


## Chapter 8

# Active Learning Strategies for Sustainable Engineering: The Case of the European Project Semester

**Abel José Duarte**

*Instituto Superior de Engenharia do Porto,  
Instituto Politécnico do Porto, Portugal*

**Benedita Malheiro**

 <https://orcid.org/0000-0001-9083-4292>


*Instituto Superior de Engenharia do Porto,  
Instituto Politécnico do Porto, Portugal*

**Manuel Fernando Silva**

 <https://orcid.org/0000-0002-0593-2865>


*Instituto Superior de Engenharia do Porto,  
Instituto Politécnico do Porto, Portugal*

**Paulo Duarte Ferreira**

 <https://orcid.org/0000-0001-6432-6366>

*Instituto Superior de Engenharia do Porto,  
Instituto Politécnico do Porto, Portugal*

**Pedro Barbosa Guedes**

 <https://orcid.org/0000-0001-9254-7692>

*Instituto Superior de Engenharia do Porto,  
Instituto Politécnico do Porto, Portugal*

### ABSTRACT

*Engineering aims to improve the quality of daily life on a planet with limited resources. This chapter describes how the European Project Semester offered by the School of Engineering of the Porto Polytechnic contributes to make engineering undergraduates conscious of their environmental and societal impact. The program is a project-based active learning framework where problem-solving is supported by intercultural communication and creativity, ethical and sustainable reasoning, and global contextual analysis. This analysis shows that it fosters scientific, technical, and interpersonal competencies, emphasizing ethical and sustainable design as recommended by several reference institutions through the testimonials left on the project reports and the evolution perceived by the participants during the semester. These findings are supported by a sample of 45 projects conducted by 228 students from 23 countries and 65 degrees. All projects aimed to have a lasting impact on the future engineering practice of participants and, somehow, transform the world positively.*

DOI: 10.4018/978-1-6684-2309-7.ch008

## ***Active Learning Strategies for Sustainable Engineering***

### **INTRODUCTION**

Life on Earth is an endless quest to perpetuate species in time through reproduction. However, reproduction does not provide a default mechanism to pass on knowledge to the next generations. From rudimentary chemical information to the demonstration of experiences and procedures by trial and error, nature finds in humanity the most complex and elaborate way of transmitting information to offspring (Besson, 2014).

Nowadays, the challenge is not only to convey knowledge, but to create an educational framework where the student can be actively committed to his/her own education and, at the same time, contribute to the preservation of life and the planet.

This chapter reports how the European Project Semester (EPS) offered by Instituto Superior de Engenharia do Porto (ISEP) combines active learning and sustainability-driven engineering education. On the one hand, active learning, which is founded in constructivist epistemology, states that learning requires the active participation of the student and comes about through transactions and dialogue among students and between faculty and students, in a social setting (Panitz, 1999). On the other hand, educating engineers for sustainable development involves fostering critical and ethical thinking and instilling a lifelong search for equity, solidarity and preservation of natural resources, cultural and genetic diversity (Duarte et al., 2020). This combination is particularly well-suited since student motivation and engagement tend to increase when challenged to design ethics and sustainability-driven solutions to real problems.

EPS@ISEP relies on project-based learning and teamwork as a means to promote the development of technical-scientific and soft skills in undergraduates, while designing sustainable and ethical solutions. This learning framework educates engineer undergraduates to become agents of change, contributing to a joint, peaceful and sustainable future on Earth.

This document is organized into five sections. Section 2 provides the background. Section 3 describes the European Project Semester and its implementation at ISEP. Section 4 presents EPS@ISEP facts and testimonies. Section 5 draws the conclusions.

### **BACKGROUND**

#### **Active Learning in Engineering**

According to Michael (2006), well-known active learning pedagogies include cooperative learning (Johnson et al., 1991), collaborative learning (Leigh & MacGregor, 1992), experiential learning (Kolb, 2014), problem-based learning (PBL) and project-based learning (PjBL) (Bell, 2010). In the case of engineering education, the adoption of PjBL pedagogies is essential to develop the required skills in young graduates. However, to motivate engineering undergraduates to drive their learning process it is necessary to adopt attractive methodologies and inspiring problems. The desire to find, together with peers, solutions for real-world problems triggers in students the will to search for knowledge, learn complex subjects and share findings. These joint search, design, development and test activities are intended to provide students with a fun, motivating and educational experience, increasing student self-confidence, interest in learning and, ultimately, in engineering (Elger et al., 2000). The Committee on the Engineer of 2020, Committee on Engineering Education, and National Academy of Engineering (2005) stated that engineering education must be realigned to promote technical excellence as well as an understanding of work strategies, team, communication, ethical reasoning, societal and global contextual analysis

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skills in practicing engineers. This implies that humanities, economics, political science, language, and interdisciplinary technical subjects must be part of the undergraduate education to prepare professionals to communicate with the public, engage in a global engineering marketplace and become lifelong learners. Thus, the essential professional competencies of an engineer are critical thinking and problem solving, effective communication, collaboration and team building, and creativity and innovation – the four C – as well as socio-professional ethics and sustainable development – the two S (Malheiro et al., 2019). These abilities are often required by the employers of the alumni and are therefore included in the curricula to educate competent practitioners (Vos & de Graff, 2004; de Graff & Christensen, 2004). Moreover, the CDIO Initiative, which is an open, innovative educational framework for engineering graduation degrees set in the context of Conceiving – Designing – Implementing – Operating real-world systems and products, identifies two main types of PjBL: (i) lecture-based, including such methods as a partner and small-group discussions, demonstrations, debates, concept questions and feedback from students about what they are learning; and (ii) experiential, when students take on roles that simulate professional engineering practice, for example, design, build and test projects, simulations and case studies (Crawley et al., 2014). PjBL corresponds, in the context of this paper, to the promotion and adoption of an autonomous self-learning attitude among staff and students. For future engineers, it supports the essential lifelong learning posture and for staff the motivation for continuous research regarding innovative student learning methodologies.

### **Sustainability Driven Engineering**

Sustainability-driven engineering plays two equally important roles: it drives sustainable development and motivates students to become actors of change as well as active learners. As of the Second World War, population, knowledge, and quality of life have experienced exponential growth. At the same time, society was confronted with the fact that human decisions cause irreversible consequences on Earth, namely climate change, pollution, depletion of resources and extinction of species. Engineering undergraduates are usually drawn by the will to tackle real-world problems directly or indirectly related to the preservation of the planet if design decisions are based on ethical and sustainability concerns. According to several international, engineering education and professional engineering organizations, engineering is a key profession for achieving sustainable development. To solve problems considering the economic, social, human, and cultural perspectives, the engineer of the future needs to be creative, mobile, and master communication as well as its field of expertise. This set of professional skills has been identified by international institutions like the Organisation for Economic Cooperation and Development (2014, 2018) and the United Nations Educational, Scientific and Cultural Organization (2010), engineering education societies as the European Society for Engineering Education (2016) and the American Society of Engineering Education (2010), engineering education accreditation associations, namely, the European Network for Accreditation of Engineering Education (2015) and the Accreditation Board for Engineering and Technology (2000), and national engineering academies such as the Royal Academy of Engineering (Lucas et al., 2014) and the National Academy of Engineering (2012). In this chapter, sustainability encompasses the environmental impact, social implications, and economic viability (Duarte et al., 2020). Sustainability-driven engineering refers to the design of solutions considering the involved ethical and sustainability dimensions.

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### European Project Semester

EPS is a student-centered integrated learning framework for undertaking engineering capstone/internship projects and, as such, adopts collaborative, experiential, PjBL methodologies. This one-semester program designed by Arvid Andersen (Andersen, 2001) aims to educate engineers with European and international dimensions. The goal of the program is to promote the development of scientific, technical, and soft skills in engineering students through multicultural teamwork and open, multidisciplinary problem-solving (Andersen, 2004). Furthermore, EPS attempts to train conscientious and responsible engineers, which can discover global integrative, innovative, and increasingly sustainable solutions (Andersen, 2001).

The program focuses on teamwork, exposes students to cultural, scientific, and technical diversity, and embraces ethics and sustainability-driven design. Teams of students from diverse scientific and cultural backgrounds collaborate and cooperate to solve real-world problems. The process involves collecting information, finding alternative solutions, choosing their own solution, including methodologies, materials and components, and design, building and evaluating the resulting prototype (Lehman et al., 2008). During this PjBL process, advisers act as coaches, consultants, and facilitators, keeping the team motivated and contributing to the success of the projects. Furthermore, EPS complies with the CDIO directives on design, build and test experiences at the level of capstone projects (Malheiro et al., 2015).

The program is currently offered by nineteen European engineering schools from twelve countries, called the EPS providers, attesting to its success. The EPS providers have discussed, agreed upon and posted on the EPS Providers website the core specification of the European Project Semester framework. The so-called “10 Golden Rules of EPS” are listed in Table 1. Moreover, providers offer EPS program implementations not only compliant with this core framework, but also with diverse “flavors”.

Table 1. 10 Golden Rules of EPS

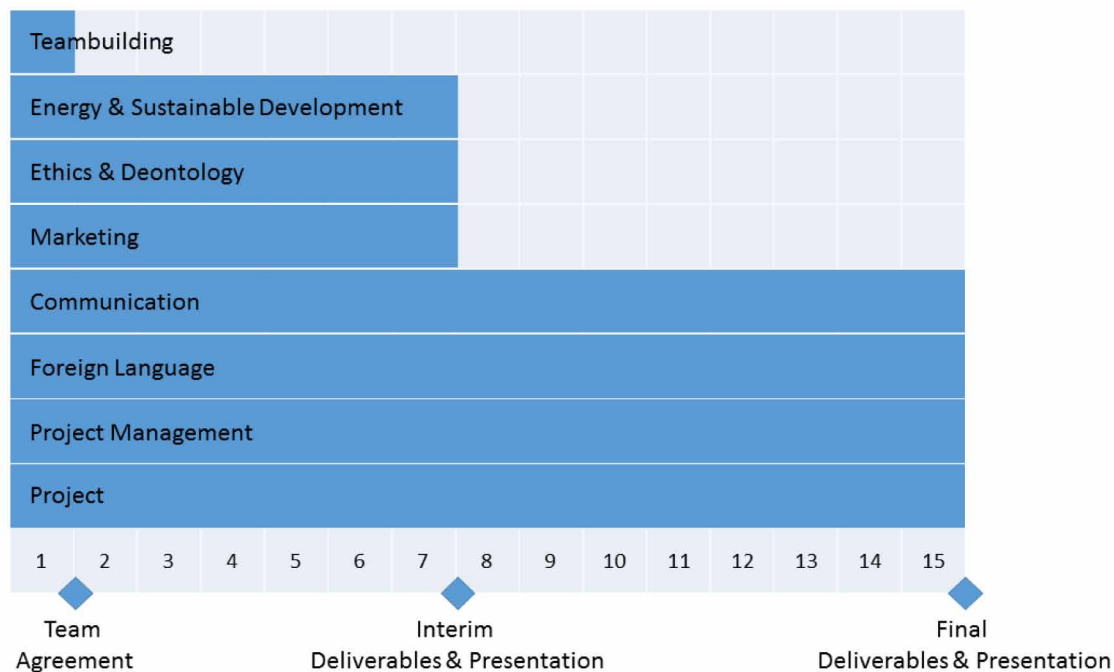
| Nº   | Rule  |
|------|---|
| I    | English is the working language of EPS  |
| II   | EPS is multinational with a group size of a minimum of three and maximum of six students, being four or five the ideal number; a minimum of three nationalities must be represented in each EPS group |
| III  | Ideally, but not necessarily, an EPS project is multidisciplinary   |
| IV   | An EPS semester is a 30 European Credit Transfer System Units (ECTU) package, the duration of which is not less than 15 weeks   |
| V    | An EPS project has a minimum of 20 ECTU and the complementary subjects account for a minimum of 5 ECTU and a maximum of 10 ECTU   |
| VI   | The focus of EPS is on teamwork   |
| VII  | The subjects included in the EPS must be project supportive; English and a basic crash course in the local language must be offered   |
| VIII | The subjects must include team building at the very beginning and Project Management at the beginning of an EPS semester  |
| IX   | Project supervision/coaching must focus on the process as well as the product   |
| X    | EPS must have continuous assessment including an interim and a final Report   |

## EPS@ISEP IMPLEMENTATION

The School of Engineering – Instituto Superior de Engenharia do Porto (ISEP) – of the Porto Polytechnic became an EPS provider in the academic year of 2010-2011 (Malheiro et al., 2013). Currently, EPS@ISEP is in its 11th consecutive year and, during this period, has welcomed 230 participants from Europe, Asia, America, and Africa.

EPS@ISEP is structured as follows: two-thirds (20 ECTU) of the credits are assigned to the project module and one-third (10 ECTU) to complementary modules (EPS rule V). The complementary modules are focused on the development of soft skills considered essential in training for the twenty-first-century engineers, such as communication or team building, project-related activities, such as project management, and transversal topics, such as energy & sustainable development or ethics & deontology (Malheiro et al., 2015). Figure 1 presents the EPS@ISEP 15-week schedule and illustrates the fulfillment of golden rules VIII and X.

Figure 1. EPS@ISEP Schedule



The teams are fully responsible for the project management (task identification, allocation, planning), the solution design (research, brainstorming, weekly meetings), selection and specification of materials and components, as well as assembling and testing of the prototype.

In terms of the learning outcomes, EPS@ISEP aims to develop the following competencies in the participants: (i) the ability to effectively work and communicate in multicultural and multidisciplinary teams; (ii) the ability to contribute, within their field of expertise, to the solution of a larger multidis-

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ciplinary problem; (iii) the ability to adopt sustainable development practices; (iv) the ability to adopt ethical and deontological engineering habits of mind; and (v) the ability to adopt a PjBL lifelong stance.

### **Proposals**

Before the beginning of the semester, the EPS@ISEP staff team gathers project proposals regarding real-world problems. The origin of proposals varies and includes industry, services, R&D institutions, or the school itself. The proposals refer to multidisciplinary problems, i.e., require the integration of multiple technical and scientific competencies, and are open, i.e., specify exclusively top-level requirements such as compliance with the applicable directives/norms and the budget.

A proposal defines the problem/challenge to tackle, the minimal set of requirements, mostly mandatory directives and standards, and the maximum budget for building a proof-of-concept prototype. This type of proposal directs the team towards the conception and design stages and then towards the implementation and test stages of the capstone project/internship. The average cost of an EPS@ISEP project, in terms of materials and components, is approximately 317 €.

While many proposals are inspired on the National Academy of Engineering 14 Grand Challenges for Engineering (National Academy of Engineering 2008), the list of proposals offered tends to be eclectic, ranging from bio-mimetic robotics (Silva et al., 2015) to sustainability (Llauradó et al., 2015; Fountain et al., 2016; Augustyns et al., 2017) and maritime (Ferreira et al., 2015) applications.

### **Teaming**

To accomplish rule II, a Belbin questionnaire is used to determine the individual teamwork profiles (Belbin, 2010), allowing the design of teams with complementary elements from as many diverse fields of studies and as multinational as possible. On the one hand, by identifying the teamwork profile/role of the participants, the Belbin questionnaire helps to assemble teams made of individuals with diverse, complementary teamwork roles. On the other hand, individuals become aware of their teamwork role and associated responsibilities in the group organization, increasing the likelihood of success significantly. The main team roles identified by Belbin are Company Worker, Chairman, Shaper, Plant, Resource Investigator, Monitor/Evaluator, Team Worker, and Finisher. In the case of EPS, since the team size is less than ten (four to six students) there are individuals with overlapping roles as well as assignments. Finally, the teams are assembled so that they include students with different team worker profiles (Belbin), at least three nationalities (EPS rule II) and diverse scientific backgrounds (EPS@ISEP).

This focus on diversity is important to prepare the students to act worldwide as engineers and members of multinational and multidisciplinary teams. One of the first tasks the teams need to accomplish during team building activities (EPS rule VIII) is to define their own organization and conflict resolution rules – the Teamwork Agreement – using two identical questionnaires as proposed by Hansen (2010).

While the first is to be filled individually, the second questionnaire must be completed and signed together by the team. The questionnaire covers operational issues, like task and responsibility assignment, communication methods, task priority and implementation, self-assessment and project monitoring, and conflict resolution approaches. Indirectly, the Teamwork Agreement promotes autonomy and responsibility as well as leads to early awareness and accountability of conflicts.

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### Coaching

EPS@ISEP adopts a unique model where a panel of multidisciplinary experts acts as a consulting committee regarding project supervision. The teams meet with this advisory panel once a week to discuss the previously agenda posted on their wiki. Each meeting is conducted in turn by a team member, promoting commitment and responsibility. After the meeting, the teams write on their wiki the respective minute, reporting the most prominent issues discussed. This interaction protocol aims to develop the ability to define agendas, leading meetings and write minutes.

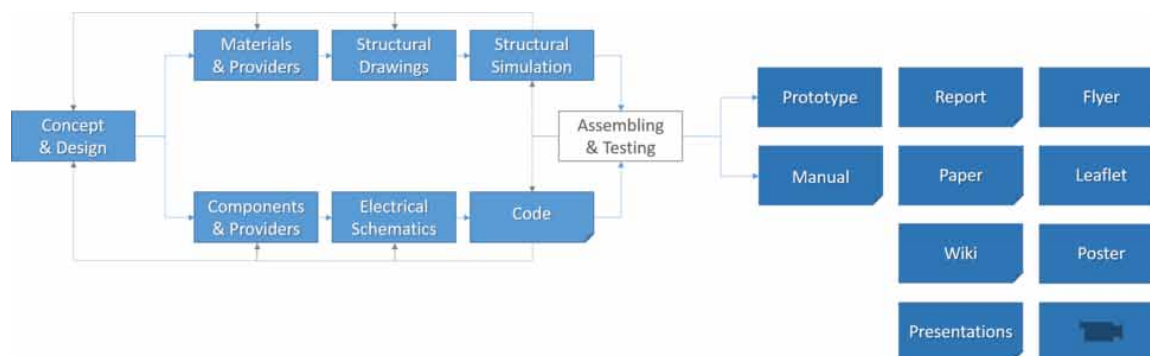
The key role of the panel is to promote a free exchange of ideas between team members, privileging original and innovative suggestions and perspectives, which stem from their distinct cultural and scientific backgrounds. Even when suggestions seem implausible, the panel uses them as the starting point of further brainstorming. During this process, the advisers identify problems and challenge the team to find innovative contributions to improve the proposed solution. As far as communication is concerned, the panel is aware that it is interacting with students from diverse scientific and cultural backgrounds.

Another particularly important aspect of the coaching methodology is the prompt feedback given to the students. The communication between the panel and the team involves presentations, discussions, e-mail messages, annotated deliverables, drawings, videos, or cardboard models.

### Deliverables

The teams must produce several deliverables, including the project wiki, report, video, paper, manual, flyer, leaflet poster and build a proof-of-concept prototype with the allocated budget. The teams develop a report, video, paper, manual, flyer, leaflet, poster and several presentations with the assistance of the communication seminar teacher and project coaches. Figure 2 displays the main deliverables with darker blocks and partial deliverables with lighter blocks. The main deliverables are located on the left and include prototype and communication related deliverables. The assembling and testing block represents a core process of prototype development, not a deliverable. The outcome of each partial prototype deliverable may impact the precedent block, defining a continuous refinement cycle represented by the light grey flow. All stages of the conception, design, implementation, and operation of the proof-of-concept prototype are reported in the wiki and report.

Figure 2. EPS@ISEP deliverables



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The report structure, which is provided beforehand, closely follows the organization of a scientific report, including as mandatory elements the abstract, introduction, state of the art, project development, marketing, sustainability, ethical concerns, conclusions, glossary, and references. The marketing, eco-efficiency & sustainability and ethics & deontology chapters are produced and refined within the corresponding complementary modules. They address several components of the future engineer profile as suggested by the United Nations Educational, Scientific and Cultural Organization (2010), the Organisation for Economic Co-operation and Development (2018), the European Society for Engineering Education (2016) or the American Society of Engineering Education (2010). Specifically, these chapters focus on the relevant project-related issues identified by the team in each of these areas and the conclusions drawn by the team become project requirements. As project requirements, they then need to be fulfilled during the development of the proof-of-concept prototype.

The paper template and structure are also provided beforehand, and the teams are challenged to prepare the paper for a given call for papers. In this context, the paper is not only a concise version of the report but, since it has a specific focus, requires additional reflection from the team.

Finally, the team wiki is essential to the EPS process since it acts as a collaborative work platform for team members and advisers as well as a project showcase platform. On the one hand, it allows team members to work and prepare together the project plan, logbook, weekly meetings, and the report and, on the other hand, it remains the repository of the deliverables and project-related activities.

### **Assessment**

In terms of assessment, EPS@ISEP follows rule X and uses the scheme proposed by (Hansen, 2010), i.e., the formal assessment takes place twice during the semester and contemplates self & peer as well as teacher and adviser assessment. While the interim assessment is intended to give individuals and teams feedback about their performance so far, from the point of view of their peers and of the advisers, the final assessment is for grading.

The self & peer assessment considers the quality and quantity of the technical contribution, openness to others' ideas, teamwork performance, leadership, attitude, and initiative shown. It is used by advisers to monitor teamwork and to give constructive feedback and advice where needed (Ashworth, 2011). The adviser assessment reflects both team performance as well as individual student performance.

### **EPS@ISEP OUTCOMES**

EPS@ISEP embraces several active learning approaches: *(i)* experiential learning, when students adopt professional engineering practices as, for example, the design, build and test of a prototype (PjBL); *(ii)* collaborative learning, when team members autonomously discover, share and brainstorm findings and commit to solutions; and *(iii)* cooperative learning, when team members work together with teachers, within the project supportive modules, in the ethical, deontological, sustainability, marketing and project management dimensions of their projects.

Table 2 presents citations from several EPS@ISEP reports related to active learning evidence. These testimonials identify several highlights contributing to the EPS vision of active learning, namely multiculturalism, teamwork, collaboration, cooperation and, above all, autonomy.

**Active Learning Strategies for Sustainable Engineering***Table 2. Active Learning in EPS@ISEP – Citations*

| Project                       | Citation   |
|-------------------------------|--|
| UV-based Disinfection         | During these four months of work, we have learned many different aspects connected with not only mechanical, electrical and chemical knowledge but also teamwork. We improved our cooperation and communication as an international team. Moreover, we dealt with conflicts and other restrictions and limitations which we encountered on our way. (Bazylińska et al., 2012)  |
| Context-aware Smart Object    | This project gave us an opportunity to connect our knowledge from different fields of study with practical skills and teamwork, like in real-life situations. This project gave us a chance to know other cultures, cooperate (...) and practice English. (Harms et al., 2012)   |
| Autonomous Environmental Buoy | “It took an organized and tuned teamwork to arrive to this point. However, we did not always cooperate perfectly; it was especially hard for us in the beginning when we barely knew one another. With time, however, we started displaying better and better teamwork qualities.” (Möller et al., 2013)   |
| Bio-Inspired Swimming Robot   | Due to our diverse professional backgrounds, experiences and personal interests, we cover a wide range of viewpoints and skills. That is why a high level of quality can be achieved. (Blazewski et al., 2014)   |
| Travel Logging System         | The fact that everyone specializes in different areas adds more diversity to our team. Despite these differences, we have taken a common goal, which is the realization of the project using the skills, experience and knowledge from different disciplines. (Holt et al., 2014)  |
| Bio-inspired flying robot     | (...) in a multidisciplinary team (...) it is very important to assign detailed tasks to all group members, (...) but, as people do not know each other backgrounds, it is harder to rely on others to do things than imagined. In short: communication management is the key to success. (Caramin et al., 2014)   |
| Reconfigurable LED Lamp       | This experience gave us definitely advantage in future life. We practiced English, studied lighting specifications, learned sustainability and marketing issues as well as improved our communication and cooperation skills. (Aedma et al., 2014)   |
| Aquaponics System             | Our main objective was to create a working system that supported both fish and plants and, through long research and development phases, we believe that we created a system that not only fulfills the required objective, but also is aesthetically pleasing. (Docherty et al., 2014)  |
| Solar Food Dehydrator         | Every team member has a specific role in this project, according to each person’s strengths and weaknesses. However, we value teamwork, working together successfully and in a joint effort, sharing our knowledge, in order to achieve our goal. After a lot of research and brainstorming, we agreed on a final design and on the required features of the product. (Berényi et al., 2015)   |
| Aquaponic Shelter             | To make everything work we need a good way to communicate with each other. We have meetings at least twice a week, when every member can tell others what they have done and if there are any problems. We also decide together future plans and set deadlines. (...) A group on Facebook was created for the team to communicate. (Bartosz et al., 2015)  |
| Aquaponic Monitoring          | Our team has grown in regard to project management and technical skills in our respective areas of study. The entire experience was focused on how we functioned and overcame challenges both culturally and academically as a team. Considering these categories our overall project was a success. (Davis et al., 2015)  |
| Autonomous Sailboat           | (...) during face-to-face meetings, where agendas and targets are clearly highlighted as topics of interest, (...) healthy discussions and debates take place. (...) Our group members have developed project management and ecological rationality. The (...) focus was partially on the functionality as a team and how we collaborated, tasked and controlled while being culturally academically challenged. (Asztalos et al., 2015) |

The program engages the students actively in learning by pre-defining a set of deadlines, ensuring timely feedback from coaches and proposing real-world multidisciplinary problems. There are two macro deadlines – the interim and final assessment – and several micro deadlines – proposal selection, task identification and allocation, black box diagrams, detailed schematics, selection of materials and components, as well as the weekly project coaching meetings (where the agenda is defined by the teams). Furthermore, the project supportive modules, the complementary technological crash courses, the collaborative construction of the team wiki (including planning, logbook, report, and deliverables

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sections) and exciting multidisciplinary problems (aggregating students from different scientific and cultural backgrounds) also contribute to this goal.

Table 3 identifies the active learning tasks and actors. EPS@ISEP is an iterative learning process composed of brainstorm, research, selection, and validation tasks, involving the (T)eam, (C)oaches, (L)ecturers and (E)xperts. The diversity of stakeholders and the imprinted work pace fosters both the autonomous discovery and sharing of knowledge – active learning.

*Table 3. Active Learning in EPS@ISEP – Tasks and Actors*

|                       | <b>Brainstorm</b> | <b>Research</b> | <b>Selection</b> | <b>Validation</b> |
|-----------------------|-------------------|-----------------|------------------|-------------------|
| Detailed Requirements | T & S             | T               | T                | C                 |
| Related Work          | T & S             | T               | T                | E & C             |
| Sustainability        | T & L             | T               | T                | L                 |
| Ethics & Deontology   | T & L             | T               | T                | L                 |
| Marketing             | T & L             | T               | T                | L                 |
| Project Management    | T & L             | T               | T                | L                 |
| Design                | T & E & C         | T               | T                | E & C             |
| List of Materials     | T & E & C         | T               | T                | E & C             |
| Prototyping           | T & E & C         | T               | T & E            | E & C             |
| Testing               | T & E & C         | T               | T                | E & C             |

Figure 3 summarizes the diversity of EPS@ISEP classes (top row) and teams (bottom row) since 2011. The multicultural experience stems from the daily interaction between individuals from diverse provenance (Figure 3, top left) and fields of study (Figure 3, top center). Moreover, this experience extends far beyond the project, e.g., the initial linguistic uneasiness, once overcome, strengthens the unity between team members. Figure 3 (top right) displays the gender diversity. EPS@ISEP has 36.4% of female participants, which is significantly higher than the default value (23.5%) of ISEP.

Figure 3 (bottom row) illustrates the diversity within the teams, which are composed of students with compatible team worker profiles (Belbin test), a minimum of three nationalities (EPS rule II) and diverse fields of study (a must at EPS@ISEP). The contemplated fields of study are the major fields of civil (CIV), chemical (CHE), electrical (ELE), informatics (IT) and mechanical (MEC) engineering as well as physics (PHY).

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Figure 3. EPS@ISEP class (top) and team (bottom) nationality, studies and gender diversity

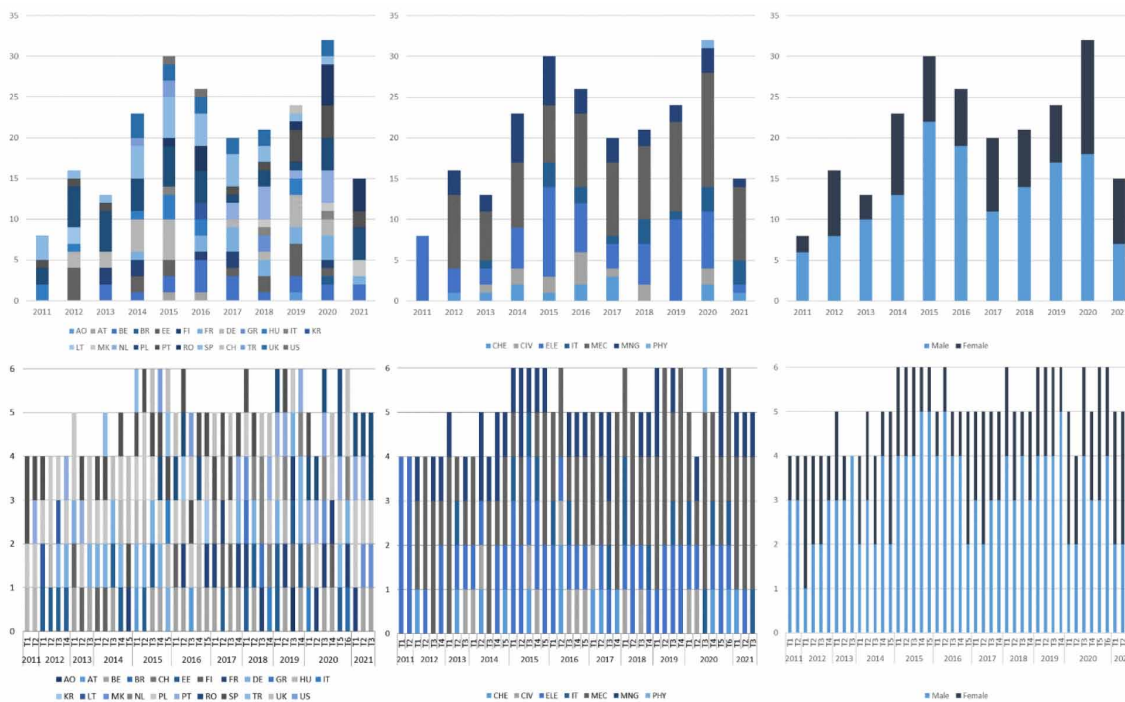
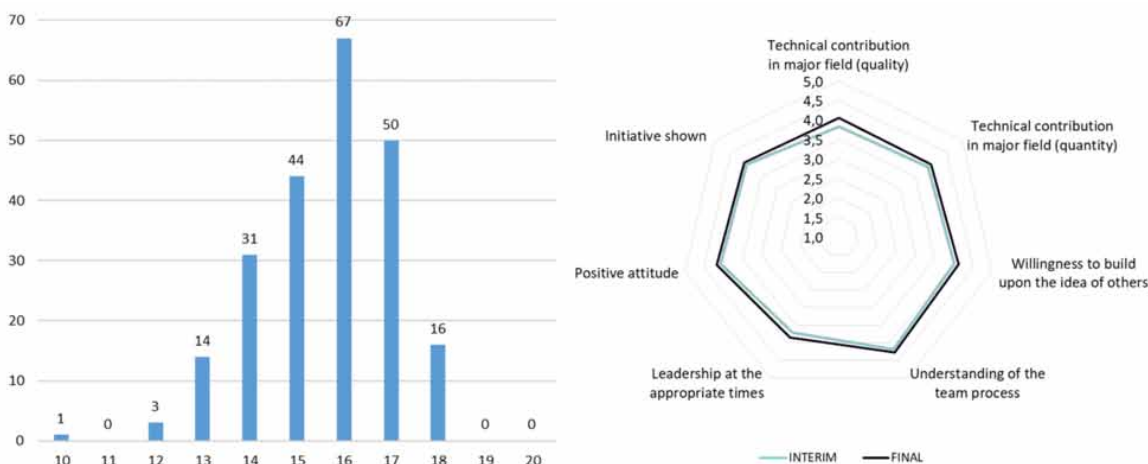


Figure 4 presents the tangible outcomes of the EPS process: the classification and the perceived self & peer evolution. These results exclude the two students, out of 230, who have failed EPS@ISEP so far.

Figure 4. EPS@ISEP classification (left) and self & peer evolution (right)



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Figure 4 (left) shows the classification histogram with a 0 to 20 grading scale. The most frequent grade is 16 out of 20. However, more important than the grade itself, is the students' perception of the impact of the EPS process. The latter analysis was based on the historical self & peer assessment, which includes the following dimensions: (i) technical contribution in major field (quality); (ii) technical contribution in major field (quantity); (iii) willingness to build upon the idea of others; (iv) understanding of the team process; (v) leadership at the appropriate times; (vi) positive attitude; and (vii) initiative shown. The self & peer questionnaire uses a Likert scale (1 to 5). Specifically, Figure 4 (right) depicts the evolution between the intermediate (lighter) and the final stage (darker). In this figure, a perfect heptagon means that all components have been apprehended equally and the size of each component indicates the level attained. The results in Figure 4 (right) show that, according to the students, all assessment dimensions improved from the interim to the final stage. There was an improvement in terms of the quality and quantity of their technical contributions and a greater awareness of how to work in a team and develop a project.

From this analysis, it is possible to conclude that EPS@ISEP is clearly aligned with the general guidelines of Organisation for Economic Co-operation and Development and United Nations Educational, Scientific and Cultural Organization, the engineering education curricula recommendations of the Royal Academy of Engineering, European Network for Accreditation of Engineering Education, European Society for Engineering Education and American Society for Engineering Education, and the accreditation guidelines of European Network for Accreditation of Engineering Education and Accreditation Board for Engineering and Technology. The program is organized around one central module – the “EPS Project” – and a set of complementary supportive modules, among which are “Ethics & Deontology” and “Energy & Sustainable Development”. Sustainability is one of the pillars of EPS@ISEP. Not only is it addressed explicitly in the “Ethics & Deontology” and “Energy & Sustainable Development” modules, but it is put into practice during the whole project.

Figure 5 shows that the budget allocated to different teams over the years has been decreasing to encourage reuse, waste reduction and improvisation with the available resources. The teams, in this context, choose to buy few affordable resources, reducing the environmental footprint of the prototypes. Moreover, the budget per team trend in the last years is to stabilize around 100 €. High budgets correspond to projects sponsored by companies and research laboratories.

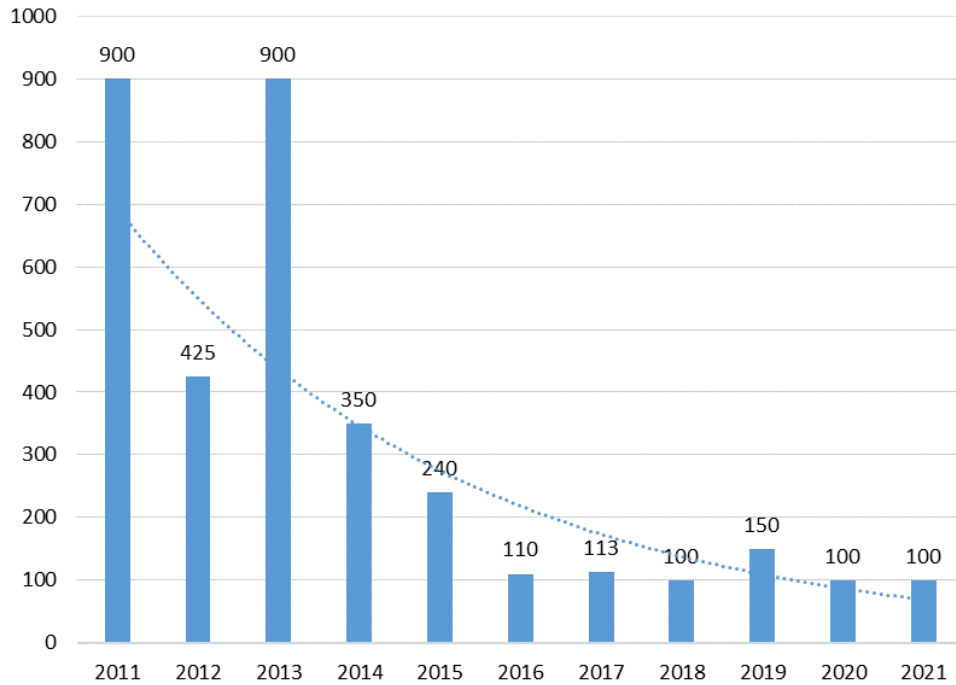
**Active Learning Strategies for Sustainable Engineering***Figure 5. EPS@ISEP budget per team*

Figure 6 displays the word cloud composed of the most frequent words found in the project reports. It reveals that the teams are highly aware of the ethical, deontological and sustainability concerns.

*Figure 6. EPS@ISEP word cloud*

### ***Active Learning Strategies for Sustainable Engineering***

In summary, EPS@ISEP promotes teamwork, active learning (lifelong learning), adopts PjBL and addresses ethics & deontology, eco-efficiency & sustainability, and cross-cultural & inter-personal communication.

The program syllabus is in accordance with the following recommendations:

- Engineering curricula must provide a capstone or integrating experience, emphasize the development of professional skills such as solving unstructured problems, communicating effectively and working in teams, and foster awareness of ethical and contextual considerations in engineering (Accreditation Board for Engineering and Technology, 2006).
- Future engineers must be aware of technology's social and environmental impacts, learn to work in complex teams, interact and cooperate with society, and be good communicators. Engineering design must go beyond the traditional objectives of schedule, cost and conventional scope and learn to include broader societal necessities (such as minimizing water, energy and materials use, respecting human and cultural rights, and looking out for health and safety). Engineering education would benefit from less formulaic and more PBL and PjBL and just-in-time approaches, reflecting the problem-based and problem-solving nature of engineering (United Nations Educational, Scientific and Cultural Organization, 2010).
- Engineering professionals need to be educated to consider sustainability issues in all aspects of design and manufacturing and to pursue collaborations with multidisciplinary teams of technical experts. Important attributes for these teams include excellence in communication, an ability to communicate using technology, and understanding the complexities associated with the global market and social context. Furthermore, it is essential for engineers to be flexible, receptive to change and show mutual respect. Attention to ethical issues in engineering will avoid repeating the mistakes of the past and increase the opportunities to emulate "best practice" successes (Committee on the Engineer of 2020, Committee on Engineering Education, and National Academy of Engineering 2005).
- Engineering colleges must promote not only the intellectual and technical development of the students, but prepare future engineers to work in teams, communicate and understand the economic, social, environmental, and international context of their professional activities. Engineering curricula need to incorporate team skills (including collaborative, active learning and communication skills), leadership, a systems perspective, an appreciation of different cultures and business practices (and the understanding that the practice of engineering is now global), a multidisciplinary perspective, a commitment to quality, timeliness and continuous improvement, undergraduate research and engineering work experience, an understanding of the societal, economic and environmental impacts of engineering decisions, and ethics (American Society for Engineering Education, 2010).

In this regard, Duarte et al. (2020) show that Iberian EPS faculty and students are aware of their projects' social, economic, and environmental impact, in terms of quality of life, social responsibility, and the use of resources and environmentally friendly technology.

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### CONCLUSION

EPS@ISEP is an engineering capstone program intended to prepare future engineering professionals. In recent decades, bodies like the Organisation for Economic Co-operation and Development, the United Nations Educational, Scientific and Cultural Organization, the National Academy of Engineering, the European Society for Engineering Education, the American Society for Engineering Education, the European Network for Accreditation of Engineering Education or the Accreditation Board for Engineering and Technology have emphasized the need, not only, to foster hard and soft skills, but also to embed sustainable and ethical design and development in the engineering curriculum.

In EPS@ISEP this is achieved through PjBL, multi-cultural and multidisciplinary teamwork, and learning autonomy. Thus, it promotes traditional technical-scientific and the desired soft skills required to design solutions for the well-being and advancement of society as well as creativity and life-long learning.

This conclusion is corroborated by the testimonials left on the project reports and by the learning experience improvement perceived by the participants from the interim to the final stage of the EPS process. This learning framework prepares engineers to become agents of positive transformation, contributing to a common, peaceful, and sustainable future on Earth.

### ACKNOWLEDGMENT

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. Nevertheless, the authors thank Jørgen Hansen for the support, the EPS providers for the fruitful exchange of experiences, students, and staff, and ISEP for believing in the program.

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### **KEY TERMS AND DEFINITIONS**

**Active Learning:** A student-centered learning method that promotes autonomous search for knowledge.

**Engineering Education:** The noble task of training conscientious and proficient engineers.

**European Project Semester:** A one-semester engineering program that implements active and project-based learning, multicultural and multidisciplinary teamwork and ethics and sustainability driven design to develop key professional competencies in future engineers.

**Project-Based Learning:** A learning framework where students are responsible for finding a solution to real-world self-motivating challenges.

**Socio-Professional Ethics:** A moral compass guiding professional actions and decisions with the goal to improve the well-being of individuals, society, and planet.

**Sustainability-Driven Design:** A conceptual design process where decisions aim to minimize the economic, environmental, and social impact of the product lifecycle.

**Teamwork:** A collaborative work method where several people work towards a shared goal (usually unattainable individually) that maximizes the strengths and minimizes the weaknesses of the participants.