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Educational Impacts on Robotic Engineering Students of an International Online Project-Based Learning Course

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Abstract: This study evaluated the impact of a voluntary international online course in industrial design, which applied a Project-Based Learning approach, on the acquisition of competencies among second-year students in the Robotic Engineering program at the University of Alicante (UA). The course, which included participants from two other European universities, aimed to enhance both generic and specific competencies. This study measured the acquisition of nine generic and four specific competencies through two types of analysis: qualitative and quantitative. The qualitative analysis involved a survey assessing students' self-perceived competency gains, while the quantitative analysis consisted of a written objective test that evaluated the acquisition of specific competencies. The results were compared between 43 students who did not participate in the course and 22 who did. The survey responses indicated that, for 10 out of 13 competencies, students reported an improvement in skills as a result of the course. Additionally, the average test score for participants was 77.2%, significantly higher than the 37.7% score for non-participants. These findings suggest a strong correlation between course participation and competency development, highlighting the potential benefits of international online courses in enhancing student learning outcomes in robotic engineering.

Keywords: online education; collaborative learning; student perception; Project-Based Learning; robotic engineering

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1. Introduction

University degrees are defined by the competencies that students must acquire throughout their academic training to ensure their professional development. Each subject in a degree program specifies the competencies that students will achieve. These competencies can be broadly classified into two main groups. Specific competencies are directly related to the field of study and are usually concentrated on specific courses. Generic competencies are applicable in various contexts and are not specific to any particular discipline or course. Specifically, the engineers of the future will require technical professional competencies, as well as a set of generic competencies, such as communication skills, creativity, continuous improvement, critical thinking, teamwork, social responsibility, leadership, an understanding of trends, and environmental integration [1].

These cross-disciplinary competencies are crucial for engineers to address the complex and multidisciplinary challenges that they encounter in their work and to interact effectively with other professionals and society in general. Moreover, as Parmar pointed out, it is common for engineering education programs to have shortcomings in teaching these generic competencies [2].

This study assesses the impact on the acquisition of both generic and specific competencies of a group of second-year students in the Robotic Engineering degree program at the University of Alicante (Spain). This assessment follows their participation in the online course, "European Study of Interactive Industrial Design I". The course was part of the planned activities of the European project "European Interactive Industrial Design Studio" (EINSTUDIO, https://einstudio.eu/, accessed on 26 November 2024).

Syllabuses are designed with a series of subjects in which students are expected to develop certain competencies. To achieve this, activities are planned to foster this development. However, one of the challenges faced by educators is the uncertainty of whether students taking a subject acquire the intended competencies.

This study aims, on one hand, to determine whether students perceive that they have acquired these competencies, especially generic or transversal competencies, which are difficult to evaluate through objective tests. On the other hand, written tests allow us to assess knowledge related to the specific competencies of the course. This approach has enabled us to verify whether the group of students who took the additional online course improved their competencies compared to the group that received only the traditional teaching of the course.

This paper is organised as follows: Section 1 is the introduction; Section 2 includes the literature review. Section 3 outlines the study's objectives, with a particular emphasis on the competencies under assessment. Subsequently, in Section 4, the research methodology followed in the course is shown. Then, Section 5 presents the qualitative and quantitative analysis conducted to evaluate the course's impact and elaborates on the findings. Section 6 presents a selection of the results achieved by UA students in a specific project. Lastly, in Section 7, we present some conclusions.

2. The Literature Review

The way in which students acquire these competencies and their assessment methods are quite diverse. Current educational approaches advocate for promoting blended learning, wherein students can acquire various competencies defined at each academic level through a variety of teaching methods [3]. These learning approaches strive to be inclusive rather than exclusive. They enable the combination of different teaching methodologies, including face-to-face and online instruction, individual and collaborative learning (with and without the use of technology), and more. As a result, educators find themselves amidst a whirlwind of methodological changes. They are increasingly aware that incorporating adaptable methodologies, which emphasise the active role of students, enhances their comprehensive education.

Flexible methodologies prioritise adapting to students' needs and encouraging their active participation. These methodologies aim to foster autonomy, collaboration, reflection, and critical thinking among students. Some of the flexible methodologies commonly employed include the flipped classroom [4,5], Project-Based Learning (PBL) [6], collaborative learning [7], and the use of technological resources such as gamification [8–10]. These methodologies have demonstrated positive outcomes when applied to engineering education. For instance, in the comparative study conducted by Mason et al., the use of flipped learning in engineering studies has been shown to enable broader curriculum coverage. Moreover, the students who participated in this approach achieved equal or better results in assessment tests and rapidly adapted to it, finding the flipped classroom format satisfactory and effective [11]. Additionally, collaborative learning offers evident advantages in teaching engineering project-based subjects [12]. Their findings indicate that group size is the most influential factor affecting the optimal implementation of this methodology.

Regarding Project-Based Learning (PBL), research performed in recent years also reveals significant benefits for engineering education [13]. PBL facilitates the development of technical, personal, and contextual competencies, addresses real-world professional challenges, and promotes collaborative learning [14,15]. Occasionally, depending on the type of project chosen, this methodology is referred to as Challenge-Based Learning (CBL).

It is obvious that CBL aligns well with the requirements and evolving contexts of what is referred to as Education 4.0 [16].

In the field of engineering studies, it is common to combine international cooperation among universities with the Project-Based Learning (PBL) methodology [17]. However, with the COVID-19 pandemic, these collaborations became more challenging. To develop the competencies outlined by the World Economic Forum in 2020 for Education in the Fourth Industrial Revolution, projects emerged to facilitate international cooperation experiences in a virtual way [18,19].

Due to the COVID-19 pandemic, numerous studies have analysed the benefits and issues associated with adopting online teaching in engineering programs. Many universities now offer this type of education, with the Massachusetts Institute of Technology (MIT) being the most renowned institution for widely disseminating online engineering courses [20].

In 2020, Chirikov et al. conducted a comprehensive comparative analysis of online, face-to-face, and blended education in the countries with the highest production of engineering graduates (USA, China, India, and Russia). The results can be summarised as follows: (1) Performance in objective assessment tests was clearly better in the case of online education and slightly better in the case of blended education. (2) The effective costs of studies are significantly lower in online education. (3) Student self-reported satisfaction is slightly lower in the case of online education [21].

In addition, many European students choose to participate in in-person international immersions through Erasmus programs. This offers them the opportunity to fully engage with a new culture, interact with people from various countries, and broaden their global perspective, enhancing their intercultural skills and adaptability [22]. Additionally, it enables them to complete a portion of their studies at another institution, connect with other experts in their field, expand their international network, and explore diverse educational approaches. All of this is pursued with the objective of enhancing their overall professional profile [23].

Generally, these programs are accessed by students in the final years of their degree courses. It is usually a rewarding experience that provides students with a competitive edge in an increasingly interconnected and globalised world. These programs are funded by the European Union and universities, and there is evidence of the benefits that they offer [24,25]. However, there are limited opportunities for first-year degree students to connect with international experiences that allow them to engage in collaborations from the beginning of their university education. Introducing these international collaborations will provide an enriching experience for students and facilitate the more efficient development of generic competencies in the early stages of courses.

University cooperation is essential in promoting quality education and fostering student development. Through collaboration, universities can share resources, knowledge, and best practices, working together to enhance the quality of teaching [26]. There are programs for faculty exchange, joint teaching programs, and the development of educational materials. However, these are generally focused on the later years of a degree or study programs where students temporarily study abroad. In Spain, the Royal Decree 822/28 September 2021 [27] establishes the organisation of university education and the quality assurance process. It states that Spanish universities, in partnership with international ones, can propose joint study plans leading to an official university degree at the undergraduate, master, or doctoral level. This is accomplished through the signing of an agreement that is incorporated into the documentation that needs to be verified. To comply with this decree, proposals for common teaching in this context should be made, using all the pedagogical resources that facilitate international education.

To implement innovative teaching practices effectively in multicultural and multidisciplinary international settings, it is essential to utilise technological tools and communication channels that connect institutions and students, fostering a learning platform. For instance, there are various online collaboration platforms (such as Google Drive, Dropbox, or Microsoft OneDrive), communication tools (Microsoft Teams, WhatsApp, Telegram, etc.), video conferencing and virtual meeting solutions (Zoom, Microsoft Teams, Google Meet, Cisco Webex, etc.), and online learning platforms that offer features for course management and content delivery (such as Moodle and Blackboard).

This article presents a study on the effectiveness of a PBL (Project-Based Learning) course in which students from different universities across Europe collaborate online on a joint industrial design project. The results demonstrate the effectiveness of the PBL methodology, contributing to the body of knowledge by showcasing the development of professional competencies in the students who participated in the course.

3. Educational Objectives

The profile of individuals who have graduated in Robotic Engineering is in high demand currently, and the interest in this field is expected to grow in the very near future. Graduates with this qualification fit easily into various sectors, including industry, services, and research.

This study aims to answer the following research questions:

1. Has participation in the online course "European Study of Interactive Industrial Design I" improved acquired learning by second-year students in the Robotic Engineering degree program?
2. What is the self-perception of the students who have participated in the online course regarding their acquisition of competencies?
3. Are there quantitative differences in the competencies acquired between those who have participated in the online course and those who have not?

Analysed Competencies

To achieve these objectives, this study was developed based on the competencies outlined in the Verification Report of the Degree in Robotic Engineering [28]. Those that could be affected by this research were selected from among the generic competencies of the degree and the specific competencies of the subjects "Graphic Expression" (first year) and "Robot Mechanisms and Modelling" (second year). The selected generic and specific competencies are presented below:

Selected Generic Competencies (GCs) of the Degree:

- GC1: Ability to solve engineering problems by applying knowledge of mathematics, physics, chemistry, computer science, design, mechanical, electrical, electronic, and automatic systems to establish viable solutions in the field of the degree.
- GC2: Proficiency in using computer tools for modelling, simulation, and engineering application design.
- GC3: Possessing and comprehending knowledge that enables originality in the development or application of ideas to solve novel or interdisciplinary engineering problems after analysing and understanding the specified requirements.
- GC4: Knowledge of the technological needs of society and industry and the ability to improve services and production processes by applying current robotics technology through the selection, acquisition, and implementation of robotic systems in various applications, both industrial and service-related.
- GC5: Knowing how to apply new robotic technologies to different business sectors, especially in industrial and service industries, to enhance their competitiveness.
- GC6: Computer and informational competencies.
- GC7: The ability to communicate effectively, both orally and in writing.
- GC8: Capacity for analysis and synthesis.
- GC9: Organisational and planning skills.

Selected Specific Competencies (SCs) of the Subjects:

1. "Robot Mechanisms and Modelling"
    - SC1: To be able to model and simulate aspects of kinematics, dynamics, structures, and mechanisms to design and analyse robotic systems.

- SC2: Understanding and applying the physical principles on which robotic engineering is based in engineering problems: statics, kinematics, dynamics, mechanics, thermodynamics, electromagnetism, and electrical circuits.
- SC3: Comprehending the principles of structures, machines, mechanisms, joints, and motion transmission systems, and applying them in the engineering of robotic systems.

2. "Graphic Expression"
    - SC4: Having spatial visualisation competencies and knowledge of graphical representation techniques that enable the design and interpretation of mechanical systems and electrical and electronic circuits. To be familiar with and proficient in using computer programs for designing and visualising circuit diagrams, structures, and mechanisms.

4. Research Methodology

To assess whether students from the University of Alicante (UA) who completed the "European Interactive Industrial Design Studio (EINSTUDIO)" course had improved their acquisition of the expected competencies in the program, a research methodology was designed that included both qualitative and quantitative analyses.

Qualitative Analysis

At the end of the course, a survey was designed using Google Forms to facilitate qualitative evaluation. The aim was to determine whether UA students perceived the acquisition of the previously selected competencies (generic GC1–GC9 and specific SC1–SC4). The use of a simple questionnaire was deemed appropriate, with the intention of obtaining a distribution of response frequencies using the Likert scale, ranging from 1 (completely disagree) to 5 (completely agree) for all the questions asked.

Quantitative Analysis

To assess specific competencies related to the subjects (SC1–SC4) in a quantitative manner, a written examination consisting of 10 questions was administered to quantify the level of knowledge acquisition in the design, modelling, and simulation of robotic mechanisms. This exam was taken by the 22 students who completed this course and by another 43 students who did not receive this specific training but had passed "Graphic Expression" and were currently enrolled in "Mechanisms and Robotic Modelling".

Statistical Methods Used for Data Analysis

The results were presented in the form of percentages and frequency distributions to facilitate detailed analysis. The responses of students who participated in the course were compared with those who did not, to evaluate the impact of the course on competency acquisition.

In addition, an inferential analysis is conducted to evaluate whether the observed differences between the experimental group and the control group are statistically significant. The analysis involves Student's *t*-test for independent samples. In this test, the following hypotheses are defined.

- Purpose: To determine whether there are significant differences between the means of two groups.
- Hypotheses:
    - Null Hypothesis (H_0): There are no significant differences between the means of both groups.
    - Alternative Hypothesis (Ha): There is a significant difference between the means.
- Significance Level (Alpha): 0.05.
- Results: The t-statistic value, degrees of freedom (df), and *p*-value. In the case that $p < 0.05$, the null hypothesis is rejected, indicating a significant difference between the experimental and control groups.

Preliminary Tests:

- Shapiro–Wilk Test: To check whether the grades of both groups follow a normal distribution.
- Levene's Test: To determine whether the variances of the two groups are similar.

Participant Selection

Qualitative Analysis Participants: The qualitative survey was offered to all 22 students who participated in the online course. However, it was a voluntary survey, and only 20 students responded.

Quantitative Analysis Participants: The written exam was administered to a total of 65 students, encompassing all students enrolled in the subject. This group included the 22 students who completed the course and an additional 43 students who did not receive the specific training but were enrolled in Mechanisms and Robotic Modelling.

Competencies Evaluated

The specific competencies (SC1–SC4) were broken down into learning outcomes and low-level indicators to accurately evaluate knowledge acquisition. This allowed for a detailed measurement of student learning.

Informed Consent

Before the survey, students were provided with an explanatory text about the study, assuring them of the anonymity of the information and requesting consent for the publication of results without personal identifying data. It was emphasised that participation was voluntary and that students could withdraw from the study at any time without negative consequences.

Online Course Methodology

Three European universities collaborated on this project: the University of Alicante (UA, Spain), the Universidade da Beira Interior (UBI, Portugal), and Gazi University (GU, Turkey). An online platform was created to facilitate the exchange of ideas.

The working groups developed innovative design solutions for the course challenges, focusing on the collaborative design of the interior furniture of a shipping container. In the initial phase, all group members participated in defining the conceptual designs. Subsequently, the students from GU and UBI focused on the formal aspects of industrial design, determining color schemes, textures, and ergonomics. Meanwhile, UA students contributed their expertise in the implementation and design of mechanisms. They worked concurrently and in parallel to optimise the design process.

At UA, this project was conducted through a specific online course titled "European Study of Interactive Industrial Design I". The course had three recognised European Credit Transfer and Accumulation System (ECTS) and was conducted via the Moodle platform specially created for this purpose. Additionally, contact and collaborative work with international teams took place online through virtual collaboration platforms, specifically, https://europeandesignstudio.com, accessed on 26 November 2024. This enabled them to exchange ideas and cooperate effectively despite being in different countries.

This course was undertaken by a group of 22 students from the University of Alicante who had previously completed the "Graphic Expression" course. Concurrently, they were enrolled in the "Robot Mechanisms and Modelling" course, a second-year subject on the Robotic Engineering degree program. Currently, the educational methodology of this subject combines lectures, laboratory and computer practical sessions, oral presentations of results, and the resolution of exercises and experiments.

The online course's main objective was to educate students about the European culture of virtual and blended (hybrid) industrial design studies. It considered and integrated various technological and pedagogical aspects that aligned with the outcomes of practices in physical-world design culture. One of the course's goals was to establish a valid industrial design study suitable for collaborative work in Europe, with a holistic approach that incorporated active learning. To achieve this, specific training for UA students included the use of tools and materials related to virtual mechanisms, laboratories, and production methods, allowing them to develop industrial designs focused on sustainability and inclusive design for a wide range of users.

The instructors proposed five projects based on the design and interior fitting of a 20-foot container for the following areas:

1. Modular emergency ward.
2. Humanitarian shelter: emergency housing modules.
3. Modular coworking station.
4. Scientific exploration for remote geographical areas.
5. Modular eco-tourism hotels.

In these projects, the available space was limited, making articulated and extendable mechanisms essential to space optimisation. The main contribution of UA students focused on providing technical solutions for the robotic mechanisms proposed in each of the projects.

A total of 88 students participated in the online course, divided into 11 groups of 8 students. These transnational groups worked collaboratively to solve the proposed design problem. Each group included two Robotic Engineering students from the University of Alicante (UA) and six Industrial Design students, with three from the Universidade da Beira Interior (UBI) and three from the Gazi University (GU). In total, 33 students from UBI and 33 students from GU participated. Each university selected their students following their own methodology.

It was perceived that there was a high level of engagement among the students. This was partly due to the exciting multicultural and multidisciplinary experience and partly because this activity was assessed as a subject within their undergraduate studies.

This online course took place during the second academic semester of the 2022–2023 academic year. The course spanned 15 weeks, as outlined in Table 1. Group project progress was monitored weekly through online sessions, where the groups presented their work updates. Simultaneously, tutors provided support to UA students using the Moodle platform and held specific Meet meetings to guide the work within each group. The educational materials provided to the students who participated in this project and to the students who did not participate were equivalent in terms of educational level. Table 1 illustrates the plan that was executed in the course described for UA students.

Table 1. Weekly course schedule.

Week	Evaluation	Objective
1	Objectives, program	Selection of functionalities to be achieved in the specific chosen minimum space
2	Industrial design research	Study of existing solutions to the additional functionality. Analysis of similar mechanisms
3–4	Concept design	Benefits of the new functionality. Basic sketches of the mechanism
5	First evaluation	Concept design presentation: articulated/actuated concept and technical solutions
6–8	Concept design	Identifying mechanism shapes, materials, and structural solutions. Parametric modelling. Joints, unions, and constraints
9	Second evaluation	Articulated/actuated concept: parametric models; justification, demonstration of structural solutions, mechanism operation, and integration into the model
10–14	Design implementation	Functionality and dimensions (materials and structural solutions, kinematic analysis of the mechanism, dynamic requirements)
15	Final evaluation	Presentation and video with simulation of the mechanical model

To assess whether UA students who completed this course had improved their acquisition of the expected competencies in the program, a research methodology was proposed

(Section 3) that included both qualitative and quantitative analyses to evaluate the expected impact.

5. Competence Analysis

5.1. Qualitative Analysis

Table 2 shows the questions asked in questionnaire 1 and the competencies related to each of them. Each question is designed to evaluate a specific competency, whether generic (GC1–GC9) or specific (SC1–SC4), and the responses are collected using a Likert scale ranging from 1 (completely disagree) to 5 (completely agree).

Table 2. Questions asked in questionnaire 1 and their related generic and specific competencies.

Num.	Compet.	Question
1	GC1	Do you believe that this experience has helped you enhance your ability to solve engineering problems by applying knowledge of design and mechanical systems?
2	GC2	Do you think this experience has helped you increase your proficiency with computer tools for modelling and simulation?
3	GC3	Do you believe that this experience has helped you acquire some of the knowledge that enables you to be original in solving novel or multidisciplinary engineering problems?
4	GC4	Has the project presented to you helped you understand some of the technological needs of society and industry where solutions based on mechanism technology could apply?
5	GC5	Have you learned to apply new mechanical or robotic technologies to industrial business sectors (such as the furniture industry) to enhance their competitiveness?
6	GC6	Have you been able to adapt to the online learning platform created for the project?
7	GC6	With this experience, do you believe you have developed, at least in part, the ability to gather and share information with other groups or sectors?
8	GC7	Do you think you have improved your oral and written communication skills to express ideas and contribute to solutions in the project you have participated in?
9	GC8	Do you believe you have enhanced your ability to analyse and synthesise when presenting the work you have carried out?
10	GC9	Has this course contributed to improving your organisational and planning skills to address project execution?
11	SC1	Do you believe you have acquired knowledge to model and simulate structures and mechanisms to design and analyse robotic systems?
12	SC2	Has this activity helped you understand and apply the physical fundamentals of statics, kinematics, dynamics and mechanics to a real engineering problem?
13	SC3	With the final design proposed, do you believe you have improved your knowledge of the functioning and applications of mechanisms, joints and motion transmission systems?
14	SC4	Has this activity improved your skills in graphical representation and spatial vision as a means of communication to propose design solutions (2D, 3D, sketches)?
15	SC4	Has this activity improved your proficiency in using design and visualisation software for structures and mechanisms?

Given the complexity of assessing competencies GC6 and SC4 in a single question, it was necessary to propose two questions for each of them. Subsequently, the obtained result was averaged to accurately score the acquisition level of these competencies according to the Likert scale.

5.2. Quantitative Analysis

To assess specific competencies related to the subjects (SC1–SC4) in a quantitative manner, a written examination consisting of 10 questions was administered to quantify the level of knowledge acquisition in the design, modelling, and simulation of robotic mechanisms.

This test was taken by the 22 students who had completed this course and by another 43 students who did not receive this specific training but had similarly passed "Graphic Expression" and were currently enrolled in "Mechanisms and Robotic Modelling". To assess specific competencies accurately, the specific competencies were broken down into learning outcomes and a set of low-level indicators to assess whether the study was meaningful and measured student learning at a low level. Below are the learning outcomes and low-level indicators for each of the specific competencies:

SC1: To be able to model and simulate aspects of kinematics, dynamics, structures, and mechanisms to design and analyse robotic systems.

Learning Outcome: The student will be able to obtain a model of a robotic mechanism to simulate its kinematics and dynamics.

Low-level indicators:

- SC1-Ind1: The student identifies the mechanism and poses the constraints of the model.
- SC1-Ind2: The student knows how to model the mechanism for kinematic and dynamic simulation.
- SC1-Ind3: The student simulates the mechanism and analyses the kinematic and dynamic variables of the model.

SC2: Understanding and applying the physical principles on which robotic engineering is based in engineering problems: statics, kinematics, dynamics, mechanics, thermodynamics, electromagnetism, and electrical circuits.

Learning Outcome: the student will be able to apply the physical fundamentals necessary to analyse the kinematics and dynamics of the mechanism.

Low-Level Indicators:

- SC2-Ind1: The student analyses the mechanism to apply the necessary physical equations.
- SC2-Ind2: The student applies the necessary physical equations to model the kinematics and dynamics.

SC3: Comprehending the principles of structures, machines, mechanisms, joints, and motion transmission systems and applying them in the engineering of robotic systems.

Learning Outcome: The student will be able to understand the joints, constraints, and articulations of the mechanism to analyse its movement.

Low-Level Indicators:

- SC3—Ind1: The student correctly identifies the joints, constraints, and articulations of the mechanism.
- SC3—Ind2: The student correctly analyses the movement of the mechanism.

SC4: Having spatial visualisation competencies and knowledge of graphical representation techniques that enable the design and interpretation of mechanical systems and electrical and electronic circuits. To be familiar with and proficient in using computer programs for designing and visualising circuit diagrams, structures, and mechanisms.

Learning Outcome: The student will be able to represent the mechanism/object by means of plan, elevation, and profile views.

Low-Level Indicators:

- SC4-Ind1: The student three-dimensionally analyses the mechanism/object in order to be able to represent it by means of the necessary views.
- SC4-Ind2: The student draws correctly dimensioned views of the mechanism/object.

The test was divided into 10 questions to assess all low-level indicators. This document can be found in Data Availabilty Statement, where the specific competencies to be evaluated are specified for each question, along with the low-level indicators. It can be seen in the document that each question evaluates some specific competencies and low-level indicators.

The objective test was completed by a total of 65 students, which allowed the comparison of the results between those who had participated in the online collaborative project on industrial design and those who did not participate (see Section 5).

6. Results and Discussion

6.1. Qualitative Assessment

Table 3 illustrates the frequency distribution of responses to Questionnaire 1, associated with the perception of acquiring generic competencies (questions 1–10, Table 2). Table 3 shows that a very significant portion of the responses is centered around Value 4 on a Likert scale ranging from "strongly disagree" to "strongly agree". This indicates that a large majority of the students agree that they have acquired the selected general competencies (GC1–GC9) through this experience.

Table 3. Sum of the total percentage of responses on the qualitative analysis of generic competencies.

Gen. Comp./Likert Scale	GC1	GC2	GC3	GC4	GC5	GC6	GC7	GC8	GC9	Average
1	0%	0%	0%	5%	5%	5%	0%	0%	0%	2%
2	5%	5%	20%	0%	10%	15%	10%	10%	0%	8%
3	20%	0%	15%	25%	25%	30%	20%	30%	10%	19%
4	50%	65%	45%	50%	30%	25%	45%	35%	70%	46%
5	25%	30%	20%	20%	30%	25%	25%	25%	20%	24%

The results of Questionnaire 1 show the percentage of students who responded to each of the questions posed in Table 2, indicating their level of agreement on a Likert scale. In detail, the results are as follows:

- Level 1 (Strongly disagree): Most competencies did not receive responses at this level, with an average of 2%.
- Level 2: An average of 8% of the students selected this level, with GC3 reaching 20%.
- Level 3: This level had an average of 19%, with GC6 and GC8 reaching 30%.
- Level 4: Most responses were concentrated at this level, with an average of 46%. GC9 stood out with 70%.
- Level 5 (Strongly agree): An average of 24% of the students selected this level, with GC2 reaching 30%.

Looking at the overall average shown in the right column of Table 3, it can be observed that 70% of the students (46% + 24%) rate the degree of perception in which the mentioned generic competencies have been acquired as 4 or 5. This means that a significant portion of the students agree or strongly agree that the course has allowed them to improve overall in these competencies.

The impact on the level of acquisition has been particularly significant in GC2 and GC9. In these competencies, the sum of the samples that rated between 4 and 5 is between 90 and 95%. These competencies are related to the ability to use computer tools for modelling, simulation, and design, and, on the other hand, the skills to plan and organise.

Additionally, the competencies with lower positive ratings were GC5, GC6, and GC8, with a sample value ranging between 4 and 5, oscillating between 50 and 60%. These competencies are related to knowing how to apply new robotics technologies to different business sectors, computer and informational competencies, and the ability for analysis and synthesis. It is very likely that this rating is due to students having already acquired, at least initially, these skills in subjects prior to this course. In any case, the impact on the students is considered very positive. For the analysis of the impact on GC6, two questions were used, questions 6 and 7, which have been averaged in the results to standardise the content.

Table 4 shows that a very significant portion of the responses is located on the right side, around values 4 and 5. It can be deduced that a significant proportion of the student body agrees or strongly agrees that the specific competencies selected (SC1–SC4) have been achieved. Furthermore, Table 4 presents the results in percentage form, enabling a more precise analysis.

Table 4. Sum of the total percentage of responses on the qualitative analysis of specific competencies.

Specific Competencies/Likert Scale	SC1	SC2	SC3	SC4	Average
1	5%	10%	5%	0%	5%
2	5%	0%	0%	5%	3%
3	15%	25%	5%	5%	13%
4	35%	45%	55%	40%	44%
5	40%	20%	35%	50%	36%

The results show that 80% (44% + 36%) of the students responded with a score of 4 or higher to the questions evaluating specific competencies. The competencies that received the highest ratings are SC3 and SC4. In these competencies, 90% of the students assessed them as agreeing or strongly agreeing. The first one (SC3) corresponds to the subject of mechanisms and robot modelling and specifically refers to the response to the question "With the final design proposed, do you consider that you have improved your knowledge of the operation and applications of mechanisms, joints and motion transmission systems?" The second one (SC4) corresponds to "Graphic Expression" and pertains to the improvement in spatial visualisation skills and knowledge of graphic representation techniques, enabling the design and interpretation of mechanical system blueprints, as well as familiarity with and the ability to use design software.

To determine the results related to competence SC4, two questions, 14 and 15, were asked and their response values were averaged to standardise the results shown. Regarding SC1, 75% of the students answered positively ($\geq$4). This competence is specific to the subject "Robot Mechanisms and Modelling", and we asked the question "Do you think you have acquired knowledge to model and simulate structures and mechanisms to design and analyse robotic systems?".

Finally, SC2 is the one that generally received a lower percentage of ratings between 4 and 5, reaching 65%. This competence relates to the question "Has this activity helped you understand and apply the physical fundamentals of statics, kinematics, dynamics and mechanics to a real engineering problem?"

Therefore, it can be deduced that students' perception of the degree of acquisition of both generic and specific competencies through this project is very satisfactory.

These results suggest that, although the course has been effective in improving most competencies, there are specific areas that could benefit from a more intensive approach or additional teaching methods. Future research could explore these areas in greater detail and consider adjustments to the curriculum to address these competencies more effectively.

6.2. Quantitative Assessment

Figure 1 presents the average score for each of the questions in the test that the two study groups took part in. A total of 65 students participated in the examination, and 22 of them completed the course under study.

The main results of the study show that the overall average grade for students who took the course was 77.2%, compared to 37.7% for those who did not receive the training. This indicates a significant improvement in the performance of students who participated in the course. Regarding differences in specific questions, the question with the smallest difference in score was C7, with an 18% difference, while the question with the largest difference was C4, with a 68% difference.

The results of the inferential analysis between the experimental group and the control group are shown in Table 5.

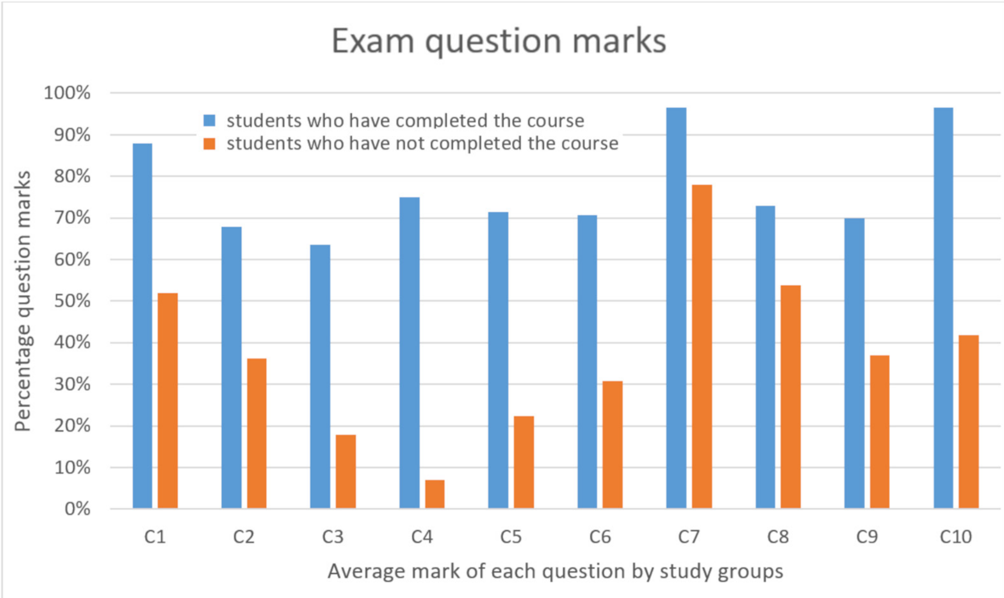

Figure 1. Percentage of student responses in the examination. Frequency test questions 1–10.

Table 5. Inferential analysis between the experimental group and the control group.

	Online Course		Control
Shapiro–Wilk test			
W-stat	0.9481		0.9566
p-value	0.29		0.105
Alpha	0.05		0.05
Normal	Yes		Yes
Levene's test			
F-test		0.1619 0.9566	
Alpha		0.05 0.05	
Variance Homogeneity		Yes Yes	
Student's *t*-test			
Mean	0.772		0.377
Count	22		43
Variance	0.178		0.315
Alpha		0.05 0.05	
t-stat		9.2042	
df		63	
p-value		1.43×10^{-13}	

Based on the data provided in Table 5, the following conclusions can be drawn. Shapiro–Wilk Test:

- W-stat: 0.9481 (online course) and 0.9566 (control).
- *p*-value: 0.29 (online course) and 0.105 (control).
- Conclusion: Since the *p*-values are greater than the significance level (alpha = 0.05), the null hypothesis of normality is not rejected. Therefore, the grades of both groups follow a normal distribution.

Levene's Test:

- F-test: 0.1619.

- Conclusion: Since the F-test is greater than the significance level (alpha = 0.05), the null hypothesis of homogeneity of variances is not rejected. Therefore, the variances of the two groups are similar.

  Student's *t*-test for Independent Samples:
- Means: 0.772 (online course) and 0.377 (control).
- Variances: 0.178 (online course) and 0.315 (control).
- t-stat: 9.2042.
- df: 63.
- *p*-value: 1.43×10^{-13}.
- Conclusion: Since the *p*-value is much less than the significance level (alpha = 0.05), the null hypothesis is rejected. This indicates that there is a significant difference between the means of the experimental group (online course) and the control group.

In summary, the inferential analyses show that the grades of the group that took the online course are significantly higher than those of the control group, suggesting that the online course had a significant positive impact on the participants' grades.

In addition, a study of low-level indicators was conducted to assess whether the PBL course helped students meet the learning outcomes associated with specific competencies.

Figure 2 summarises the differences between the questionnaire scores obtained in the study of the low-level indicators analysed. These data are represented in box-and-whisker plots of each low-level indicator.

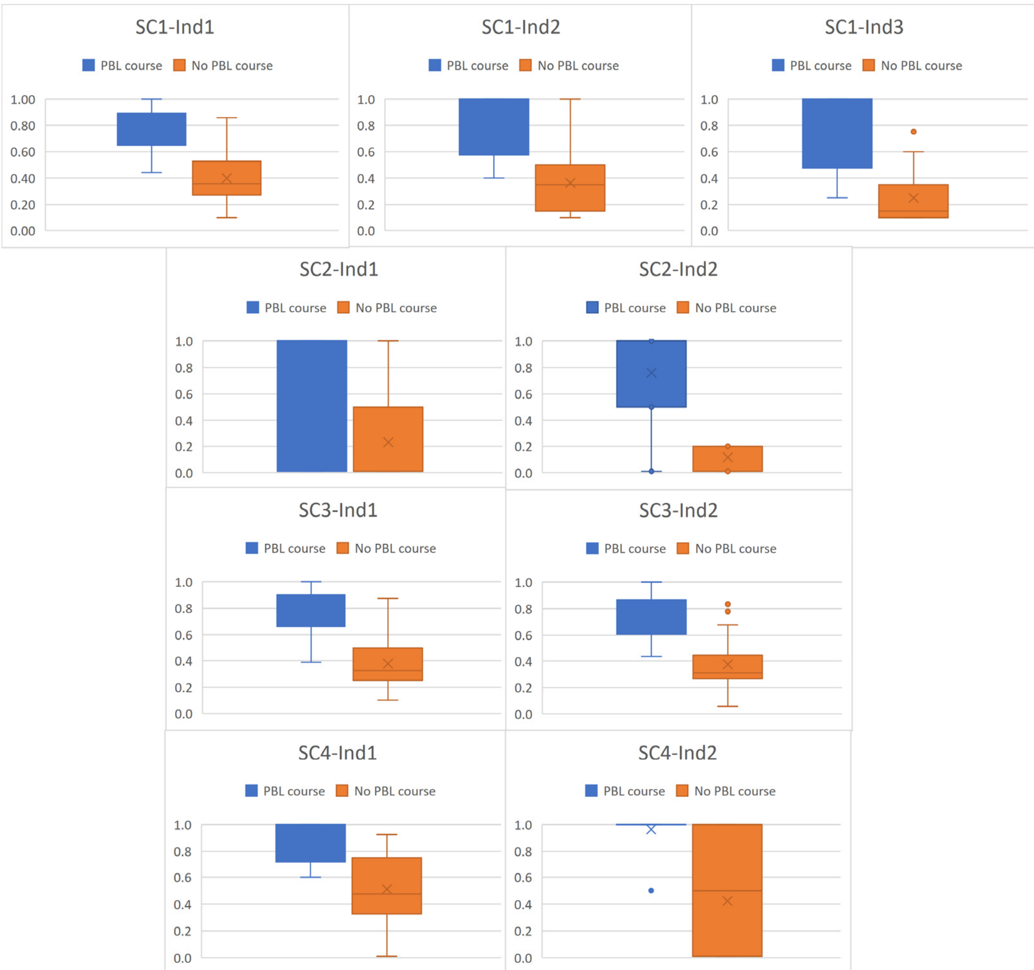

Figure 2. Percentage of student responses in the examination. Frequency test questions 1–10.

As shown in Figure 2, the mean of the scores obtained by the students who completed the PBL course is higher than that for the other students in all the low-level indicators. In addition, Table 6 shows in detail the mean and standard deviation for each low-level indicator.

Table 6. Low-level indicators employed for quantitative analysis.

Low-Level Indicator	PBL Course (Yes/Not)	Mean	Standard Dev.
SC1—Ind1	Yes Not	0.74 0.31	0.17 0.18
SC1—Ind2	Yes Not	0.73 0.29	0.21 0.24
SC1—Ind3	Yes Not	0.73 0.34	0.19 0.18
SC2—Ind1	Yes Not	0.27 0.04	0.45 0.35
SC2—Ind2	Yes Not	0.45 0.11	0.38 0.09
SC3—Ind1	Yes Not	0.73 0.34	0.19 0.18
SC3—Ind2	Yes Not	0.73 0.33	0.17 0.17
SC4—Ind1	Yes Not	0.83 0.43	0.15 0.24
SC4—Ind2	Yes Not	0.95 0.12	0.13 0.4

This analysis shows that the average scores obtained by students who took the PBL course were higher in all low-level indicators compared to students who did not take the course. As illustrated in Figure 3, the average final grade in the subject "Mechanisms and Robot Modelling" showed a 22% difference in favor of the students who took the PBL course.

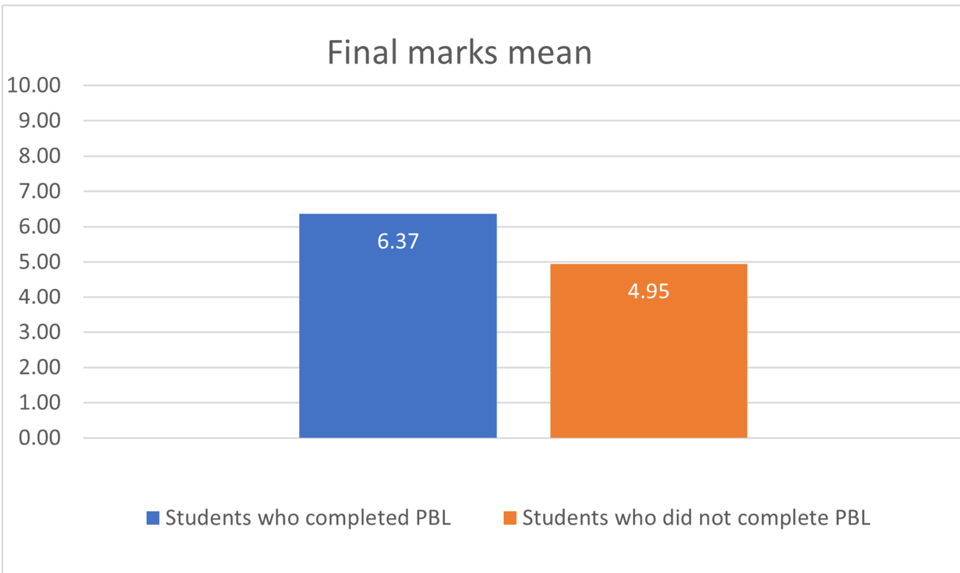

Figure 3. Comparison of the average final grade (over 10) in the course between students with and without PBL.

It is important to note that the final grade for this subject is determined based on the aforementioned score and other assessed activities that contribute to the overall final grade.

The critical analysis of the results indicates that the PBL course had a significant positive impact on students' academic performance. The improvement in average grades and low-level indicators suggests that students who participated in the course better acquired specific competencies. However, it is important to consider several factors when interpreting these results. Although 65 students participated in the exam, only 22 completed the course under study, which could affect the generalisability of the results.

6.3. Limitations of the Study

It is important to note several limitations of this study. The quasi-experimental design and the specific characteristics of the participating university and program may limit the generalisability of the findings. The sample size, while sufficient for initial insights, may not be representative of all student populations. The effectiveness of the PBL course may vary depending on the implementation and the instructor, and differences in teaching methodology among instructors were not evaluated. Additionally, external factors that could have influenced student performance, such as access to additional resources, time spent studying outside of class, and external academic support, were not controlled. The evaluation focused on low-level indicators and final grades. In conclusion, although the results are promising and suggest that the PBL course improves academic performance, additional studies with larger samples and more rigorous control of external variables are needed to confirm these findings.

7. Conclusions

This article examines the impact of the Project-Based Learning methodology, within an international work environment, on the enhancement of generic and specific competencies in two undergraduate courses of the Robotic Engineering program. The project involved designing and adapting the interior of a modular container for various purposes focused on social assistance and environmental integration. The project was conducted through an online course that used virtual communication platforms.

Nine generic competencies from the program, three specific competencies from "Robot Mechanisms and Modelling", and one specific competency from "Graphic Expression" were selected for assessment.

Upon completion of the project, a questionnaire was provided to assess students' perceptions regarding their acquisition of competencies. The results indicate that this innovative learning experience was positively perceived by students in terms of enhancing both generic and specific competencies. Regarding generic competencies, 80% of the students agreed or strongly agreed that the experience helped them improve these skills. The two most highly valued generic competencies were the ability to use computer tools for engineering modelling, simulation, and design (GC2), and organisational and planning skills (GC9), with 95% and 90% of students rating them positively or very positively, respectively. Six out of nine generic competencies received a positive or very positive rating of 70% or higher.

Concerning specific competencies in "Robot Mechanisms and Modelling", students showed improved ratings for SC3, where 90% of students rated it as a 4 or 5 on the Likert scale. In "Graphic Expression", the specific competency analysed also had a high percentage of students (90%) agreeing or strongly agreeing.

The exam allowed for the demonstration of differences in the level of competency acquisition on a quantitative basis. At the level of low-level indicators for each of the analysed competencies, there is a clear difference between the students who completed the course and those who did not. This indicates that the former have a higher acquisition of the analysed competencies and, consequently, greater learning in the "Robot Mechanisms and Modelling" course, as evidenced by the higher final grades that they obtained in the course.

The results presented in this article align with the conclusions of other extensive studies based on the PBL methodology [29]. The cited study suggests delving deeper into pillars such as "multidisciplinarity" and "technology", highlighting the acquisition of competencies in these areas through this methodology. It can be inferred that these aspects have been addressed and evaluated in the present study.

In conclusion, while this PBL course and internationally orientated experience significantly improved all the studied competencies, these results should be interpreted with caution due to the aforementioned limitations. The quasi-experimental design and the specific characteristics of the participating university and program may limit the generalisability of the findings. The sample size, while sufficient for initial insights, may not be representative of all student populations. The effectiveness of the PBL course may vary depending on the implementation and the instructor, and differences in teaching methodologies among instructors were not evaluated. Additionally, external factors that could have influenced student performance, such as access to additional resources, time spent studying outside of class, and external academic support, were not controlled. The evaluation focused on low-level indicators and final grades. Future research should aim to replicate this study in different contexts and with larger sample sizes to validate and extend these findings. Despite these limitations, the positive results suggest that this methodology can be further developed and potentially applied in other educational settings.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw/processed data required to reproduce statistical analysis has been shared in Mendeley Data [30]: https://doi.org/10.1016/J.PSCR.2014.08.018.

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