Chapter 11
Robotics and the European Project Semester

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ABSTRACT

Robotics is a multidisciplinary subject that typically involves mechanics, electronics, and computer science concepts. For this reason, robotic projects are particularly well suited to the European Project Semester framework since they allow students with different backgrounds to contribute to the overall team objective in their specific knowledge areas. This chapter briefly presents illustrative examples of robotic projects that have been developed by teams of students participating in the European Project Semester at the School of Engineering of the Polytechnic Institute of Porto. It concludes by presenting and discussing student feedback, namely on the program and the projects developed.

INTRODUCTION

The EPS@ISEP is the EPS implementation at Instituto Superior the Engenharia do Porto (ISEP) – the School of Engineering of the Porto Polytechnic. This one-semester program welcomes engineering, business, and product design students since the academic year or 2010-2011 and, naturally, follows

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the European Project Semester concept: prepare future engineers to think and act globally, by adopting project-based learning and teamwork methodologies, fostering the development of complementary skills, and addressing ethics, sustainability and multiculturalism. Multidisciplinary collaborative teamwork (Duarte *et al.*, 2015) as well as ethics and sustainability-driven design (Duarte *et al.*, 2020) are pervasive concerns within EPS@ISEP projects. EPS creates a diverse environment within each team, where each member brings his/her own specific set of skills, knowledge, and culture. All projects developed within the EPS@ISEP are based on the application of scientific, economic, social, and practical knowledge to design and invent solutions to improve the quality of life on Earth.

EPS@ISEP is a 30 European Credit Transfer System Units (ECTU) package structured in six modules: Project (20 ECTU), Energy & Sustainable Development (2 ECTU), Ethics & Deontology (2 ECTU), Marketing & Communication (2 ECTU), Project Management & Team Building (2 ECTU), Portuguese Culture & Language (2 ECTU). Apart from Portuguese, the remaining 2 ECTU are project support modules. They allow students to analyze essential aspects with impact in their solution's design and development, such as sustainability, marketing, ethics, and teamwork. The faculty involved in project coaching and module teaching are from seven departments of the School of Engineering (chemical, electrical, informatics, mechanics, management, mathematics, and physics).

Before the beginning of the semester, a set of project proposals regarding multidisciplinary problems affecting society are collected. The origin of proposals varies and includes industry, services, R&D institutions, or the school itself. The proposals tend to be multidisciplinary problems, *i.e.*, require the integration of multiple technical and scientific competences. A proposal defines the problem/challenge to address, the minimal set of requirements, mostly mandatory directives and standards, and the maximum budget. Depending on the complexity of the projects, the average cost of an EPS@ISEP project in terms of materials is approximately 200 €. Each team is expected to choose, design, build, test, and deliver a prototype of the solution to the chosen problem together with several other deliverables, ranging from reports (interim and final), presentations (interim and final), a paper, poster, video, leaflet, user manual as well as the drawings, 3D model, code developed and demo of the prototype. A strong effort is made to ensure the team elements are from different countries and have a diversified technical background. This aims to fulfill all technical, scientific, and commercial demands of a successful prototype evolution while maximizing the cultural and knowledge exchanges among the students.

These projects share another ulterior goal in the context of engineering education: to help the students develop personal, teamwork and problem-solving skills while applying and enriching their technical-scientific knowledge. Gopakumar has coined this ability as public leadership, *i.e.*, engineers who excel not only in technical problem solving but also have the understanding and skills to operate within a complex, fast-changing social, political, and cultural environment (Gopakumar, 2014).

The above-stated objectives can be fulfilled by developing biomimetic or artistic robots. Furthermore, the development of biomimetic robots has already been used for attracting K–12 students to pursue careers in science, technology, engineering, and mathematics (Laut *et al.*, 2015). This type of project directs teams towards the conceptualization, design, implementation, and operation stages of the capstone project/internship (Malheiro *et al.,* 2015).

Given these ideas, the four projects analyzed in this paper are: (*i*) Bro-Fish, an educational construction kit, directed to children between eight to twelve years old; (*ii*) Bubbles, an educational robotic toy for teaching young children the basics of programming through play; (*iii*) MyBird, a bioinspired flying robot; and (*iv*) GraphBot, a color drawing robot for children, commanded by voice.

Following this introduction, the remainder of this chapter is organized according to the following structure: Section 2 describes four examples of robotics projects developed within EPS@ISEP. Section 3 analyses the impact of robotics projects, including student testimonials, and, finally, Section 4 presents the conclusions.

EXAMPLES OF ROBOTIC PROJECTS DEVELOPED WITHIN EPS@ISEP

The following subsections present four examples of different robots developed by teams of students participating in different editions of EPS@ISEP. First, it describes three examples of biologically inspired robots, mimicking fish (BroFish and Bubbles) and birds (MyBird), followed by a more conventional drawing robot (GraphBot).

Bro-Fish – An Educational Construction Kit

The Bro-Fish robot was developed by a gender-balanced team composed of Spanish, Finnish, German and Polish undergraduates enrolled in Civil Engineering, Electrical Engineering, Naval Architecture and Maritime Engineering, and Mechanical Engineering and Computer Science.

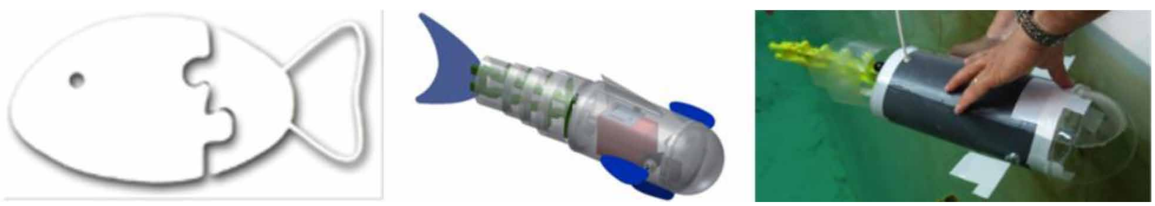
According to the team, their motivation for choosing this project was based on the following main reasons: (*i*) the unquestionable relevance of oceans to Earth, which derives from their cumulative dimension (70% of the surface of the planet) and amount and variety of life forms supported (99% of existing habitats); and (*ii*) the challenge of designing a biomimetic swimming robot, a design choice which, when compared to thrust propelled vehicles, grants higher efficiency and increased maneuverability (Ishii *et al.*, 2014).

With this motivation, their main goal was to provide an innovative and engaging opportunity for children to learn. The idea is that children who are early exposed to technology will hopefully be able to contribute to future technological innovation and development. To stem children´s curiosity and enthusiasm for technology, the team wants to provide kids the opportunity to experiment with laws of nature and state-of-the-art technologies rather than having them spend more time in traditional classroom activities. Therefore, they decided to develop a toy for children, which is a construction kit for a swimming robot with biomimetic features. According to the team's opinion, by self-assembling the product and being able to program and configure certain features, the user naturally learns about robotics and the physics of floating objects.

Based on these ideas, the team embraced the design and development of a biologically inspired swimming robot prototype with a 12-hour power autonomy. The literature review performed on bioinspired mechanisms of displacement led the team to adopt the movements of the body and/or caudal fin, the undulation of the middle or pectoral fins and oscillations of the middle or pectoral (Lindsey, 1978) (Sfakiotakis *et al.*, 1999). The key features of the anguilliform-inspired design include: a waterproof body, forward propulsion, horizontal steering, depth control and exchangeable parts to allow children to conduct physical experiments. The considered changeable parts were the tail and fins (shape, size, and motion pattern) as well as the mass (number and distribution of mass modules).

The students, within the Marketing and Communication module, defined the market plan for their product. They started by conducting a survey among twenty-one twelve years old kids from a school in Porto, Portugal, to better understand the market and the customer's requirements, so that the product fits their needs exactly. This allowed them to clearly identify their product and the target market (EU and, in particular, Germany) (Ishii *et al.*, 2014). According to the team, "Bro-Fish" should be an educational construction kit, directed to children between eight to twelve years old, presenting the following features: (*i*) fish-like movement, (*ii*) remotely controlled (left/right and up/down), (*iii*) easy to program, and (*iv*) allow learning about physics of motion in the water by changing parts. Children should: (*i*) assemble the toy following the user manual, (*ii*) write programs based on the provided templates, corresponding to the various levels of expertise, and (*iii*) play and experiment by changing the customizable parts like the fins and the tail. The idea is that "Bro-Fish" is not only a toy but also a laboratory to experiment with physics and robotics. Therefore, to make their brand known, they developed the logo presented in Figure 1 (left).

Figure 1. Logo (left), anguilliform design (center) and prototype (right)
(Ishii et al., 2014)



In summary, "Bro-Fish" was designed as a construction kit targeted to kids of an age range between eight and twelve. Not only does it develop competences in three different fields (mechanics, robotics, and programming), but continued learning through customizable parts (tail, fins, mass) and different programming levels.

In the Energy and Sustainable Development module, the team addressed the set of eco-efficiency measures for sustainability. Since the beginning of this project that sustainability engineering was in the team's minds since this toy is going to operate in water and is made for kids, and in the Marketing Plan, was already mentioned the development of an "Eco-friendly plan". This plan considers the inclusion, in each toy of their future product line-up, of an environmental leaflet for kids. In the case of the "Swimming Robot", kids will find a leaflet called "Why are our oceans important?".

Supported by these background studies, the next step was to design the structure of the bioinspired swimming robot meeting the identified requirements. First, it was necessary to define the number of actuated segments and fins to propel and steer the robot. Considering it was intended for children, the team decided to use motor-based propulsion. The approach adopted was aimed at creating a command-response pattern that is easier to handle. Therefore, the designed robot has one back fin and two pectoral fins at (one per side of the body), and a steering fin at the tail. Unlike the prototype proposed by Silva *et al.* (2014), BroFish uses the back fin for propulsion instead of the pectoral fins – an approach identical to the natural locomotion of fish. To propel the robot with an oscillating back fin, the designed solution, rather than using a servomotor, transfers the continuous rotation of a DC motor into a swinging tail movement. For this, a rotating shaft was bent and placed inside vertical slots of the body, leading the body segments to move in accordance with the shaft´s shape in the horizontal plane. The final design of the bioinspired robot was simulated using 3D design software (Figure 1, center).

After selecting suitable components (Ishii *et al.*, 2014), the BroFish prototype was successfully assembled and tested (Figure 1, right). During the experimental evaluation, the pool tests revealed the potential to improve the robot forward motion (refinement of the tail design) and the longitudinal mass distribution. A list of adaptations was proposed for the tail refinement, namely, to increase its dimensions and, thus, improve force transfer.

A detailed description of this project can be found on the team's final report (Ishii *et al.*, 2014) and accompanying paper (Ishii *et al.*, 2015).

Bubbles – An Educational Robotic Toy

The didactic robotic fish was selected by a team of five members comprising a Media and Technology student from Germany, an Engineering and Architecture student from Spain, a Logistics Management student from Poland, an Electrical Engineering student from Scotland and a Mechanical Engineering student from the U.S.A.

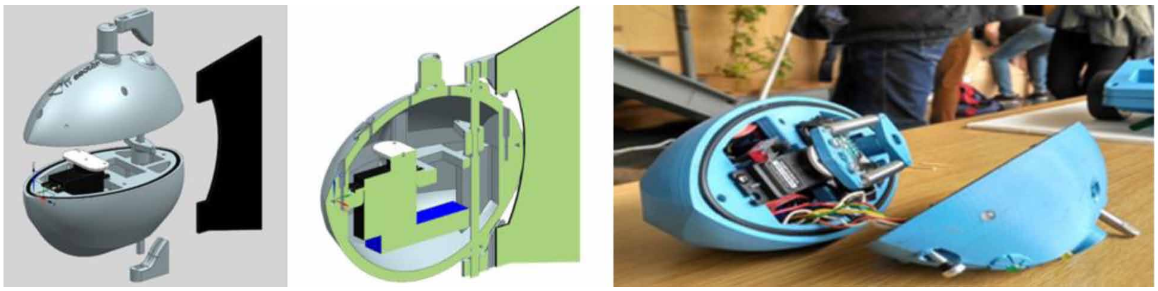
The specified goal of the robotic fish was to create a robot able to swim in the water which had at least a single degree of freedom. To provide this movement, the design team looked for inspiration in nature. Millions of years of evolution have filled the oceans with the perfect swimming machines: fish. Most fish (85%) utilize as main source of propulsion body and/or caudal (back) fin (BCF) locomotion (Reinhardt, *et al.*, 2016a). Inspired by this finding, the team decided early on to mimic BCF propulsion. However, this form of movement falls on a spectrum from undulatory to oscillatory. These classifications concern how the propulsion wave propagates from the tail through the body (Lindsey, 1978). With the imposed design restrictions of this project, ostraciiform locomotion made the most sense. In accordance with the project charter, the fish should be inexpensive, controlled by servo motor(s), and have a 3D printed body, and there is no straightforward way to create undulatory movement without sacrificing one or more of these tenets.

Given this, the team decided that the body shape should be based on that of a typical wider body of ostraciiform fish, like the box fish and the puffer fish. It was designed to be 150 mm long and with a compartmentalized dry interior, designed to house all the fish's electronic components, as depicted in Figure 2 (left and center). The main body consists of two pieces, top and bottom. These are connected via bolts and separated by a waterproof gasket.

As dictated by the project directives, the body is 3D printed (Figure 2, right). This print was completed using polylactic acid (PLA) due to its easy printability, nontoxicity, and biodegradability. However, the body can be created using any 3D printable material.

The motion of the fish is provided by a single servo motor connected to the rear fin vertical drive axle via springs. The springs dampen the motion and help to prevent component damage from repetitive stress. The axle, which is split into two sections to allow for simple disassembly, leaves the fish's interior through holes waterproofed with O-rings. The movement is controlled by an Arduino Nano, which is custom programmable by the user. To start an input program, the user removes a magnet from the exterior surface of the fish. This magnet opens a reed switch, and the Arduino begins to run its code. Finally, the team chose a 7.4 V / 900 mAh battery due to budget constraints. This battery grants power autonomy of over one hour and has a charging time of approximately two hours.

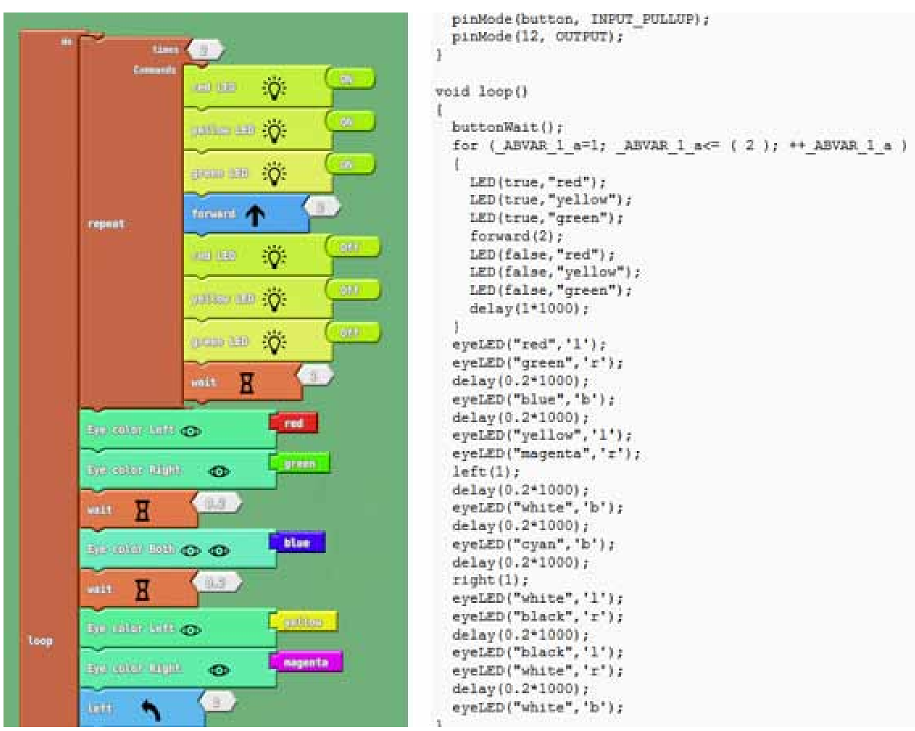
Figure 2. Exploded (left), vertical cut (center) and prototype (right)
(Reinhardt, et al., 2016a)



The tail is attached to the vertical drive axle, using small 3D printed parts placed on the top and bottom parts of the body. These parts slide over a flattened portion of the axle and are secured via setscrews. This design allows experimenting with several types of tails, namely, in terms of dimensions and materials.

To provide a programming environment suitable for children's cognitive abilities, the team considered both block and text-based development environments. Different from the text-based programming concept, the block-based concept relies on blocks that can be arranged by the user to create computing processes. The advantage of this workflow is that the correct syntax and terminology do not have significance because the user can only use pre-built elements. On the other side, block-based programming does not support the same level of complexity and number of functions as text-based programming. Since no complex functionalities are required for this project, the team decided to use the concept of block-based programming (Figure 3, left).

Figure 3. Ardublock program (left) and corresponding Arduino code automatically generated (right)
(Reinhardt et al., 2016a)



The team developed an illustrative program using the Ardublock (Figure 3). The code was uploaded to the Arduino, and successfully tested. The Arduino Nano recognized the software, and the program ran smoothly. Bubbles operated as expected, becoming a fully functioning robot.

A detailed description of this project can be found in the final report (Reinhardt *et al.*, 2016a) and accompanying paper (Reinhardt *et al.*, 2016b) produced by the team.

MyBird – A Bioinspired Flying Robot

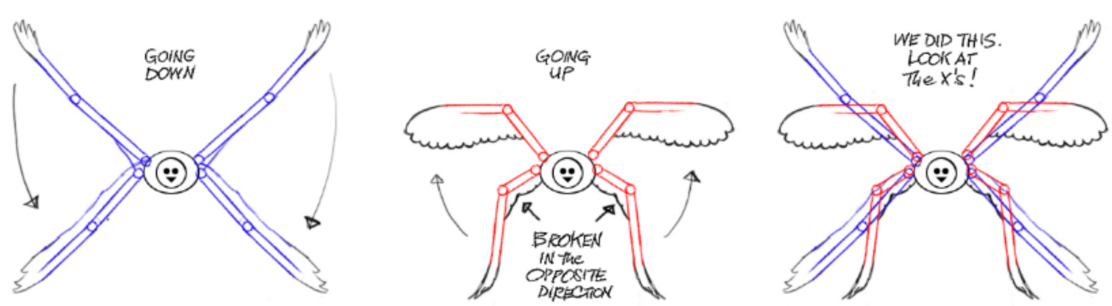
The biologically inspired flying robot project was developed by a team of four including a Mechanical Engineer student from the United Kingdom, a Product Designer student from Belgium, a student of Sales and Purchasing Engineering from Germany and a student of Materials Engineering from Estonia.

The main goal was to create a robot that could fly up, and land safely but without any kind of propeller, within a budget of 250 €, and their motivation for choosing this project is in their statement: "This project appealed to us because it would be challenging, yet possible. Furthermore, we found it to be an interesting topic since none of us has any experience with robotics, but all are interested in the field of mechanics. Besides our interest in robotics, we liked the bio-inspired aspect of the proposal, since nature creates the most elegant and intelligent solutions to its problems" (Dunn *et al.*, 2014).

The team started their work by making a state-of-the art study, including some historical aspects of crewed flight (in particular, some preliminary models of human-powered flight), and analyzing several academic and research prototypes as well as commercially available ornithopters. During this phase, they also got acquainted with the characteristics of some electrical components and materials used in the construction of radio-controlled (RC) flying toys, namely power sources, actuation systems, communication systems, structural and wing materials. In the end, they were able to choose the materials and components for their prototype.

In parallel, in the Marketing and Communication module, the students tried first to understand the market and the customers' requirements. Next, they determined the features matching these requirements. With this knowledge, they were able to create a customer-orientated marketing strategy and develop an integrated marketing program. Finally, they clearly identified their product – a remotely controlled bioinspired flying robot that mimics the movement of an ornithopter – and the target market – Australia since it displays a sustained toy sales growth in the last years (Dunn *et al.*, 2014). Furthermore, the flying bird should have replaceable wings and a camera to further engage children.
At the end of these two stages, the team decided to model the robot after a white dove (Figure 4).

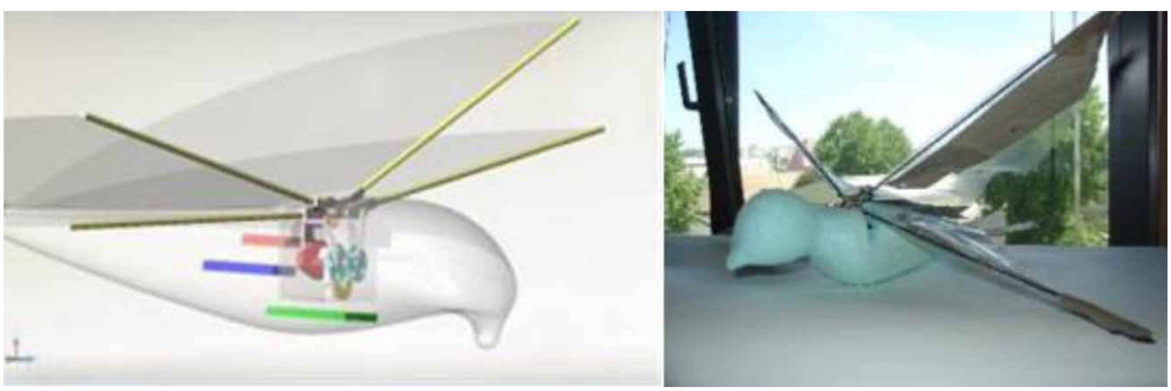
Figure 4. Planned wing beat of the ornithopter
(Body, 2009)



In the Energy and Sustainable Development module, the team addressed the set of eco-efficiency measures for sustainability considered during the project development and latter industrialization and commercialization. The team concluded that sustainability adds value to toys and influences buyer attitudes and purchasing behavior. According to the results of the consumer and trade study "Toys go green – Sustainability in Toys" (Spielwarenmesse, 2014), not only quality and the game concept convince the consumers to buy a toy, but it is also the sustainability which counts to their three most important purchasing criteria for toys.

During the state-of-the-art study, the team identified several different solutions to make the ornithopter fly and decided to implement a biplane. The reasons behind this decision are presented and justified in Dunn *et al.* (2014). After some conceptual studies, the complete ornithopter (including the wings, mechanical structure, and detailed actuation system) was designed in SolidWorks™, as depicted in Figure 5 (left), and the lift and drag forces involved in flight were determined (Dunn *et al.*, 2014). These studies lead to the design of a 30 cm long and 7 cm wide body (at the thickest points), a wingspan of 50 cm (when the wings are positioned horizontal) and a weight around 100 g (due to the materials chosen). MyBird flaps the wings at a frequency of 11 flaps per second and has an autonomy of 10 minutes (Dunn *et al.*, 2014; Caramin *et al.*, 2015).

Figure 5. Flying robot design (left) and prototype (right)
(Dunn et al., 2014)



The body was built in polystyrene and the wings in Mylar (as depicted in Figure 5). Polystyrene is a lightweight, shock absorbing material which can be easily shaped without any specific tools or skills. Mylar is the most common material for ornithopter wings due to its low density and mechanical properties. Leading edges and connection rods were made from carbon fiber rods. The flight is controlled by an Arduino Pro Mini together with a brushed inrunner motor and a motor driver, to amplify the Arduino output current. The chosen motor already had a 10:1 gear reduction. With this ratio, the output shaft would be spinning at approximately 2000 rpm at 4 V. However, the team's design required further gear reduction to obtain the desired rotating speed. The final reduction stage of 3:1 ensured the desired wing flapping frequency (11 flaps per second) at a velocity of 660 rpm. The battery was chosen according to its weight, capacity, and discharge rate. In the end, MyBird was able to flap its wings at around 11 flaps per second for 10 minutes. However, it was not able to achieve sustained flight.

A detailed description of this project can be found in the team's final report (Dunn *et al.*, 2014) and accompanying paper (Caramin *et al.*, 2015).

GraphBot – A Color Drawing Robot

A team of five undergraduates chose this proposal. It was composed of an Information Technology student from Poland, an Electrical, Electronic and Energy Engineering student from Scotland, a student of Power Systems Engineering from Finland, a student of Mechatronics from Romania and a student of Industrial Design from Belgium.

According to the team, the development of this robot was an opportunity to learn more about robotics and programming. The team had limited experience with Arduino and had never embraced a project of this size. As future engineers, they considered this project interesting since it builds upon the multidisciplinary skills pre-acquired by the team members and develops new skills in robotics, which are in high market demand. The development of a drawing robot, considering project management, marketing sustainability and ethics, while working in a team composed of people with distinct cultural and study backgrounds was a challenge and an advantage. The team had the chance to learn from each other and, by sharing knowledge, achieve a common goal: bringing this project to a good end.

After conducting a marketing study on drawing robots, the team decided to build a drawing robot that targeted children between the ages of 5 and 12. It was named Graphic Robot (GraphBot). The robot should be able to draw in assorted colors and move in different directions, the area of drawing being defined by the paper size. The robot is intended to introduce children, in particular girls, to technology from an early age, motivating girls to study and embrace later a career in Science Technology Engineering and Mathematics (STEM). Since girls are traditionally directed towards other fields than STEM, few tend to choose an engineering related field for further education (Royal Academy of Engineering, 2016). The team goal was to change this perception and familiarize girls with technology and engineering at an early age. According to the team's view, the robot should support creativeness (create art), and be versatile by allowing the reconfiguration and upload of new code to the GraphBot.

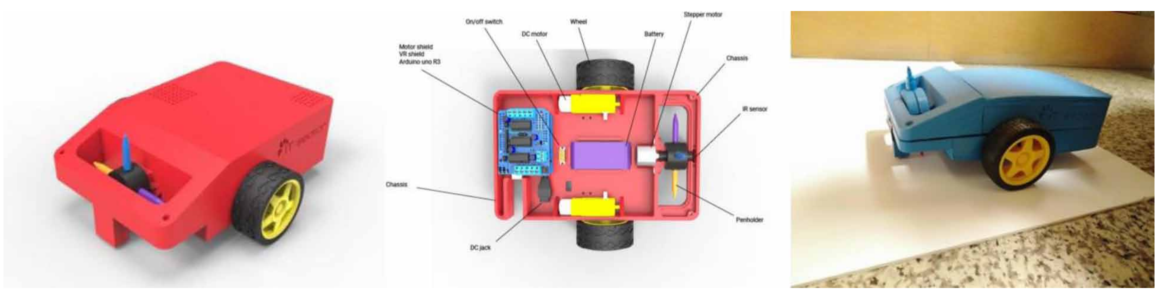
The specified robot requirements were the following: (*i*) move on a plane; (*ii*) work with assorted colors; (*iii*) be aesthetically pleasing; (*iv*) allow changing the drawing paper; (*v*) maximum dimensions of 1.0 m × 1.0 m × 0.8 m; (*vi*) reuse provided materials; (*vii*) use low-cost hardware solutions and open-source software; (*viii*) comply with the applicable EU Directives; and (*ix*) a maximum budget of 150 €.

After performing a literature review, the team compared the candidate parts, including cost, to decide the type of structure and user interface to be used with the GraphBot. The decision was to adopt a wheeled robot approach, since this solution allows the device to move and draw over a large surface and the structure of the robot is easy to build with low-cost components. The robot should be able to hold a pen and move it over a surface to draw freely or follow instructions previously stored or provided in real-time by a person. The team decided to implement a user voice interface. This way, the robot is controlled in real-time through voice or sound commands, which can be used by people of all ages and be fun.

Based on the performed marketing, sustainability and ethical analyses and multiple discussions, the team specified that, in addition to the initial requirements, the GraphBot should: (*i*) recognize simple voice commands and respond accordingly in a timely manner; (*ii*) be user-friendly, easy to use and robust; (*iii*) detect the drawing area automatically; (*iv*) change the drawing color easily; and (*v*) provide access to the micro-controller interface, allowing the refinement of the code for more advanced users. With this set of requirements clearly defined, the team focused on addressing the following open issues: how to change the drawing color; which components to choose; how to assemble the electronic and structural components; and how to control the system.

Figure 6 (left) presents the preliminary sketch of the GraphBot, a two-wheeled robot equipped with four assorted color pens (Dziomdziora *et al.*, 2016a), with the casing 3D printed in recyclable plastic. Figure 6 (right) displays the placement of the electronic components inside the robot. Two direct current (DC) motors implement a differential wheel motion system and are connected to the micro-controller through the L293D motor driver. A caster wheel is placed underneath the rear of the robot for extra support. The stepper motor, which controls the color pen change, rotates the penholder. The GraphBot detects the edge of the paper using an infrared (IR) sensor placed on the bottom front. The microphone, speaker and complementary components are assembled on a dedicated printed circuit board (PCB) attached to the upper part of the casing. The microphone is used to receive the user commands and the speaker provides feedback, *i.e.*, informs whether the voice command was recognized. The microphone and the speaker are connected to an EasyVR shield. A 7.2 V lithium-polymer ion battery, placed in the center of the robot, powers all electronic components. The battery is accessible for charging through the bottom. A DC jack is used to connect the Arduino to the battery.

Figure 6. GraphBot design (left), internal placement of components (center) and prototype (right) (Dziomdziora et al., 2016a)



After assembling all parts and updating the code, the GraphBot was ready for the final tests (Figure 6, right). The final tests identified some problems: (*i*) the wheels touched the chassis, requiring a higher torque and drawing imperfect straight lines; (*ii*) the microphone of the EasyVR proved to have low sensitivity, ignoring voice commands at times; (*iii*) the markers occasionally got stuck or did not touch the paper; and (*iv*) the robot failed to detect the end of the drawing area when moving backward. The team solved the first issue by rearranging the positioning of the wheels in relation to the chassis. Regarding the second issue, the team suggests it can be solved with a better microphone, and, regarding the last issue, the team believes it can be addressed by positioning a second IR sensor at the back.

The detailed description of this project can be found in the final report (Dziomdziora *et al.*, 2016a) and accompanying paper (Dziomdziora *et al.*, 2016b) produced by the team.

DISCUSSION

EPS offers students the experience of being integrated in a multicultural and multidisciplinary team, *i.e.*, with people of diverse engineering fields and nationalities. This exposure to the multicultural perspective develops cross cultural communication skills essential to the global market. Furthermore, it involves students in all the phases of the engineering process, ranging from the initial open problem statement to the prototype. Project proposals refer to open multidisciplinary real-world problems. Its purpose is to expose students to problems of a greater dimension and complexity than those faced throughout the degree program as well as to put them in contact with the so-called real world, in opposition to the academic world. The teams are free to find their own solution to the problem, taking into consideration not only technological and financial constraints, but also the sustainability, ethical, deontological, and marketing perspectives. This autonomy directs students to independent thinking and comprehension of the engineering process, essential to fostering future entrepreneurship.

As the EPS participants are undergraduate students, their adaptation to an unfamiliar environment of total independence, at their age, may provoke social retraction, leading to isolation, or in reverse, an exaggeration of "social life". This has only been seen in a small number of cases, that have been solved with the help of the other students and/or the student support office, both providing discrete and efficient assistance on these cases.

We claim that the development of robots, whether using wheels, legs, wings, or fins for displacement, as capstone projects, help EPS students to achieve the above-stated goals more effectively at the capstone project/internship level. Since the number of bioinspired robots found in the literature is low, there are no definite solutions available. Students, constrained by the project budget and duration, need to think out of the box, fostering their creativity. First, they define the robot's purpose or application, and then devise how to transform it into an attractive product and which marketing strategies to adopt. The same applies to ethical and deontological concerns. The fact that robots are new machines raises several questions, especially concerning their use (one of the most cited questions is their use for military purposes), on which the students must think and reflect. Finally, to be able to assemble and test the prototype they need to choose and purchase components in an unknown country, sometimes facing delivery delays and sold-out materials (promoting their autonomy and decision-making abilities).

The building of small robots, using commonly available modules, places the students with a variety of issues (mechanical, electrical, chemical, programming, etc.) that are representative of the issues faced when developing a "real product". When compared with a pure simulation-based study, the development of a physical prototype is more rewarding, providing physical tactile feedback to the students. This physical interaction is many times completed with the integration of the robot in an Internet of Things framework, to solve more complex problems.

The diversity of project themes requires a multidisciplinary, dynamic, and motivated team of supervisors. EPS coaching may need a period of adaptation since the students define the agenda of the weekly meetings and the professors ensue, i.e., the role of teachers changes from leader to consultant.

In terms of the personal and learning outcomes of this process, the students gain autonomy, self-confidence and develop technical, scientific, and complementary skills with this multidisciplinary, multicultural teamwork experience – the design and development of a prototype.

As a partial conclusion of their learning process, the team involved in the development of the biologically inspired flying robot project stated in their final report:

In the first few months of the project, we learned a lot about teamwork. All of us have worked in teams before, but it is more difficult in a multidisciplinary team. In short: communication management is the key to success, and this is not only the case in your own team but also out with the team. If the communication management is not going well, the time management fails too because meeting the deadlines depends on everybody (Dunn et al., 2014).

In the words of the students involved in the development of Bubbles:

The team encountered many obstacles and, without teamwork and the support provided, it would not have been possible to finalize Bubbles. It was vitally important to utilize planning tools to remain up to date with all deadlines and to ensure that the budget was not exceeded. The EPS@ISEP allowed the team to grow stronger and it was important to learn and move on from any mistakes. It also enabled the experience for any future projects. Every team member has gained a much deeper insight into the engineering world, including those without previous engineering experience. It was a thoroughly enjoyable experience for the team as not only did people get to work and support people from across the world, bonds and friendships were also formed. Although the creation of Bubbles was a success, there is always room for improvement and the team could have potentially tackled certain situations differently. Overall, the project was a success, and the creation of bubbles was one that was enjoyable, challenging and life-changing (Reinhardt et al., 2016a).

Finally, the GraphBot team members shared that:

The European Project Semester at ISEP was a great life experience. I very much enjoyed working on and developing the GraphBot with my teammates from all over Europe. While a multidisciplinary team member, I was able to learn from other members when working on the parts of the project in which I was less experienced.

The European Project Semester has been very good practice on engineering and project work in general. Working as a group on a problem for a full semester is an effective way to learn important skills that are needed in the future. I have done a lot of different group work before, but never anything like what the EPS has to offer. Working on a practical project in a multinational group is a great experience for anyone.

Participating in an EPS is great preparation to start your own company and shock the world with a breathtaking innovative solution. We, with our different skills and origins, were able to convert our ideas into a working prototype. We learned the importance of cooperation, i.e., that acting alone does not achieve the same success as a team! Trusting a team member does not only allow you to work properly, but creates friendships, which may even last after EPS is ended. Facing problems and difficulties during project development was an opportunity to learn to find solutions for unexpected situations. Being an engineer is being able to design a solution for a problem, and this is exactly what EPS teaches you.

EPS is a very good way to learn how to work in a team. It teaches people with quite different views on how to work together as a team, namely, how to overcome differences. There is support from the teachers, but problems must be sorted out by the team alone. It is hard to anticipate the knowledge and *capabilities of the other team members, which often leads to misunderstandings. EPS taught me a lot about teamwork, different cultures, and study fields.*

The EPS Program has been a good experience. I had never done anything like this before. To work with different people from different countries and cultures is wonderful since I met eager students who enjoyed this project with me. I am glad I am a part of the best team I have ever worked with. Together we have made some good memories. I visited beautiful places in Portugal with wonderful views and I recommend everyone to come here and join this program. I learned how cooperation is essential and how important it is to work as a team. Five people from different countries in one team can realize extraordinary things (Dziomdziora et al., 2016b).

CONCLUSION

EPS prepares undergraduate students for their professional life. The diversified engineering and cultural backgrounds of the team members, which are difficult to achieve in a traditional engineering degree, and the freedom to direct the project promotes creativity. The initial specification, procurement, and marketing phases expose the students to engineering tasks usually absent from project-based learning, contributing to the development of standard entrepreneurship-related tasks. As stated by Dunn *et al.*, (2014), the project suffered setbacks caused by the team itself, namely late purchasing of components and delayed decision-making and planning. However, the students claimed they learned a lot from the project and the teamwork experience. In this context, robotics provides a challenging, motivational, multidisciplinary project backdrop to foster ethics and sustainability-driven conceptualization and design.

As a result, we claim that the design and development of robots within EPS promotes the development of highly appreciated professional skills, and, thus, we recommend the adoption of this combination of engineering capstone projects and learning framework for the satisfaction of the students and the benefit of the engineering profession.

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KEY TERMS AND DEFINITIONS

Collaborative Learning: A learning method where students work together on a problem, task, or product.

Engineering Education: An area of higher education dedicated to the training of engineering professionals.

European Project Semester: A one-semester learning framework based on project-based, multicultural, and multidisciplinary teamwork as well as ethics and sustainability driven practices.

Multicultural and Multidisciplinary Teamwork: A work method where teams, composed of members from distinct cultural and knowledge backgrounds, address a problem, task or product spanning multiple disciplines, usually too complex for a single individual.

Project-Based Learning: A learning method where students work together on a challenging problem, task, or product for several weeks to gain new knowledge and skills.

Robotics: A multidisciplinary field, involving biology as well as computing, electrical and mechanical engineering, dedicated to the design and implementation of autonomous or supervised aerial, terrestrial, and aquatic platforms.

Student-Centered Learning: A method of teaching where students are responsible for their own knowledge and skill acquisition, fostering lifelong learning and independent problem-solving.