The European Project Semester at ISEP: the challenge of educating global engineers

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Abstract

Current engineering education challenges require approaches that promote scientific, technical, design and complementary skills while fostering autonomy, innovation and responsibility. The European Project Semester (EPS) at Instituto Superior de Engenharia do Porto (ISEP) (EPS@ISEP) is a one semester project-based learning programme (30 European Credit Transfer Units (ECTU)) for engineering students from diverse scientific backgrounds and nationalities that intends to address these goals. The students, organised in multidisciplinary and multicultural teams, are challenged to solve real multidisciplinary problems during one semester. The EPS package, although on project development (20 ECTU), includes a series of complementary seminars aimed at fostering soft, project-related and engineering transversal skills (10 ECTU). Hence, the students enrolled in this programme improve their transversal skills and learn, together and with the team of supervisors, subjects distinct from their core training. This paper presents the structure, implementation and results of the EPS@ISEP that was created in 2011 to apply the best engineering practices and promote internationalisation and engineering education innovation at ISEP.

Keywords

European Project Semester; engineering education; project-based learning; learner-led- learning; teamwork; multidisciplinary projects

1. Introduction

Current challenges faced by engineering education are multiple and hard to address. Institutions and students are experiencing constant changes, including financial constraints, focus shifting and the need to provide and acquire new competences. Project-based learning (PBL) and problem-based learning approaches are particularly well fitted for engineering education, but they no longer provide all competences required in future engineers. Engineers are expected to be able to act in the global market, work in multicultural multidisciplinary teams, hold expertise in a specific engineering field and be proactive lifelong learners. This is the context that led to the European Project Semester (EPS) design and creation by Prof. Andersen (2004) in 1995 in Denmark. The EPS is a one semester PBL programme addressed to engineering students from diverse scientific backgrounds and nationalities. The goal is to offer engineering students a programme not only focused on developing scientific and technical competences, but also focused on soft transversal skills, which are in high demand by the market (Jollands, Jolly, and Molyneaux 2012; Lunev, Petrova, and Zaripova 2013). Over 300 students from 40 countries participate in this exchange programme each semester at 11 engineering college sites forming a significant network of international engineering education exchange (Abata, Andersen, and Krause 2013). The programme is offered by a selected group of European high education institutions. In order to run an EPS programme, the candidate institutions have to apply and follow a set of mandatory requirements.

Instituto Superior de Engenharia do Porto (ISEP), until 2011, offered undergraduate (B.Sc.) engineering programmes taught exclusively in Portuguese, making it difficult to attract foreign students from other countries. An internal effort was made in order to solve this situation and, in 2010, ISEP applied to run the programme, launching the EPS at ISEP (EPS@ISEP) in 2011. For ISEP, the programme is regarded as an additional tool to apply the best engineering education practices, increase the employability of its graduates and promote internationalisation.

Although in the case of EPS@ISEP, only European students have, so far, taken part, EPS, in general, encourages student exchange from all European countries, China, Japan and the USA. In the case of other EPS providers, several students from the USA have participated in this primarily European programme for the benefit of broadening their educational and career horizons as well as gain valuable insight to engineering design international approaches. The students from the USA have commented that the experience was very rewarding; however, there are several hurdles that US students must accept and overcome, such as meeting engineering requirements that, in some cases, has been problematic due to interpretation of Accreditation Board for Engineering and Technology Inc. senior design requirements. Another aspect is the fact that Memorandums of Understanding between universities and colleges in the USA and each of the EPS providers must be established to specify the conditions that apply to the exchanged students. These formal memoranda establish a one-to-one reciprocal student exchange allowing tuition transparency for participating students (on a mutually beneficial note, these memoranda have encouraged many students from Europe to attend a semester of study in the USA). These hurdles are not insurmountable but may require investment of both time and money (Abata, Andersen, and Krause 2013) as well as the willingness of the involved institutions. Nevertheless, there are also similar programmes for US institutions (Oladiran et al. 2011). Engineering students from the rest of the world wishing to participate in the programme may experience similar bureaucratic obstacles: (1) their home institution must recognise the EPS programme; (2) the EPS provider must recognise their background studies and (3) they may be required to pay fees if there is no exchange agreement between the student home institution and the EPS provider.

Given this brief introduction, this paper includes the following sections: introduction, EPS background, the EPS@ISEP programme, related programmes, the EPS@ISEP results and the conclusions.

2. Background

The EPS was created in Denmark by Prof. Arvid Andersen in 1995 to foster the development of international competences, project organised learning, teamwork and complementary transversal skills among engineering graduates (Andersen 2004). In the academic year of 2013–2014 EPS was offered in ‘s-Hertogenbosch and The Hague in the Netherlands, Oslo in Norway, Lodz in Poland, Kiel in Germany, Valencia and Vilanova i la Geltru in Spain, Vasa in Finland, Tarbes in France, Antwerp in Belgium, Bucharest in Romania, St Pölten in Austria and Porto in Portugal. These high education institutions share a common site – the EPS Providers site[1] – where prospective candidates can get information on the programme as well as on the providers.

Typically, students apply to the EPS programme during the precedent academic year via their home institution International Office. While students from partner institutions follow the accorded application procedure, the remaining students can apply as free movers and will be required to pay the applicable fees (750 €). In the specific case of the European students from partner institutions, the students apply under the Erasmus+ programme framework, *i.e.* they are fee exempted. Eligible EPS applicants must be third year or higher level engineering students, hold a Common European Framework of Reference for Languages B2 English level and have succeed all the modules from the previous academic semesters. Due to local human and physical resource constraints, the providers may define a *numerus clausus*, above which no more applicants are accepted. In the case of the EPS@ISEP, the students are accepted in a first come, first served basis and the current *numerus clausus* is 25 students.

The EPS programme is a 30 European Credit Transfer Units (ECTU) package structured generically as follows: two-thirds (20 ECTU) assigned for the project module and one-third (10 ECTU) for complementary modules. The complementary modules are focused on the development of soft skills considered essential in the training for the twenty-first century engineers (Jollands, Jolly, and Molyneaux 2012), such as communication or teambuilding, project-related activities such as project management and transversal topics such as sustainability (Mills and Treagust 2003; Rydhagen and Dackman 2011; Nicolaou and Conlon 2012) and ethics and deontology (Chang and Wang2011).

The EPS providers have discussed, agreed upon and posted on the EPS providers site (see note 1), the set of mandatory EPS programme features. These are the so-called 10 Golden Rules of EPS that all providers must follow:

(1) English is the working language of EPS.
(2) EPS is multinational with a group size of minimum three and maximum six students, being four or five the ideal number; a minimum of three nationalities must be represented in each EPS group.
(3) Ideally, but not necessarily, an EPS project is multidisciplinary.
(4) An EPS semester is a 30 ECTU package, the duration of which is not less than 15 weeks.
(5) 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.
(6) The main focus on EPS is on teamwork.
(7) The subjects included in the EPS must be project supportive; English and a basic crash course in the local language must be an option.
(8) The subjects must include Teambuilding in the very beginning and Project Management in the beginning of an EPS semester.
(9) Project supervision/coaching must focus on the process as well as the product.
(10) EPS must have continuous assessment including an Interim Report and a Final Report.

2.1. Teams and proposals

The EPS candidates are composed of international and national students. Before the start of the semester, the EPS candidates receive, via email, a Belbin questionnaire and are asked to fill and send it back to the provider. The goal is to determine the individual worker profiles and, thus, design balanced teams composed of complementary elements from as many diverse scientific backgrounds and as multinational as possible, according to Rule 2.

Before the beginning of the semester, a set of project proposals regarding real-world problems are collected by the provider. The proposals are intended to be multidisciplinary, *i.e.* require the integration of multiple technical and scientific competences, open, *i.e.* define the overall goal, but not the approach, with clearly defined milestones and maximum budget. The origin of proposals varies and includes industry, services, R&D institutions or the provider itself. The proponent or client must ensure the budget availability for the project execution.

After the selection/assignment of the proposals by/to the teams, the process begins. Team members must define how to work together in order to achieve the project goal, *i.e*. establish a work plan, identify and distribute the tasks as well as determine the approach to address the problem. Thereafter, teams must elaborate a list of the equipment required to accomplish the project, including the price of the components and the suppliers. In the case of external proposals, the project coaching/mentoring includes regular and close interaction with the client in order to ascertain that the goals are being pursued in an adequate way.

2.2. Seminars

The seminars, or complementary modules, support the main EPS activity – the EPS project. The aim is to provide soft skills such as communication, teambuilding, intercultural relationships or English. They address multidisciplinary topics such as sustainability or ethics and deontology, project-related themes such as project planning, management or product-related subjects such as product design and marketing.

2.3. Team coaching

One or more supervisors are assigned to each team. The supervisors act as coaches or consultants rather than leaders or instructors. The team and supervisor(s) meet at least once a week and feedback is provided by the supervisor(s) to help the team to improve their process performance and maintain focus and motivation. The supervisor(s) should not lead the meeting nor impose views on the team, but rather promote brain storming, foster the ideas of the team and act as a facilitator between the team and the real world (businesses, institutions or experts). The team must feel in charge and fully responsible for the project.

According to the EPS Guidance Notes (Andersen 2002), the main contribution of the academic supervisor is to help students to understand the content of their project and to ensure that they are making progress. It is also to nurture and facilitate the group work and the group process. The supervisor must make sure that the advantage of working together in groups is sustained.

2.4. Deliverables

Each team has to produce several types of deliverable materials. The interim and final presentation, the interim and final report and the product or prototype are mandatory deliverables. Then, depending on the provider, there are additional contents that the students must hand in such as posters, papers and videos. These deliverables constitute the EPS repository and are used by the providers to showcase the programme.

2.5. Team and individual assessment

The assessment is an essential component of the EPS programme. There are two assessment periods: the intermediate assessment by the seveth/eighth week and the final assessment in the last week (15th) of the programme. Since assessment strongly influences learning, any programme that intends to improve peer learning and collaboration must adopt an assessment approach that promotes both. Self and peer assessment is a valid solution for promoting these objectives and overcoming potential inequities of equal marks for unequal contributions. Group members are responsible for negotiating and managing the balance of contributions and then assessing whether the balance has been achieved (Self and Peer Assessment Resource Kit 2013). Therefore, in EPS both assessment periods include a self and peer component where the students grade themselves and their team members. This assessment involves seven dimensions and uses a scale between one and five. Whereas the interim assessment is intended for feedback purposes, allowing the teams to work on their weakest points, the final assessment is for the final grading.

The assessment is performed according to the EPS Guidance Notes (Andersen 2002) and is based both on the individual project execution and oral presentation as well as on the team performance and quality of the deliverables.

3. EPS@ISEP

ISEP is the engineering school of the Polytechnic Institute of Porto, the largest polytechnic in Portugal. ISEP was created in 1852, under the designation of Escola Industrial do Porto, and nowadays offers first cycle and second cycle engineering degrees to a universe of approximately 7000 students. Furthermore, it accommodates several R&D groups with strong industrial and academic links at both the national and the European levels. In terms of internationalisation, ISEP has a long list of active partners including European, African and South American institutions.

The mainstream learning methodology followed at ISEP is a balanced combination of sound scientific–technical background together with a strong practical approach. As a result, PBL comes as a natural choice to promote a pro-active autonomous learning attitude among the students. The EPS@ISEP addresses open real-world multidisciplinary problems with the aim of developing critical thinking, collaboration, communication and creativity/innovation in engineering students. Currently, EPS@ISEP is the sole undergraduate level programme offered in English by ISEP.

3.1. Study plan

The EPS@ISEP programme includes the following modules: Project (20 ECTU), Project Management and Team Work (2 ECTU), Marketing and Communication (2 ECTU), Portuguese (2 ECTU), Energy and Sustainable Development (2 ECTU) and Ethics and Deontology (2 ECTU). These seminars are organised around each team project. For example, communication, which includes English, contributes to the development of the project deliverables; project management focuses on task identification, human resource allocation, task planning and scheduling, resource management, plan enforcing and eventual rescheduling; sustainability addresses the ecological footprint; ethics and deontology analyses the ethical and deontological concerns; and marketing tackles the market analysis, segmentation and positioning of the prototype.

The complementary modules are finished by the intermediate assessment. There are, however, two exceptions: Portuguese and Project Management, which accompany the students throughout the semester.

3.2. Resources and organisation

The EPS@ISEP structure is light. It involves a coordinator, the international relations office, the student support office, a set of teachers that lecture the complementary modules, a group of supervisors that coach the teams and guest lecturers from other EPS providers. Furthermore, it relies on the ISEP laboratories, facilities, technicians and in-house experts as well as in external companies and research facilities.

The human resources included: 12 teachers, 11 ISEP teachers from 6 departments and 1 teacher from another school of the Polytechnic Institute of Porto in the spring of 2011; 12 ISEP teachers from 7 departments in the spring of 2012; 13 ISEP teachers from 7 departments in the spring of 2013 and in the spring of 2014, 12 teachers from 7 ISEP departments. The students occupy a dedicated room throughout the semester where the project development and the complementary seminars take place. The weekly coaching meetings are located in another room to allow the coaching panel and the team of students to brainstorm together, reinforce their relation and focus on each project at a time.

Depending on the complexity of the projects, the average cost of an EPS@ISEP project in terms of materials is approximately 350 e.

3.3. Modus operandi

The EPS@ISEP follows the EPS formula, *i.e.* follows the '10 Golden Rules'. However, there are specificities that make the EPS@ISEP unique, namely in the supervision, deliverables, modules and tools adopted.

During the preceding semester, the supervisors meet to start the project proposal gathering and to decide on the short list of proposals. This process is highly distributed and multiple proposals are collected for analysis. The ones that regard real-world problems, require several competences and have sufficient budget are selected for the final list of proposals.

Project selection occurs during the first week of the programme. In this initial week, students engage in several team building activities and, by the end of the week, send their choices by email. Typically, the projects are attributed on a first-come, first-served basis. However, in 2011, the same problem was proposed to two teams.

The supervision is performed by the panel of supervisors. This joint supervision model is unique. The panel of supervisors is composed of seven teachers from different departments: physics, mathematics, chemical engineering, electrical engineering, mechanical engineering and informatics.

Several electronic tools commonly adopted nowadays in industrial and service companies worldwide are used by the teams and teachers such as Dokuwiki, Dropbox, Google Mail, Google Calendar and Moodle. Moodle is the Learning Management System adopted at ISEP and is used in all modules to share materials and information between teachers and students. The Dokuwiki is used by all teams as the project log. Dropbox is used as a shared file system between all those involved in the process.

The wiki is a key tool in the EPS@ISEP process. The EPS@ISEP team provides a wiki template structured in Home, Work Plan, Logbook, Deliverables and Report. The teams are expected to use it as a repository, as well as a log. In the Work Plan area, the teams include all data relevant to the project management (identification of tasks, task allocation, Gantt chart, *etc.*). The Logbook registers the evolution of the process. Every week the teams need to write a short weekly report (one or two paragraphs), define the agenda for the upcoming supervision meeting and then add the minute of the meeting. The Deliverables area is intended for show casing all materials produced: interim and final report, interim and final presentation, paper, video, leaflet, poster and a user manual. The Report area contains the wiki version of the report. Templates are provided for the report, paper, presentation and poster. Figure 1 presents the main page of a project wiki.

The report structure is provided beforehand and includes as mandatory sections the introduction, state of the art, project development, marketing, sustainability, ethical concerns and conclusions. The marketing, ethical and deontological concerns as well as eco-efficiency and sustainability measures chapters are produced and refined within the corresponding complementary

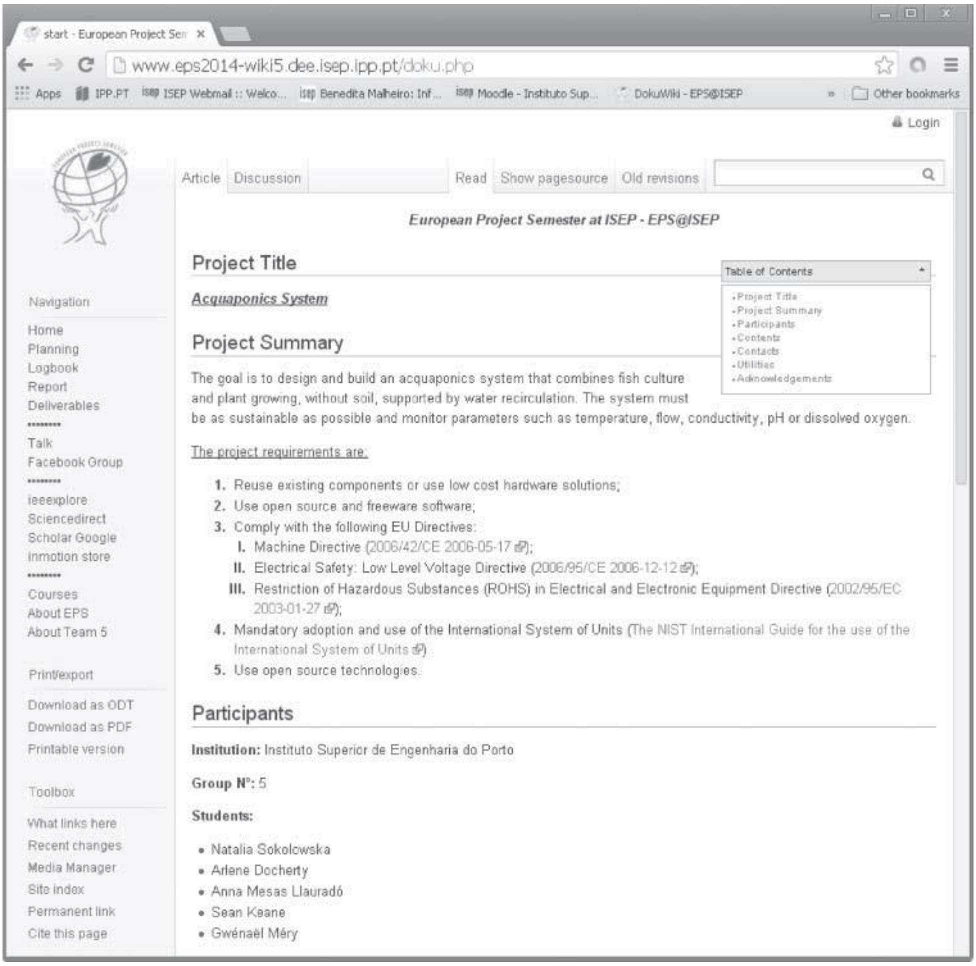

Figure 1. EPS@ISEP – example of a wiki. http://www.eps2014-wiki5.dee.isep.ipp.pt.

modules. The structure and presentation of the deliverables are addressed in the communication seminar.

Finally, a Google email account has been created and used as the email box for all EPS@ISEP related affairs and Google Calendar is used for scheduling all activities.

3.4. Coaching

In a standard engineering capstone project, the problem to solve is usually well defined, the solution is outlined and the technologies are chosen or suggested beforehand to the students. These standard projects are highly focused and, typically, encompass only one engineering scientific area. Both the supervisor and the student(s) share the same area of study, with only incidental incursions into sustainability and marketing. The supervision is assured by one (at most two) teachers usually from the same nationality as the students.

In an EPS project, the problem is not well defined, alternative solutions have to be identified, studied and proposed and the technologies to use are undefined, since open-ended problem solving is a central skill in engineering practice, and consequently, it is imperative for engineering students to develop expertise in solving these types of problems (Douglas et al. 2012). The focus of the project is more holistic, encompassing the sustainability and marketing areas.

The panel of supervisors acts as a consulting committee rather than 'directors'. As far as communication is concerned, the supervisors have to be aware that they are interacting with people from diverse scientific and cultural backgrounds. Furthermore, in the weekly supervision meeting only the topics previously specified by the team in the wiki agenda are discussed.

The greatest contrast with standard projects is the dynamic nature of EPS projects. While a standard project proposal includes typically the project guidelines, the EPS project proposal only states a broad problem and specifies a budget. It does not intentionally specify instructions, approaches or technologies. During supervision new problems, alternative solutions and competing technological approaches may arise each week. Additionally, the solution to a specific problem may also lie outside the supervisors' expertise. In this case, the supervisors have to admit their lack of expertise and find scientific support within their school peers. In this sense, supervising is also a scientifically enriching experience.

Students who take the EPS project usually have no prior experience on large projects or as working within a large team. It is therefore expected that they could lose motivation as they face difficulties. The fact that projects are organised in two stages, with clear and well-defined milestones, allows students to timely reconsider their options, learn from the mistakes, recover and successfully finish the project. Additional motivation comes from the fact that the students feel that they are in control of the project, *i.e*. they decide the approach, the design and the technologies.

Another very important aspect of the coaching methodology is the prompt feedback given to the students by the coaching team. Students meet with supervisors once a week in a meeting room, where they discuss the topics the team has previously indicated in the wiki agenda. This way, extremely productive discussions are generated since the supervisors know beforehand which aspects will be addressed in the meeting and can get prepared in advance.

Supervising EPS projects is both challenging and uncomfortable. From the supervisor point of view, it widens the somewhat over focused perspective of the classic engineering teacher. It is a very enriching experience since the main driver of the project is not the proposal, but the team of students. The supervisor acts as an expert consultant that helps the students to achieve their goals. And the reward of all the coaching effort lies here.

3.5. Conflict resolution

Disagreements and conflicts arise naturally among team members during project development. While the majority of these differences tend to contribute positively to the process, some are irreconcilable. As a result, it is necessary to put in place a conflict resolution mechanism.

EPS@ISEP has adopted the mechanism proposed by Hansen (2010). Once the teams are made, one of the first tasks the members are faced with during teambuilding activities is to define their set of conflict resolution rules. An initial set of rules is provided and, first, each member identifies and orders them according to his/her own opinion and, then, as a team, order them together by relevance. The resulting document is signed by all team members and archived in the team folder.

The supervisors are responsible to identify when irreconcilable views or tensions arise among team members and recommend the application of the conflict resolution mechanism.

3.6. Assessment

It is known that assessment drives learning and hence a good assessment design is the key to effective student development (Rossiter 2013). EPS@ISEP uses the assessment scheme proposed by Hansen (2010). The assessment occurs twice during the semester and has two components: self and peer (S&P) and supervisor assessment. The S&P assessment takes into account the quality and quantity of the technical contribution, openness to others ideas, teamwork performance, leadership, attitude and initiative shown. The S&P assessment is handed in by the students prior to the interim and final presentations. Students get individual grades.

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 supervisors. The final assessment includes again S&P and supervisor assessments. The S&P is used to modulate the process performance grade attributed by the supervisors, accounting for 35% of the final Project module grade. The final EPS@ISEP student grade is the weighted average of all modules grades, where the weights are the number of ECTU of each module.

4. Related programmes and EPS@ISEP

This section presents EPS and Global Engineering Teams (GET) programmes and makes comparisons between the EPS and GET approaches as well as between the EPS@ISEP and other EPS programmes. The related programmes covered include the EPS programmes at Copenhagen University College of Engineering, Technical University of Catalonia (UPC), Technical University of Valencia (UPV) and Artesis University College (AUC) as well as the GET programme.

4.1. EPS at Copenhagen University College of Engineering

As stated in the previous section, EPS was created in Denmark by Prof. Arvid Andersen in 1995 and was based on Denmark’s long tradition for project organised and problem-based learning. By 2010, this exchange semester for engineering students at Copenhagen University College of Engineering had already involved 1148 students from 35 countries. According to Hansen (2010), EPS has been a great success and students acquire international competences and soft skills at the same time as they learn from the technical project work.

All existing EPS programmes generically follow the Copenhagen University College of Engineering EPS matrix.

4.2. EPS at the UPC

The EPS programme offered at the School of Engineering of Vilanova i la Geltrú (EPSEVG) – UPC strongly emphasises the introduction of competences in sustainability and human technology (Segalàs Coral, Esbrí Solanas, and Benson Murphy 2011). At this school, the complimentary modules (seminars) include courses in Sustainable Technologies, Business and Sustainability and Human Technology, among others. The projects are real-life projects proposed by local companies and research groups that must meet a set of criteria, namely, be multidisciplinary, complexity adequate for final year Bachelor students, difficulty adequate for project completion in 12 weeks and the company has to provide a supervisor and facilitate all the information needed to carry out the project in English. Since 2008, the number of participants has increased from 9 in 2008 to 30 in 2011. The students, who have participated in a total of 15 projects, have come from 16 different European and North American universities and from over 18 different academic disciplines, and more than 40 teachers have participated in the EPS either as teachers or supervisors (Segalàs Coral, Esbrí Solanas, and Benson Murphy 2011). The assessment of the programme shows excellent results as all the students who have participated in the EPS at the EPSEVG have successfully passed the EPS programme and, most importantly, the programme has always been very highly rated in the internal questionnaires addressed to teachers and the comments from students have always been very positive.

4.3. EPS at the UPV

The School of Design Engineering (ETSID) – UPV started the EPS in September 2005 (Pena et al. 2009). This school selected as supervisors professors with experience working with foreign students and with a good knowledge of project management. For the seminars, ETSID counted with the help of lecturers from other universities who were experts in team work and PBL. Teachers from ETSID also participated in the fields of communication and cultural activities. On the first year, the EPS ran with 21 students from 12 distinct universities. By 2007, there had already been conducted 14 projects by students from 18 different countries and a wide range of fields of study, including Process Engineering, Environmental Technology, Agronomy, Export Engineering, Mechanics, Electricity, Electronics, Industrial Computing, Industrial Design, Interior Design, Ergonomics, Business Management, Economy and Human Technology, among others. As with the case of EPSEVG, the projects are proposed by local companies. Some of the students participating in EPS have used the programme as a part of their Master studies, some as a part of their Bachelor degree. However, for ETSID students, it represents their Final Project (Pena et al. 2009).

4.4. EPS at AUC

AUC started the EPS in September 2012, having 16 students in its first edition, being able to build on the experience and expertise of other schools in Europe who had run a similar programme for several years. Furthermore, they could count on the teachers of two experienced EPS providers to teach courses of Teambuilding and Project management in the context of EPS during their first edition, and received several EPS principles and assessment procedures which had been developed and redesigned over the years by these more experienced EPS providers, with whom they discussed intensively their EPS experiences (Rohaert, Baelus, and Lacko 2012). At this school, EPS is offered as a multidisciplinary programme in close collaboration with the following study programmes: product development, engineering, business studies, social work and teacher training. This school selected for the EPS a team of lecturers and supervisors comfortable with teaching students in English, committed to design adequate courses with the right content and level of difficulty and well prepared to coach multidisciplinary teams with students from very heterogeneous backgrounds. However, due to the choice to embrace more disciplines in its EPS programme, some changes were implemented by AUC. AUC is the only EPS provider who originated the EPS programme starting from the study programme of Product Development instead of starting from the department of engineering. Therefore, they emphasise foremost the integrated approach of interdisciplinary product development in their EPS project proposals and supportive courses, next to the PBL and problem-based learning tradition, which have always been the fundaments of their product development study programme. In the first edition of this school's EPS programme, the students were given a list of discipline experts, whom they could meet (upon appointment) whenever they needed their expertise and who would evaluate the team's midterm and final project reports and presentations. Based on this experience, for the second edition they opted to indicate specific discipline experts for each team and organise frequent meetings between these experts and the students from week 2 till the end of the semester. The advantages of the introduction of these team specific discipline experts are twofold: first, besides acquiring all the competences involved in working on a challenging real-life problem in an international and multidisciplinary team, the professional development of each team member in his or her own discipline is now more closely and more regularly monitored, and second, they invite future project supervisors to operate as discipline experts for at least one EPS semester, to become familiar with the EPS learning concept, to obtain a better insight into the kind of project challenges which can be handled by the team and to get a realistic estimate of which project outcomes to expect when developing their own EPS project proposal for the next edition.

4.5. Virtual alliances for learning society

The objective of the Virtual Alliances for Learning Society (VALS) project is to establish sustainable methods and processes to build knowledge partnerships between Higher Education Institutions (HEIs) and companies to collaborate on resolving authentic business problems through open innovation mediated by the use of Open Source Software. The innovative approach of VALS is to leverage virtual placements of students in companies in order to foster entrepreneurial skills and attitudes and to make use of the results to establish new learning and teaching methods. This will result in the Semester of Code methodology, a sustainable set of methods and processes for creating and managing virtual placements and for integrating these practices into innovative teaching and learning strategies (García Peñalvo et al. 2013).

In order to achieve its goals, VALS will develop guidance for HEI, businesses and foundations, detailing the opportunities and the benefits to be gained from the Semester of Code as well as the required changes to the existing organisation and practice. A Virtual Placement System will be developed, adapting Apache Melange, and extending it where necessary. In piloting, the necessary adaptations to practice will be carried out, particularly in HEI, and commitments will be established between problem owners and virtual placement applicants. The Semester of Code approach will then be mainstreamed.

4.6. Global engineering teams

A somewhat similar project in its objectives is the GET, which started in 2004, based in the previous experience of Technische Universität Berlin, which has been one of the pioneers of the development of international, blended learning and project-oriented engineering courses, with activities in this field starting in 2002 with the Global Product Development course (Oladiran et al. 2011). GET is a multinational, intercultural and geographically dispersed team-based approach at solving practical engineering problems, and each edition lasts for about six months between April and October. The groups in the GET programme are virtual teams (a challenge in using virtual teams is the availability of high-speed Internet access) consisting of students located in different countries and usually across multiple time zones. GET aims to foster teamwork and digital collaboration among students with different technical and cultural backgrounds by engaging them in challenging industry-sponsored projects. GET has three main objectives: (1) solving engineering tasks in international groups comprising students from different countries; (2) using interdisciplinary project-oriented principles based on ‘learning by doing’ and (3) considering engineering tasks holistically to promote global sustainability in terms of economical, ecological and socio-political principles. In summary, GET is a programme that promotes project-oriented tasks in virtual student teams working in collaboration with industry partners (Oladiran et al. 2011). There are two main conditions for GET projects: they should be challenging and sponsored by industrial partners. The industry partner who orders a project is treated as a normal business partner. That provides a realistic situation in which the students are motivated to work as regular professionals. In this sense, GET provides exposure to ‘real’ engineering, sometimes interdisciplinary, hands-on, industrial-specific problems. Therefore, students have an opportunity to use their knowledge and creativity to solve real-world problems contracted by industry. Academics from the participating institutions and industry partners serve jointly as project supervisors. Supervisors and students communicate by using modern telecommunication tools (*e.g.* Skype, videoconferencing, SMS and email) in order to deliver an engineering project, particularly in the area of sustainable product development and manufacturing.

4.7. EPS versus GET

Both EPS and GET programmes are similar in terms of industry sponsorship of projects and the idea of students working in teams, and one of the GET programme objectives is also to foster soft skills and, in particular, teamwork in students, aspects which are not usually covered in many engineering programmes. However, students participating in EPS have to write an end of programme report for examination purposes whereas students in GET are assessed at different milestones during the programme. Teams in EPS comprise mainly European students, whereas GET facilitates collaboration between students from developed countries (*e.g.* Germany) and developing countries (*e.g.* South Africa, Botswana, Brazil and lately Chile).

Finally, Oladiran et al. (2011) mention other programmes worldwide that promote innovative approaches towards student learning, namely Engineers without Borders (EWB), Engineers for a Sustainable World (ESW) and Engineers in Technical, Humanitarian Opportunities of Service Learning (ETHOS). These programmes, namely EWB, ESW and ETHOS, have shown that project-oriented multidisciplinary teamwork is highly effective in promoting design experience and international collaboration.

4.8. EPS@ISEP versus other EPS Programmes

By comparing the EPS@ISEP programme with these other programmes, it is possible to identify a few process differences. A major difference resides in the fact that in the EPS@ISEP the project supervision is assured by a team of supervisors, from distinct scientific areas and with different backgrounds, whereas in the other programmes the teams are usually supervised by a unique supervisor. The EPS@ISEP coaching approach presents advantages since the projects developed are inherently multidisciplinary and the joint supervision provides a larger scientific and technical support to the teams. In terms of support tools, the wiki plays a decisive role in the EPS@ISEP process. The way the complementary modules are organised, *i.e*. as project supportive modules and, thus, focused around each team project, motivates students to address non-technical topics such as ethics, deontology or broad range topics such as sustainability.

Another significant distinction has to do with the fact that all enrolled students in the programme, up until this academic year (2013–2014), have been from European countries; other institutions running the programme have received students from other non-European countries.

Finally, one last distinction has to do with the project proposals offered to the students. In the EPS@ISEP, the vast majority of the projects are based on suggestions by the supervisors or ISEP internal research teams, while in most of the other programmes the projects are offered by industrial companies. This is due to the severe financial crisis that Portugal is facing and to the fact that it is preventing companies from investing in applied R&D developed by HEIs.

5. Results

The EPS@ISEP has been running consecutively since the academic year of 2010–2011. In this period, 60 students have successfully accomplish the programme.

Table 1. EPS@ISEP students – nationality diversity.

Nationalities	Number of students			
	Spring 2011	Spring 2012	Spring 2013	Spring 2014
BE			2	1
DE		2	2	4
ES		4		2
FR				1
HU	2	1		1
FI			2	2
LT		2		
PL	2	5	5	4
PT	1	1	1	
SP	3	1	1	4
TR				1
UK				3

The EPS@ISEP programme was launched in the spring of 2011 with eight students from four nationalities and four different engineering backgrounds. These students were organised in two teams of four students and both teams were confronted with the same project proposal/problem: how to maintain the humidity level in a data centre within a pre-specified range? The teams adopted diverse approaches to address this problem and the two prototypes were handed to the client – ISEP data centre. The decision to propose the same problem to both teams, which was based on the available funding, produced surprisingly interesting results. The prototypes, although fulfilling the requirements, were quite different in terms of technical approach and design.

The spring 2012 welcomed 16 students from 7 nationalities and 10 different engineering backgrounds. These students were organised in four teams of four students and each team chose a different project proposal. The project proposals included an interactive table, a fluid disinfection system, a smart object and a level monitoring system for oil containers.

Thirteen students from 6 nationalities and 10 different engineering backgrounds participated in the programme in the spring of 2013. They were organised in two teams of four students and one team of five students. The teams developed a solar algae dryer, a pet tracker and the structure of an autonomous environmental buoy/regatta beacon.

The 23 students of the spring of 2014 came from 10 countries and are from 12 engineering programmes. They were organised in three teams of five students and two teams of four students. The projects include a bio-inspired swimming robot, a travel logging system, a bio-inspired flying robot, a modular LED lamp and an aquaponics system.

Table 1 presents the EPS@ISEP students per nationalities and semester. There are 12 different nationalities represented in this 4-year period.

The contribution of the programme to the undergraduate student mobility (incoming students) at ISEP during the second semester was 23% in 2011, 58% in 2012, 55% in 2013 and 41% in 2014, as presented in Figure 2.

Table 2 shows the list of projects developed as well as the clients.

Figure 3 provides an overview of the diversity in terms of engineering background. The background of the EPS@ISEP students ranges from bioengineering, printing, marketing, logistics or international purchase and sales engineering to standard areas such as civil, electrical, industrial design or mechanical engineering.

Figure 4 presents the aggregated S&P final assessment results, where the numbers represent the seven S&P assessment components: (1) quality and (2) quantity of the technical contribution, (3) openness to others ideas, (4) teamwork performance, (5) leadership, (6) attitude and (7) initiative.

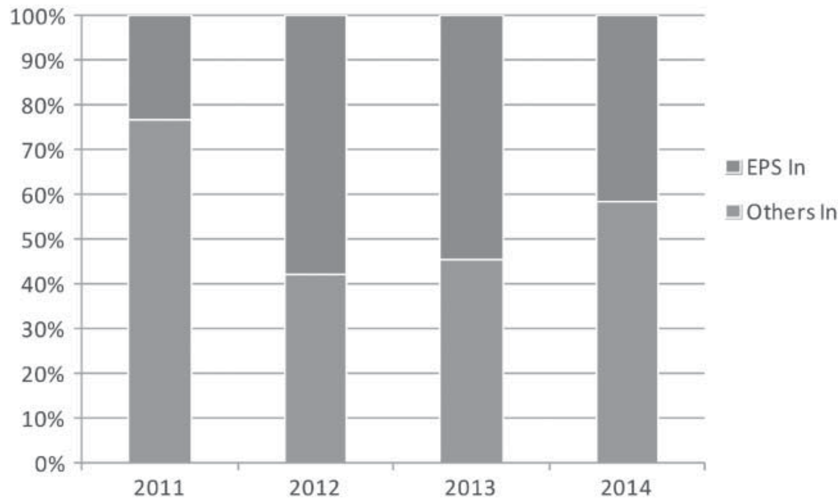

Figure 2. EPS@ISEP undergraduate student mobility impact.

Table 2. EPS@ISEP projects and clients.

Project title	Client
Humidifier with a Web Interface	ISEP Data Centre
Interactive Light and Sound Table	ISEP Museum (http://www.isep.ipp.pt/museu/)
Fluid Disinfection System using UV Technology	Chemical Technology Laboratory (ISEP)
Smart Object	ISEP Museum (http://www.isep.ipp.pt/museu/)
Level Monitoring System for Waste Oil Containers	EGi – Energie Generation Industrie, Lda (http://www.egi-energia.eu/)
Solar Algae Dryer	Chemical Technology Laboratory (ISEP)
Pet Tracker	ISEP
Environmental Buoy/Regatta Beacon	Autonomous System Laboratory (ISEP) (http://www.lsa.isep.ipp.pt/)
Swimming Robot	ITSector, Sistemas de Informação, SA (http://www.itsector.pt/)
Travel Logging System	ITSector, Sistemas de Informação, SA (http://www.itsector.pt/)
Bio-inspired Flying Robot	Autonomous System Laboratory (ISEP) (http://www.lsa.isep.ipp.pt/)
Modular LED Lamp	Manuel Silva
Aquaponics System	Reaction and Chemical Analysis Group (ISEP)

These results show clearly where there are deviations between the self and the peer perceptions. In the spring of 2011, which was more homogeneous regarding scientific backgrounds, the peer assessment is higher than the self-assessment. On subsequent years, the self-perception of personal regarding the technical quality contribution is higher than the peer assessment. The rather different backgrounds, associated to cultural differences, explain partially these results. Regarding team work, there is also a high disparity between the self and peer assessments, *e.g.*, there are differences of more than three points in a scale from one to five. In the spring of 2013 and 2014, an overall deviation between the peer and the individual teamwork appears on the results.

The S&P assessment evolution between the interim and the final presentation provides feedback on how the students react to the adopted process. Figure 5 provides an overview of the ratio

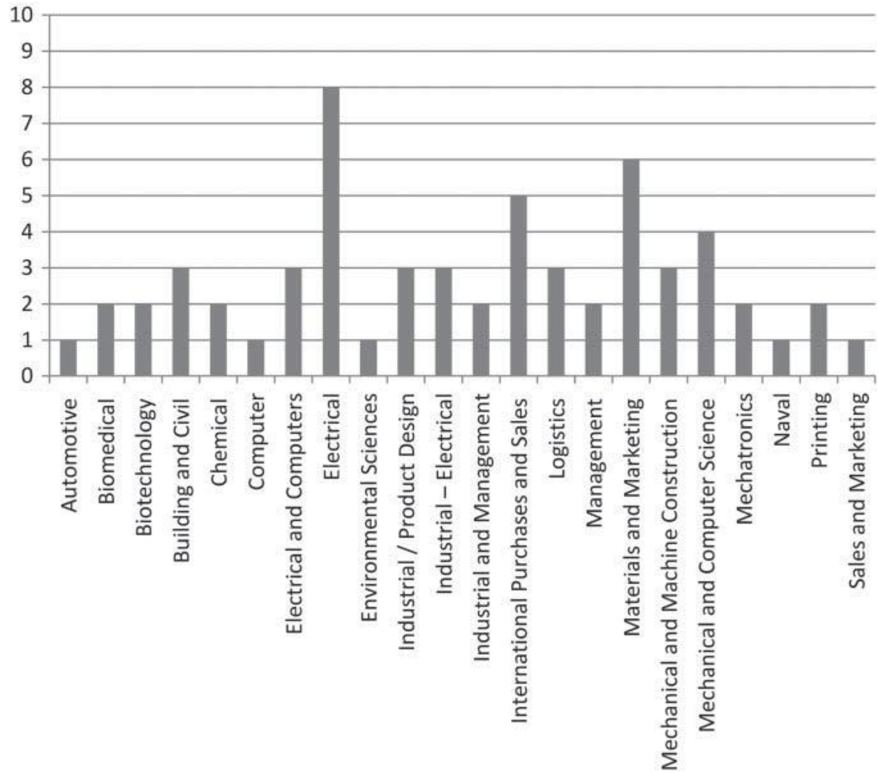

Figure 3. EPS@ISEP students – scientific background diversity.

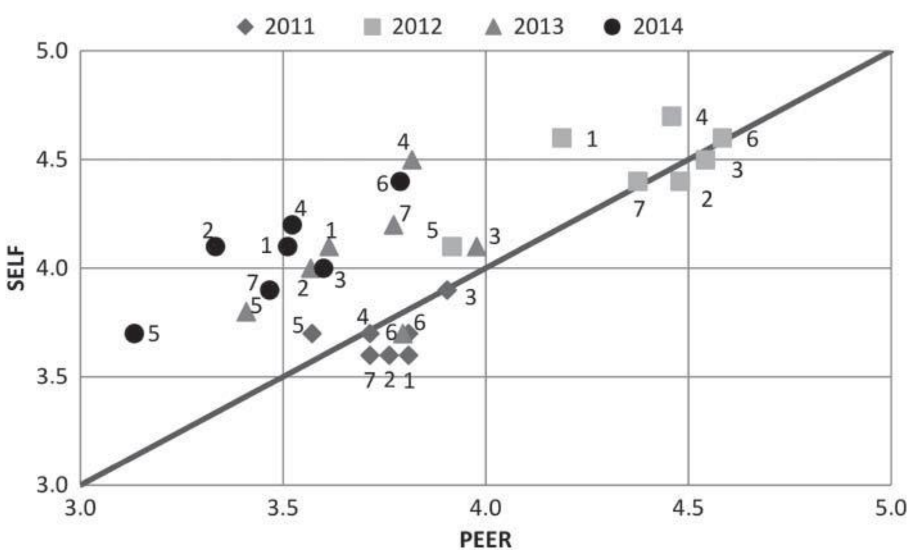

Figure 4. EPS@ISEP students – final S&P assessment.

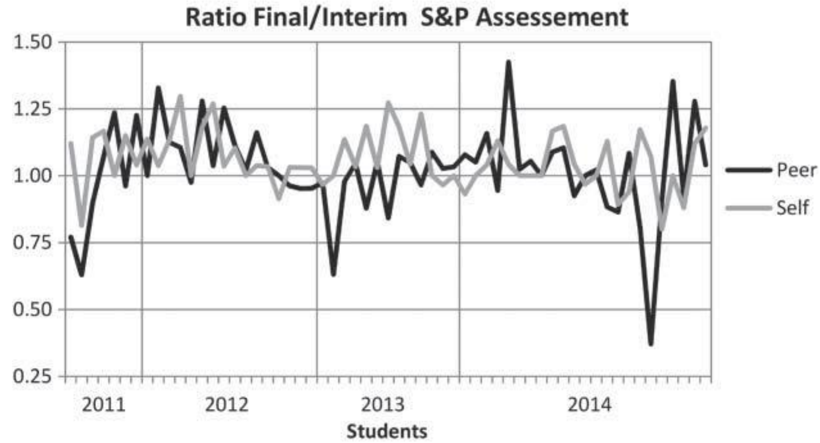

Figure 5. EPS@ISEP students – final/interim ratio of the S&P assessment.

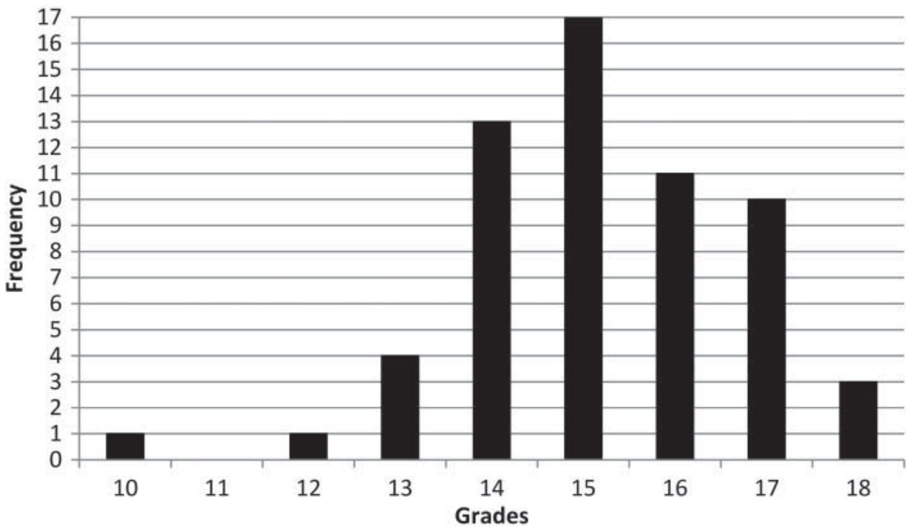

Figure 6. EPS@ISEP students – histogram of the final grades.

between the final and the interim S&P assessment component, where the students are ordered by year. Values higher than the unit mean that there was a higher level of individual commitment during the second half of the semester, when the teams are focused on the prototype development.

The student success rate is 100%. Figure 6 presents the histogram of the grades regarding 2011, 2012, 2013 and 2014. The mean grade is 15.2/20, the standard deviation is 1.5/20, the highest grade is 18/20 and the lowest is 10/20.

In terms of external recognition, the four projects from the spring of 2012 were submitted and accepted for the Conceive Design Implement Operate (CDIO) Academy Exhibition 2013, which took place at the Massachusetts Institute of Technology, Cambridge, Massachusetts, USA in June 2013 (CDIO Academy 2013). Two former EPS@ISEP students presented their projects and represented the EPS@ISEP programme at this international engineering project display involving teams from the most prestigious engineering schools in the world. Additionally, a preliminary and short version of this paper (Malheiro et al. 2013) and two projects from the spring of 2012 have been accepted as posters at the first International Conference of the Portuguese Society for Engineering Education 2013: the interactive light and sound table (Reimus et al., 2013) and the level monitoring system for waste oil containers (Moura et al. 2013). An extended description of the smart cube project developed in 2012 was published as a book chapter (Harms et al. 2014). The pet tracker and the environmental buoy/regatta beacon projects from the spring of 2013 were submitted and accepted at the CDIO Academy Exhibition 2014, which took place at the Universitat Politècnica de Catalunya, Barcelona, Spain in June 2014 (CDIO Academy 2014). However, since none of the students involved in these projects was still enrolled at ISEP at the time of the exhibition, these projects were not presented.

6. Conclusions

The EPS@ISEP programme was implemented in 2011 and has, since then, run always in the spring semester. The results are, so far, encouraging both in terms of student performance as well as in terms of external recognition.

The project module acts as a pivotal unit around which the team, supervisors and complimentary modules revolve. The complimentary modules are project supportive modules and, thus, are focused around each team project. This instantiated approach is a strong incentive for engineering students to address non-technical topics such as ethics, deontology or broad range topics such as sustainability. Even project management skills are easier to develop when there is a project to run with predefined intermediate and final milestones.

The experience gained with the EPS@ISEP reinforces the recommendations of Mills and Treagust (2003) that urged the adoption of PBL as a key component of engineering programmes and that, as such, should be promulgated as widely as possible (Mills and Treagust 2003).

6.1. Achievements

The EPS@ISEP programme is a tool for the internationalisation of the EPS students as well as for the school. It is the sole programme offered in English at ISEP and, as such, contributes with 44% of the incoming student mobility in the last four years. The success of the programme is based on the methodology, the process, teamwork and diversity in terms of cultural and scientific backgrounds. It is a PBL programme intended to prepare engineering students to work in international teams and, thus, tries to replicate the international engineering environment.

The EPS@ISEP approach addresses some of today's engineering education challenges – the graduates become familiar with teamwork, cross-cultural communication and real-world engineering practices and are aware of the ethical, deontological, eco-efficiency and sustainability concerns that arise when developing a new prototype. Furthermore, the students are encouraged to be proactive learners, designers and implementers with good communication skills. This integrated engineering education approach, involving PBL, the development of complementary skills, teamwork and cross-cultural experience, helps preparing engineering students for their professional life, *i.e*. to identify their 'role' in the world.

The students are motivated to work together since the first week where teambuilding activities are proposed. The teams are then encouraged to be autonomous, creative and responsible. They are expected to lead their project and solve their problems. For the students, the approach is novel and challenging. Not only they work in multicultural teams and use a foreign language, but, for the first time, the team is in control of the process, *i.e*., they decide how to solve a problem. The variety of deliverables they have to produce, including a report, a poster, a paper, a video and a user manual, and the interim and final presentations promote their communication skills.

The adoption of the wiki as the team log, deliverables repository, project showcase and team-supervisor interface proved to be correct. The wiki prevails once the students have finished and remain as a testimonial of the EPS@ISEP process.

The results and the interpretation presented are based on the data set available. Further data would allow a more accurate interpretation and, eventually, additional conclusions.

The EPS@ISEP staff is a dedicated group that works also as a team, follows the process guidelines and enjoys contributing actively to this metamorphosis where engineering students learn to become engineers.

6.2. Future

The EPS@ISEP can be further consolidated and improved, *e.g.*, every year the requirements of the deliverables have been refined and the templates perfected.

The short list of project proposals should be made available sooner so that the students can investigate and prepare on their own prior to their arrival. The number of companies involved, *i.e.* contributing with multidisciplinary problems and funding, needs to be increased.

The feedback provided during the programme can be strengthened to allow the fast identification of and recovery from internal team conflicts.

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Note

1. http://www.europeanprojectsemester.eu.

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