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# Inspiring engineering education: Service learning in manufacturing projects for ecological entities

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GQ1

## GQ2 Abstract

GQ4 This study explores the educational and practical impacts of a service-learning project,  
GQ5 focusing on the collaboration between a university and vocational training schools. The  
AQ2 project aimed to develop various initiatives related to ecological entities with focus on  
an innovative prototype for controlling invasive aquatic turtles, addressing need of and eco-  
logical entity from xxx blinded xxx region. Using the CDIO (Conceive, Design, Implement,  
Operate) educational framework, students applied theoretical engineering concepts in a  
hands-on, real-world context, fostering strong interdisciplinary collaboration between  
the academic institutions and the ecological entity requesting the prototype. The research  
question that guided this work was: How can a service-learning project, integrating the  
CDIO educational framework, enhance students' academic learning, interdisciplinary col-  
laboration, and civic responsibility while addressing real-world ecological challenges. The  
methodology employed was based on the analysis of CDIO educational framework in a  
service-learning project. For this analysis, we analyzed the information interchanged  
between university and vocational training school students, the integration of the

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Data Availability Statement included at the end of the article

social entity needs into the projects, the students' reflection on engaging in service-learning with the social organization and the vocational training school and the results of a student's survey. This project is part of the mechanical engineering degree program at xxx (blinded) xxx during the third academic year. The research instruments were projects and reflections analysis as well as student's survey. The project demonstrated how service-learning can enrich students' academic experience, with improvements in faculty and external support over time. The aquatic turtle control prototype was designed and manufactured according to client expectations, and the students' involvement highlighted the societal impact of engineering solutions aimed at environmental conservation. This study also illustrates how integrating service-learning with the CDIO framework enhances both academic learning and civic responsibility, demonstrating the potential of such projects to produce socially responsible engineers capable of addressing real-world problems.

### **Keywords**

Service learning, mechanical engineering, manufacturing, ecological entities, vocational school, university

## **Introduction**

Service-learning is a course-based, credit-bearing educational experience in which students participate in organized service activities that address identified community needs. Additionally, students reflect on these activities to gain a deeper understanding of course content, a broader appreciation of their discipline, and an enhanced sense of personal values and civic responsibility<sup>1</sup>

Compared to other interactive and experiential-based learning approaches, such as project-based learning or problem-based learning, service learning stands out for its direct engagement with community issues and its integration of service as a core component of the educational experience. While project-based learning often revolves around completing a project to demonstrate mastery of academic content, and problem-based learning centers on solving complex problems,<sup>2</sup> service learning goes a step further by emphasizing the importance of social responsibility and civic engagement.

The implementation of service-learning in engineering education, particularly within mechanical engineering programs, addresses several key educational outcomes. These include the ability to function on multidisciplinary teams, an understanding of professional and ethical responsibility, effective communication skills, and a recognition of the impact of engineering solutions in a global and societal context.<sup>3</sup> Moreover, service-learning encourages lifelong learning and provides knowledge of contemporary issues.<sup>4</sup>

This projects not only stands out for the implementation of service learning but is also made possible through collaboration with several vocational schools. As noted by Zeman and Hrad,<sup>5</sup> collaboration between a technical university and a vocational school enhances pedagogy and the joint development of technical laboratories. This partnership improves

educational quality and motivates students by providing access to advanced equipment and facilitating ongoing knowledge exchange between institutions.

The implementation of a methodology promoted by the international CDIO initiative is a key highlight of this projects. The Conceive-Design-Implement-Operate (CDIO) methodology<sup>6</sup> emphasizes hands-on, project-based learning and is structured around four key stages: Conceive: Identifying needs and defining project objectives; Design: Developing detailed plans and specifications; Implement: Building and testing the solution; Operate: Deploying the solution in a real-world context. CDIO enhances students' ability to develop engineering solutions through iterative design and implementation processes. When combined with service-learning, CDIO projects gain additional depth as students not only design and implement solutions but also engage with community, thereby ensuring that their projects address genuine needs and have a tangible impact.

The CDIO framework emphasizes integrating engineering fundamentals with practical experiences in real-world contexts, fostering skills for conceiving, designing, implementing, and operating systems and products. It is designed to be adaptable across institutions and disciplines, supporting outcome-based education. Examples of its successful implementation include its integration into curricula for aerospace, electrical, and mechanical engineering programs worldwide, which has significantly improved students' technical and professional competencies.<sup>6</sup> Additionally, CDIO Standards, updated to version 3.0, provide a comprehensive structure to guide institutions in curriculum design and teaching practices. These standards emphasize interdisciplinary learning, hands-on workspaces, and sustainable development. However, challenges such as resource allocation for specialized engineering workspaces and adapting CDIO to diverse educational contexts have been documented. By addressing these issues, this research aims to contribute to refining CDIO's application in collaborative environments, particularly with vocational education partners. This project is part of the mechanical engineering degree program at xxx (blinded) xxx during the third academic year. Within this program, the project is linked to the 3-ECTS course "Manufacturing" and the complementary "Manufacturing Laboratory" course, also 3 ECTS. These courses provide students with a deeper understanding of manufacturing processes and their limitations, equipping them with practical skills to apply to their projects. It's worth noting that these subjects integrate both theoretical content and the practical execution of the project in a coordinated manner. This methodology has been developed since the academic year 2017–2018. However, this paper will focus on showcasing one of the projects carried out during the 2022–2023 academic year. The project involved a total of 60 students, aged between 20 and 24, with a gender distribution of 12% female and 78% male.

Participation in the project was voluntary, and students were informed about the opportunity during an introductory briefing at the start of the semester. If students did not want to participate in the project they had to do a manufacturing project without service-learning activities. However, since the manufacturing project is challenging and with service-learning the vocational training school gives support and also students like the motivation to create a project for a social entity provides, 100% opted to participate in the project in service-learning modality. For those who did not volunteer, (even all students participated) the alternative assignments aligned with the course's learning

objectives were explained, ensuring that all students had an opportunity to meet the academic requirements of the manufacturing course. This approach ensured inclusivity while allowing interested students to engage deeply with the service-learning initiative.

In this work, we present an example of a student group that developed a prototype specifically designed for controlling invasive aquatic turtles (*Trachemys scripta*) that are affecting the local ecosystem. This prototype was created in collaboration with an ecological association xxx (blinded) xxx.

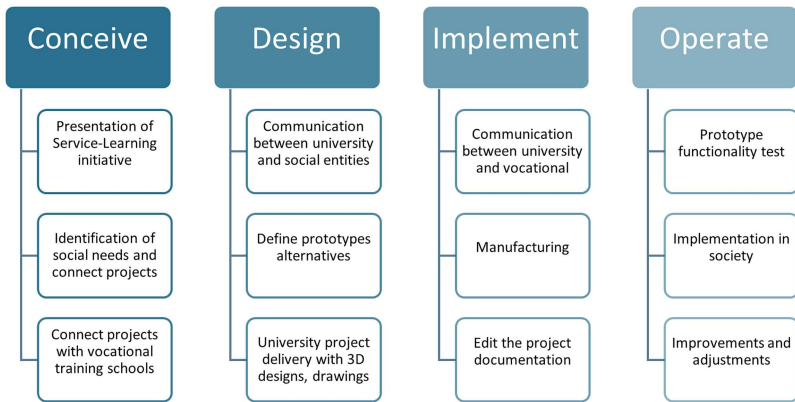
xxx (blinded) xxx is a non-profit organization dedicated to the study and protection of Catalan ecosystems. Its main objective is the conservation of biodiversity and the promotion of sustainable practices in environmental management.

The Florida turtle, known as *Trachemys scripta* (Ministerio de transición ecológica, 2024), has become one of the most widespread invasive exotic species in Spain, displacing native species like the European pond turtle and posing a health risk due to salmonella transmission. Popular as a pet in the 80 s and 90 s, these turtles grow significantly, and many were released into the wild, causing an invasion. This species competes aggressively with native turtles for sunlight and food resources, and its superior reproductive capacity makes it more competitive. Although their commercialization is now prohibited, many remain in Spanish homes, requiring awareness to prevent their release. There are shelters for these turtles, and eradication campaigns are conducted to protect native fauna.<sup>7,8</sup>

## Methodology

The project was structured around two distinct groups of students: one group from a vocational school and the other from the Mechanical Engineering degree program. The vocational school students contributed their practical expertise, focusing on the hands-on aspects of manufacturing, such as operating machinery and optimizing workshop processes. Meanwhile, the Mechanical Engineering students brought a strong theoretical foundation, working on design, calculations, and the application of engineering principles. This collaboration between the two groups created a dynamic learning environment, where practical and theoretical knowledge merged to achieve the project's goals efficiently and effectively.

At the university, the project was integrated into two courses, each running over a 15-week period, with a total of 7 h per week, 4 h dedicated to theoretical lectures and 3 h to laboratory sessions. During the theoretical lectures, all students attended in a single group, whereas the laboratory activities were conducted in smaller, divided groups to encourage hands-on learning. The theoretical classes covered essential concepts related to manufacturing processes, including part fabrication, geometric verification, tolerances and fits, as well as the identification of necessary machines, tools, and fixtures. Students also studied calculations for various forming processes, computer numerical control (CNC), and welding techniques. In parallel, the laboratory sessions allowed students to apply these theoretical concepts in a practical setting, reinforcing active learning through real-world exercises. The project grade accounts for 30% of the final grade in one of the two courses.



**AQ6 Figure 1.** Project phases related to the principles of the CDIO initiative.

Students from vocational schools participate in this project, known as the ‘synthesis project,’ which is a global, integrative task completed during the final year of vocational training in xxx blinded xxx. This project combines the knowledge and skills acquired throughout the course and evaluates the students’ ability to apply them in a practical, often interdisciplinary, manner. The project involves 264 h of work, of which 165 h are spent in the workshop manufacturing parts and creating a prototype.

As previously mentioned, the project follows the CDIO (Conceive, Design, Implement, Operate) framework, a project-based learning approach that fosters problem-solving skills by guiding students through the design and development of real-world solutions that address societal needs. In this work, we present a particular example where students developed an aquatic turtle control prototype aimed at addressing environmental issues caused by invasive species. The project began with a “Conceive” phase, where students selected the problem and collaborated with a vocational training school for its development. They then moved through the “Design” and “Implement” stages, optimizing the prototype through iterative design processes and hands-on manufacturing. Finally, in the “Operate” phase, the prototype was tested in real-world conditions, demonstrating the practical application of the theoretical knowledge acquired in the course. Figure 1 illustrates how project phases relate to the principles of the CDIO initiative.

The 15-week manufacturing course incorporated the CDIO framework to provide a practical, hands-on learning experience while covering essential topics in manufacturing.

### 1. Conceive (Weeks 1–3)

The course began with the **presentation of the service-learning initiative**, focusing on solving ecological challenges such as controlling invasive aquatic turtles. During this phase:

- **Students identified social needs** by collaborating with a local ecological association (blinded for confidentiality).
- Projects were connected to vocational training schools to foster interdisciplinary teamwork.

This stage included discussions on **metrology and verification**, where students were introduced to precision measuring tools and verification techniques essential for prototype development.

## 2. Design (Weeks 4–7)

The design phase emphasized collaboration between universities and social entities to create **prototype alternatives**:

- Students developed **3D designs**, technical drawings, and process sheets to ensure precise manufacturing.
- This stage integrated **ISO tolerance systems** to guide tolerances, adjustments, and surface roughness standards in the prototypes.
- Students applied their learning on **machining, CNC turning, and sheetmetal processes** to select the best processes for their project to be applied to the prototype.
- **Welding techniques and threaded joints**, were applied to assemble components of the prototype.

## 3. Implement (Weeks 8–12)

Students transitioned to the implementation phase, where:

- **Communication between universities and vocational schools** facilitated knowledge sharing during the prototype's manufacturing process.

This phase required students to document the project, which included metrology-based verification of the manufactured parts and machining time calculations.

## 4. Operate (Weeks 13–15)

Finally, the prototype was tested and refined during the operation phase:

- **Functionality tests** ensured alignment with ecological objectives, connecting back to the service-learning focus.
- Students incorporated improvements based on feedback.
- The final implementation addressed real-world ecological needs, preparing students for **societal integration of engineering solutions**.

### *Educational outcomes*

Throughout the course, students developed technical skills while engaging in interdisciplinary teamwork and addressing civic responsibilities. The CDIO approach allowed them to see the direct impact of their work on ecological challenges, enhancing their learning experience and professional readiness.

Finally, to evaluate the project, a survey was conducted to gather students' perceptions. The survey aimed to achieve three main objectives:

- To understand students' perception of the tasks completed.
- To assess students' views on their interactions with faculty and the vocational school.
- To gauge students' overall evaluation of the Service-Learning (SL) experience.

The survey consisted of six questions, where participants rated their responses on a scale from 1 to 10, with 1 representing "completely disagree" and 10 representing "completely agree." The six questions were as follows:

- Q1. I have carried out the proposed tasks.
- Q2. The performed tasks have had a direct relationship with my academic training.
- Q3. I have put into practice the knowledge acquired previously at the University.
- Q4. The SL experience has been a formative complement.
- Q5. I have received information, guidance, and support from the university faculty.
- Q6. I have received supervision and support from the external organization in the development of tasks.

Additionally, a general assessment question was included, also rated on a scale from 1 to 10.

Apart from the general survey carried out to all students, the group that participate in the aquatic turtle control prototype were asked to answer more specific questions related to CDIO methodology. Table 1 shows the statements of the survey. The objective of this survey was to evaluate if the methodology was aligned with the CDIO Initiative and detect improvements to be done in future editions.

## **Results**

This study presents the design and construction of an innovative aquatic turtle control prototype as a specific example to illustrate the methodology in practice. The project demonstrates the application of theoretical concepts at each stage, from initial project formalization to final operation. This example highlights how academic theory can be effectively translated into a practical, real-world solution that addresses a societal need, reinforcing the impact of the project and showcasing its contribution to environmental conservation efforts.

**Table 1.** Statements used in a students survey an its relationship to CDIO syllabus.

CDIO Syllabus 3.0	Statements
1. Fundamental knowledge and reasoning	S1- This project allowed me to put into practice the concepts learned in classes of this or other subjects. S2- This project has contributed to strengthening critical reasoning and problem-solving skills?
2. Personal and professional skills and attributes	S3- I had to search and analyze information from different sources to understand the problem and propose a solution. S4- Working on this project helped me identify the strengths and weaknesses in my technical knowledge. S5- I had to manage time and resources effectively to achieve the objectives of the activity.
3. Interpersonal skills: collaboration, teamwork and communication	S6- Defining the roles and responsibilities of team members was essential for the development of the project. S7- In this project, I have realized the importance of knowing how to work in a team. S8- Through this project, I was able to enhance my oral (video presentation) and written (project document) communication skills. S9- During this project, I encouraged the feedback between team members.
4. Conceiving, designing, implementing and operating systems in the enterprise, societal and environmental context – the innovation process	S10- The fact that the project had a real-life statement helped me realize the impact of my discipline on society and the environment. S11- The project's design process allowed me to enhance the prototypes from a functional perspective. S12- I find it satisfying to see how my idea transforms into a design and, ultimately, into a functional prototype. S13-Aspects of sustainable design and environmental responsibility were covered in the project. S14- The project contributed to understanding real-world constraints like costs, time, and resources.

The results of the project are structured following the CDIO framework, showcasing the progression from conceptualization to final implementation and testing.

### *Conceive*

In the initial phase, the concept of Service-Learning (SL) was introduced with the goal of developing a project that provides significant societal benefits and could be produced by a vocational training school. The team decided to address the issue of invasive Florida turtles (*Trachemys scripta*) in the xxx blinded xxx region, which have been displacing native species and causing environmental harm. The project aimed to create a more efficient and humane method for capturing these invasive turtles to help restore local

ecosystems. The project was proposed by xxx blinded xxx, a conservation organization, and was subsequently approved by the professor and posted in the class forum. A collaboration was also established with xxx blinded xxx vocational training school to support the development and implementation of the prototype.

**Design**

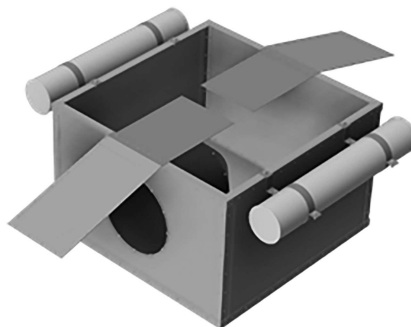
In the design phase, led by the university students, the team explored various design alternatives for the Aquatic Turtle Control Prototype, considering existing real-world solutions such as floating traps, eel nets, and umbrella-shaped traps.

A qualitative evaluation was conducted to determine the optimal prototype, based on criteria including ease of assembly, cost of materials, turtle safety, capture effectiveness, maintenance, and service life (Table 2).

Based on this assessment, a hybrid design was chosen, combining features from eel nets and floating traps. A 3D design model was then developed (Figure 2), and detailed manufacturing drawings were created.

**Table 2.** Selection criteria with classification of different types of traps.

	Floating Trap	Nansa Trap	Longline	Umbrella Trap
Ease of assembly	Positive	Neutral	Negative	Neutral
Cost of materials	Neutral	Positive	Positive	Positive
Turtle safety	Positive	Negative	Negative	Neutral
Capture effectiveness	Negative	Positive	Neutral	Positive
Maintenance	Neutral	Neutral	Negative	Neutral
Service Life	Positive	Positive	Negative	Negative
Advantages	3	3	1	2
Neutral	2	2	1	3
Disadvantages	1	1	4	1
Results	2	2	-3	1



**Figure 2.** 3D design of the prototype.

The manufacturing methods were adapted to the capabilities of the machinery at the vocational school, and manufacturing time calculations were completed to apply theoretical course concepts (Figure 3)

Upon completion of this phase, the university group presented the project documentation along with a video presentation.

### Implementation

The implementation phase was carried out by the vocational school, where students evaluated and optimized the design for workshop manufacturing. Adjustments were made to ensure the parts aligned with the machinery available, and close communication was maintained between the vocational and university students throughout the process. The prototype was then constructed, including tasks such as machining and welding the necessary components (Figure 4).

### Operate

In the final “Operate” stage, the Aquatic Turtle Control Prototype was tested in the real-world environment for which it was designed. The prototype underwent trials to assess its




Part 9. Machining piece with drill								
Nº	Tool	Sketch	Pass (mm)	Progress (mm/min)	RPM	Vc (m/min)	Time (min)	Observations
5	TC-32 ERLO column drill		-	-	-	-	1	Position and secure the workpiece to the drill
6	TC-32 ERLO column drill		0,1	68	680	6	0,0074	Drill with a Ø3.2 mm drill bit one of the previously marked holes. Set a cutting speed (Vc) of 6 m/min since the material being drilled is stainless steel. The resulting value is quite small, so it is advisable not to run too fast.
7	TC-32 ERLO column drill		-	-	-	-	0,2457	Repeat the process with the next hole using the same parameters calculated earlier

Figure 3. Example of a process sheet.

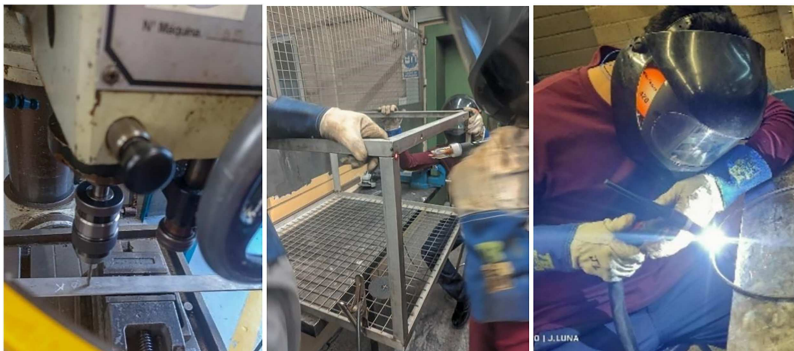


Figure 4. Prototype construction: hole drilling, necessary welds for the base and the net.



**AQ7 Figure 5.** Extract of the published article related to the presentation of the prototypes.<sup>11</sup>

**Table 3.** Summary of service learning survey results from the aquatic turtle prototype group.

	Q1	Q2	Q3	Q4	Q5	Q6	GA
Aquatic Turtle Control Prototype	8	8.7	8.6	8.1	8.1	6.6	7

effectiveness in capturing invasive turtles. Additionally, the project’s outcomes were highlighted in a local newspaper,<sup>11</sup> which covered the presentation of the prototype. Both prototypes were handed over to nonprofit organizations for further testing and potential long-term use (Figure 5).

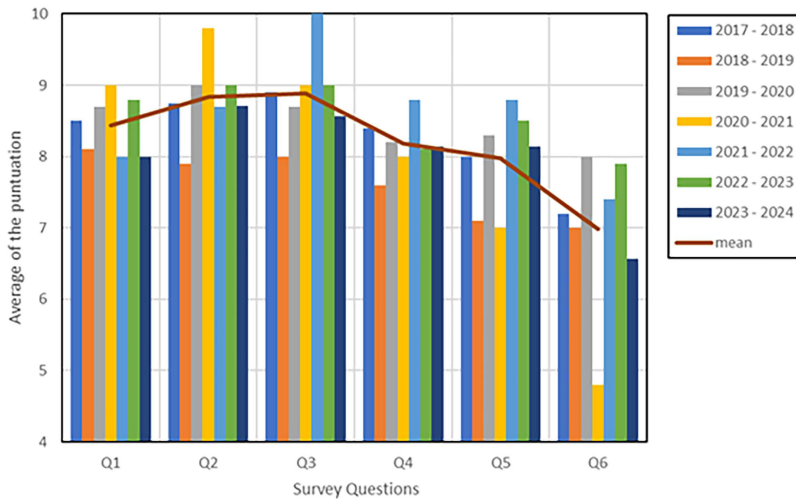
xxx blinded xxx

Finally, Table 3 shows the average values of the six questions of the survey plus the general assessment (GA) question.

Similar service-based projects have been carried out involving the same university and vocational school, with students responding to the same questionnaire. To provide context for the Service-Learning project over the past seven years, Figure 6 presents a bar plot of the survey results over this period. The mean per each question among years is also represented.

The survey results provide insights into students’ experiences with the Service-Learning (SL) projects over the course of seven years. The scores for task completion (Q1) are relatively consistent, ranging between 8 and 9. Overall, students generally felt confident in completing the tasks, though there was a slight decline in more recent years. The alignment between tasks and academic training (Q2) shows strong results, peaking at 9.8 in 2020–2021 and remaining consistently high. This indicates that students generally found a strong connection between the SL tasks and their academic background, with particularly high alignment in recent years.

Students consistently reported high scores for applying previously acquired university knowledge (Q3), with a peak of 10 in 2021–2022. This indicates that they felt confident in utilizing their academic learning effectively during the project. The perception of SL as a valuable complement to students’ education varied over the years (Q4). The lowest



**Figure 6.** Results of the Service-Learning survey since course 2017–18.

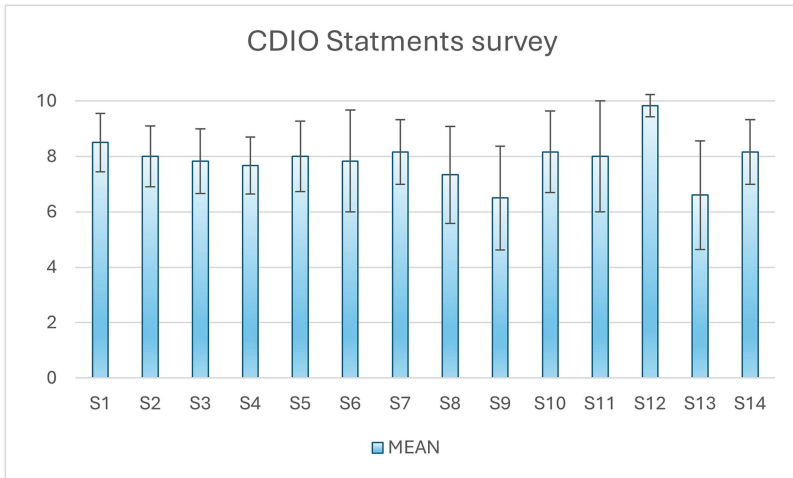
score was in 2018–2019 (7.6), indicating that fewer students found the experience formative that year. However, the score improved in later years, suggesting an increasing recognition of SL’s educational value.

Students’ perception of faculty support saw fluctuations (Q5). It dipped to 7 in 2020–2021 but improved significantly to 8.8 in 2021–2022, though it slightly declined again to 8.1 in 2023–2024. This suggests that while support improved after a low point in 2020–2021, there is room for maintaining consistent guidance. External support showed the most variability (Q6), with a notable low in 2020–2021 (4.8), indicating challenges in receiving adequate supervision from external partners that year.

The results reflect generally positive experiences, with students consistently feeling that the tasks aligned well with their academic training and allowed them to apply university-acquired knowledge effectively. However, challenges were particularly evident during the 2020–2021 academic year, likely due to the disruptions caused by the COVID-19 pandemic. Faculty and external organization support saw significant dips during this period, reflecting the difficulties in providing effective guidance and supervision in a remote or restricted environment. Despite these challenges, improvements were observed in subsequent years, with stronger support from both faculty and external organizations. The increasing recognition of the Service-Learning (SL) experience as a formative educational complement and the strengthening of external partnerships indicate that the program is rebounding positively.

The results from the group of students of the aquatic turtle control project to the specific questions of CDIO methodology were answered by 6 team members (75%). Results were analysed and are shown in Figure 7.

Apart from quantitative results of Figure 7, students also write comments on each statement. The analysis of the comments, combined with the results from Figure 7, leads to the following results.



**Figure 7.** Results of CDIO statements related survey to the aquatic turtle control prototype group.

Statements S1 and S2 show similar good results and deviation, which demonstrate that project activities allowed to apply fundamental knowledge and reasoning. Statements S3, S4 and S5 results also demonstrate that personal and professional skills and attributes were correctly recognized from students perspective. S6, S7, S8 also show similar results which indicates good interpersonal skills and collaboration, but S9 shows a lower mark. S9 identifies that during this project, feedback between team members was not always encouraged and it reflects an improvement for next years, where evidences of encouraging team members feedback will be asked. S10 and S11 shows good results which indicates that real-life need from the ecological entity helped to impact the students and design process helped to have a functional perspective. S12 has the maximum mark and the lowest variability which indicates that transforming the idea to a real prototype motivates most the students. S13 results indicate that more efforts have to be done to involve sustainable design and environmental responsibility on the project activities. Finally, S14 demonstrates that the project positively contributed to understanding real-world constraints like costs, time, and resources

From the comments to the statements, the survey responses highlight the practical application of cross-disciplinary knowledge, skill development in machining processes, and the importance of iterative feedback. The project reinforced theoretical concepts, encouraged hands-on learning, and integrated competencies from various courses, aligning strongly with CDIO principles and fostering an active, real-world engineering experience.

The survey responses also emphasize how project constraints fostered critical thinking and problem-solving. Participants collaborated to address challenges, such as designing a turtle capture system by integrating various trapping methods, demonstrating creativity, teamwork, and practical application of knowledge. This approach highlights the importance of thorough analysis and problem-solving to achieve an optimal solution.

The responses reflect the importance of team roles in leveraging individual strengths and addressing weaknesses. Participants gained insight into their technical skills through task division, collaborative problem-solving, and peer learning, highlighting areas for personal growth and reinforcing the value of teamwork.

The responses also highlight the importance of time and resource management in the project. Participants navigated deadlines, coordinated through various platforms, and adhered to budget constraints, emphasizing collaboration and strategic decision-making.

The responses reveal mixed experiences with team dynamics. While defining roles and responsibilities was acknowledged as essential for project success, challenges with communication and role clarity hindered effectiveness in some cases.

The responses emphasize the critical role of interpersonal and communication skills in project success. Participants highlighted the growing realization of teamwork's importance, particularly in coordinating with a large group, a tutor, and an external institution.

The responses highlight issues with feedback and task division within the team. One participant noted a lack of communication, leading to division in the group, which was addressed through an anonymous survey. The other mentioned attempts to discuss individual contributions during meetings.

The responses emphasize the increasing significance of the project over time. Participants noted a deeper connection to their work and recognized its broader societal and environmental impact.

The responses highlight the iterative design process and the importance of prototyping. Participants noted how multiple prototypes were tested and refined, with feedback from the academic tutor contributing to the final functional design.

The responses reflect a strong sense of ownership and pride in the project. Participants expressed fulfillment in seeing their ideas come to life, not motivated by grades but by the opportunity to see their work realized in the real world and contribute to sustainability.

The responses reflect the challenges of managing a project within strict budgetary and resource constraints. Participants recognized the importance of staying within budget, acknowledging that in a real-world engineering context, exceeding the budget would have consequences.

Summarizing, the qualitative results related to the aquatic turtle control prototype offer valuable insights. In their comments, the group noted that they successfully designed a prototype that met the functional requirements and client expectations. They faced challenges during the process, such as machining complexities, but addressed these issues through design modifications that reduced costs and simplified production. From an educational standpoint, the group experienced significant growth in their engineering knowledge, advancing from the design phase to manufacturing. They also expanded their understanding of different alternatives evaluation and ecological approaches by comparing existing models and developing their own design.

Furthermore, the group emphasized the importance of communication and teamwork in efficiently solving problems. Their collaboration with xxx blinded xxx proved to be an enriching experience, and students expressed confidence that their project will make a meaningful contribution to the organization's efforts in controlling invasive turtle populations.

## Conclusions

The conclusions from this study highlight the educational and practical benefits of the Service-Learning (SL) experience, particularly through the development of the aquatic turtle control prototype. The project successfully demonstrated how academic theory can be effectively applied in real-world contexts, addressing societal and environmental needs. By following the CDIO (Conceive, Design, Implement, Operate) framework, students were able to progress from conceptualizing a solution to testing a functional prototype, illustrating the value of integrating SL into the academic curriculum.

Survey data over the past seven years reveal that students consistently found strong alignment between the tasks performed and their academic training, particularly in applying university-acquired knowledge. However, the study also noted some fluctuations in support from faculty and external organizations, particularly during the 2020–2021 academic year, when the COVID-19 pandemic significantly disrupted project collaboration and communication. Despite this, recent improvements in faculty and external support suggest a recovery, with stronger partnerships and more effective guidance enhancing the overall student experience.

The students involved in the aquatic turtle control prototype provided valuable qualitative feedback, emphasizing that the project not only met client expectations but also offered a comprehensive educational experience. The team encountered and resolved real-world challenges, such as machining complexities and material issues, which enhanced their practical skills and deepened their understanding of both engineering and fishing techniques.

Overall, the project and associated SL experience have proven to be an effective method for promoting engineering education while addressing meaningful societal challenges. Through active collaboration between university students, vocational schools, and external organizations like xxx blinded xxx, the project succeeded in developing an innovative and humane solution for controlling invasive turtle populations. These results underscore the long-term value of integrating service-based projects into the curriculum, benefiting both student development and societal needs. Continued efforts to strengthen communication and support structures are necessary to ensure the program's ongoing success and positive impact. The limitations of this study mainly relate to the fact that even this methodology has been applied for several years, with many students involved, only a group of students give qualitative feedback and we need more data to fully validate the results on next year students results. Moreover, the results are linked to the collaboration with vocational training schools an ecological entity that had very good disposition to help students, but if the collaboration with vocational training schools and ecological entities should not be similar, even the project will use the same CDIO methodology, the results would be different and students' motivation would be reduced. For this reason, we acknowledge the contribution of collaboration entities on this project.

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## Data availability statement

- AQ8** The data supporting the findings of this study are available upon request from the corresponding author. Access to the data will be granted in accordance with applicable privacy and ethical considerations.

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