observation objectives:

- W1 – Introduction: introduction to the activity, group establishment, appointment of group responsible, hand in of hardware (HW) materials. Ice-breaking exercises were proposed to trigger initial socialization.
- W2 – Intermediate progress monitoring: intermediate presentations with focus on project status, organizational aspects, and used tools, questions by peer students and supervisors, and feedback.
- W3 – Final product presentation: focus on final "operational" product – including demo, questions by peer students and supervisors, grading, and final feedback.

It should be noted that expert offline support was made available for the students in case it was needed. This was done emulating the operation in any engineering company where you have access to a supervisor or manager to check up or solve technical difficulties. In this case, the activity included support by 4 facilitators, categorized within the following technical roles: senior industrial engineer, senior telecommunications engineer, senior computer scientist, and junior engineer.

Figure 2

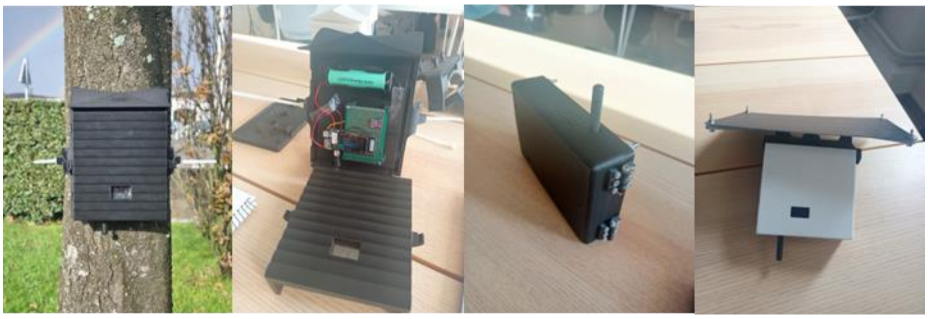
Planned workflow for the resulting teaching activity, including unsupervised group work ("trabajo grupos") and supervised sessions ("workshops"); as well as other specific teaching sessions (introduction to the technology: "introduccion a la tecnologia") and evaluation activities (questionnaires: "cuestionario inicial/final").



The main technical challenge proposed as core of the technical group work collaboration was the development and commissioning of an IoT "smart object" for remote online monitoring of climate parameters (temperature, humidity, and atmospheric pressure) using LoRaWAN technology. From an engineering perspective, in brief, this task involves: analysis of the specific engineering use case, planning and design of the overall technical solution, identification of individual components within the different fields of expertise, design and implementation of HW and software (SW) electronic components, dimensioning and implementation of the network communication, design and implementation of the online monitoring service. Each of the three groups was assigned the same task, but different deployment conditions at different locations with the aim of providing them with a broad vision of the general applicability of the technology. As a reference, the final products implemented by the different groups are depicted in Figure 3. It should be apparent to the reader the mixture of technological components related to the different disciplines: electronics, telecommunications, and mechanical engineering.

Figure 3

Pictures of the different climate sensing IoT devices (final products) implemented by the students.



From a teaching perspective, the evolution of the teaching approaches adopted in the different workshop sessions should be noted. As shown in Figure 4, while in W1 the session was teacher-centric, it evolved towards student-focused in W2 and W3. Further, in W2 to W3 the students were tested on different professional presentation skills (slides and organizational skills in W2, and physical implementations and technical knowledge in W3).

Figure 4

Pictures taken at the 3 supervised sessions (workshops).

4. RESULTS

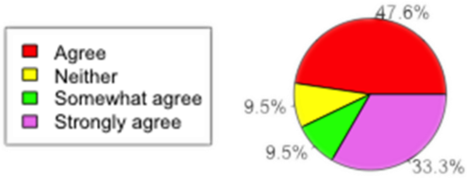
In general, the activity was satisfactory from both the perspectives of students and facilitators. All three groups managed to have a deployable and functional final product implementation capable of sensing, communicating, and logging the desired parameters. All solutions from the different groups, despite being based on the same baseline HW components, were original and different from each other's. The implementation from one of the groups was outstanding and of much higher technical quality than the other two. As a reference, the final gradings obtained by the groups were 98%, 60%, and 68%. No technical evaluation is analyzed in this work. In the following, we set the focus on reporting results from a teaching perspective, including main learning outcomes, satisfaction and professional competences, and teaching observations.

4.1. Main Learning Outcomes

As shown in Figure 5, more than 80% of the students found the exercise useful and representative of future professional engineering activities. Among those strongly agreeing with this fact, the students from GIMECA were the most convinced ones (44.4%), followed by the students from GITELE and MINGTELE with scores of 33.3% and 22.2%, respectively.

Figure 5

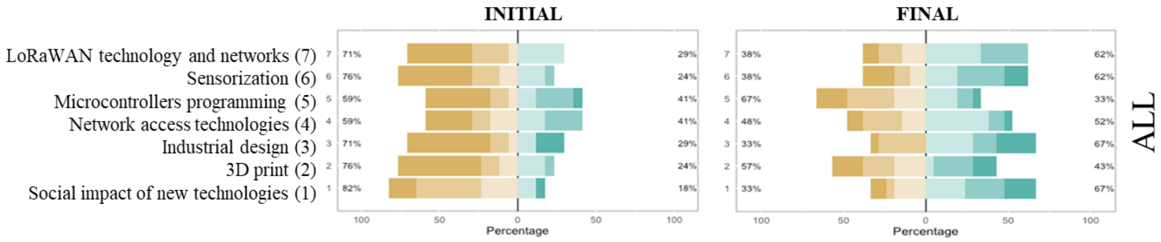
Overall learning evaluation by all students. Question: "I believe that the project has provided me with a learning experience that is representative of what I will encounter in my future professional career."



Comparing the answers provided in the initial and final questionaries, we analyzed the technical knowledge evolution self-perceived by the students. We discuss perception and not actual knowledge as in the questionaries we are asking for their opinion and not examining their technical expertise. Figure 6 describes the overall perception of the students within the different technical domains involved in the activity. As detailed, there is a positive shift of the perception for most areas, indicating that, in general, the students feel that they have increased their multi-disciplinary knowledge, not only on their direct expertise areas, but also in the complementary ones.

Figure 6

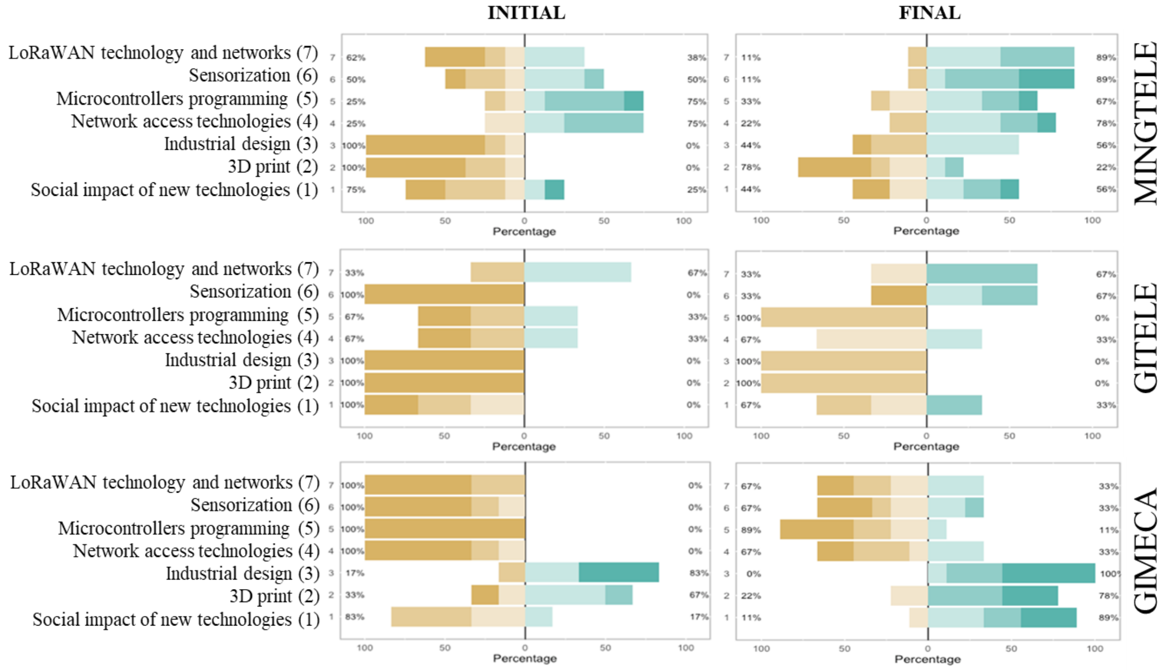
Evolution of the technical knowledge perception by all the students for the different topic areas addressed by the multi-disciplinary project. Question: "Rate from 0 (-100) to 5(+100) your knowledge in the different project topics/areas."



By breaking down the analysis for the different educations, as shown in Figure 7, the following interesting findings were made. The most experienced students (MINGTELE) reported the largest learning perceptions, while GITELE and GIMECA students reported incremental learning, and mainly in their areas of expertise. This verifies that the level of maturity and education level has an impact on the unsupervised learning process. While the MSc students, which are close to graduation, perceive the importance of acquiring as much experience and learnings as possible, the BSc students seem to be mainly interested in completing the activity, passing their course examination, and moving forward within the education.

Figure 7

Evolution of the technical knowledge perception by the students in the different educations for the different topic areas addressed by the multi-disciplinary project. Question: "Rate from 0 (-100) to 5(+100) your knowledge in the different project topics/areas."

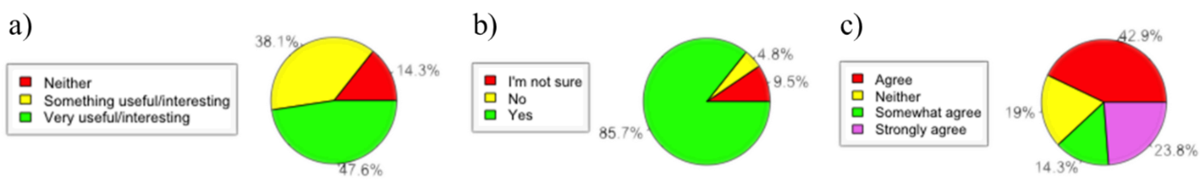


4.2. Satisfaction and Professional Competences

Overall, students were satisfied with the activity, felt that it was useful for their future career, and have a positive attitude towards multi-disciplinary developments. This is illustrated in the results reported in Figure 8. Over 60% of the students believe that the activity was very useful/interesting. Within specific educations: 100% for GITELE students, 88% for GIMECA students, and 77% for MINGTELE students. More than 80% of the students feel more prepared for their future professional career and agree on the benefits of multi-disciplinary engineering training. Within specific educations: 100% for GITELE students, 88% for GIMECA students, and 77% for MINGTELE students. This indicates that the more experienced students are slightly more skeptical or relaxed about the full scope of this type of activity.

Figure 8

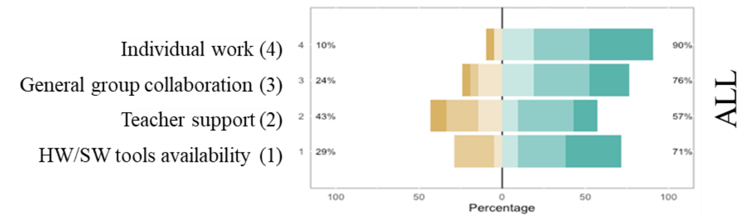
Overall satisfaction level and opinions about professional competences. a) Question: "What do you think of the multi-disciplinary project?", b) Question: "After the project, do you feel more prepared to tackle multi-disciplinary work?", and c) Question: "After the project, I believe that acquiring multi-disciplinary engineering knowledge will motivate me to carry out my work with a professional approach."



By looking into specific satisfaction levels, summarized in Figure 9, it was noted how the overall satisfaction is good in all areas. Interestingly, the lower satisfaction was reported for the teacher support. This is something that should be explored in future editions of the activity.

Figure 9

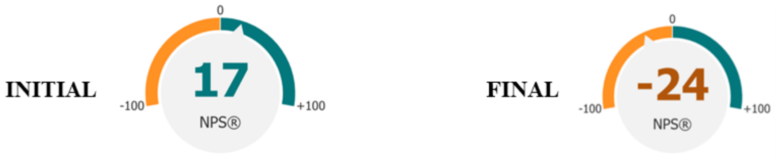
Satisfaction levels for the different activity components. Question: "Rate from 0 (-100) to 5(+100) your level of satisfaction with the following aspects related to the project."



Another aspect that should be addressed in future editions is student motivation. As illustrated in Figure 10, despite all positive previous indicators in terms of satisfaction and professional relevance, the students reported a significant decline in motivation after the project. The overall decay was approximately 50%, being the MSc students the most negative ones with a 20-30% lower motivation than the BSc students.

Figure 10

Evolution of the student motivation during the activity. Question: "Rate you level of motivation from -100 to +100."



4.3. Observations from the Supervised Sessions

As part of the analysis, it is also important to consider the notes and reflections done by the facilitators about the supervised workshop sessions:

- W1: while forming the groups, the students were asked to freely appoint a responsible person as group coordinator. All groups appointed one of the MSc students as coordinator, indicating that within peers they acknowledge the technical experience and maturity levels.
- W2: the three-group prepared very disparate presentations. It was noted that 2/3 groups were on track (~50% realistic progress in all domains, including prototype). Interestingly, the less advanced group reported the more "professional" structure with very well-defined engineering roles and showcased a "marketing-like" presentation. All groups reported good interaction within the group and used similar tools for organization/communication withing the unsupervised group work.
- W3: again, the group prepared very disparate presentations. The progress trends observed in W2 was confirmed in W3, and one of the groups did not achieve as many technical goals as the other groups. In the evaluation, this group failed within all technical domains but had a very good grading in presentation due to the "marketing-like" aesthetics. It should be noted that at this stage, several issues between volunteers and non-volunteers

were reported. These are not addressed in this work but, if of interest, further details are given in (Rodriguez, 2024).

5. DISCUSSION

By considering the bigger picture of the results reported for this multi-disciplinary multi-education pilot, we noticed that the level of maturity of the students mattered a lot both at organizational/leadership level and technical level. While the BSc students focused their efforts mainly in incrementing their specific knowledge in those main areas of their education, the MSc students seemed to be more aware of the importance of acquiring multi-disciplinary knowledge towards their future jobs after graduation. This is directly related to the fact that MSc students took the lead of the groups as coordinators, understanding the importance and benefit for training management skills and not only technical ones. On the other hand, BSc students focused on delivering the right amount of work effort to successfully complete the technical activity, forgetting about other soft skills. They probably foresee that they will have similar activity opportunities in the future.

The decreased level of motivation detected at the end of the activity is probably related to the stress caused by the final product delivery deadline and potential frustration with the late implementation developments. This would also explain why demotivation is more pronounced within the MSc students. It should be noted that this group of students may also feel more pressured since they are closer to full completion of their higher education.

In teaching development and organizational terms, all groups of students from the different educations stuck to their primary roles and correctly fulfilled their parts of the project. This indicates that technical roles were properly understood within the multi-education setup. In general, all groups indicated a good solid organization and made use of face-to-face meetings, remote online meetings, and other digital tools for knowledge sharing.

In this trial it was chosen to bet fully on student unsupervised work. Interestingly, teacher support was evaluated quite low by the students, despite none of the groups making use of the offered remote teaching support. There is room for improvement in this respect, to prevent some of the groups from non-succeeding technically or lagging.

5.1. Corrective measures

Based on the reported results and discussion, the corrective measures described in Table 2 are proposed for potential implementation in future editions of the activity.

Table 2

Summary of identified areas of improvement for future editions of the activity.

Detected issue	Severity	Corrective measures
Low multi-disciplinary knowledge transferred to BSc students	Medium	Improved explanation of roles in W1. Introductory crash course. Potential increase project duration.
Decrease of motivation in MSc students	High	Potential increase of project duration.
Groups failing technically or lagging	High	Integrating dedicated group tutorships between workshops. Potential integration of more students from other educations (e.g. Electronics). Simplified IoT use cases.

6. CONCLUSIONS

Overall, the reported trial of the multi-disciplinary multi-education activity was successful. Based on the analysis of the activity carried out by 3 different blended groups with engineering students from different BSc and MSc educations, it can be concluded that technical goals where achieved, and learning and knowledge transfer goals were partially achieved. Social learning aspects were also successful and led the students to value the usefulness of the activity towards their future career upon graduation outside university. Several issues were identified, and corrective measures were proposed to apply in future editions of the activity.

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