Floating Trash Collector - An EPS@ISEP 2020 Project

Andrea-Bianca Serafia[1], António Santos[1], Davide Caddia[1], Evelien Zeeman[1], Laura Castaner[1], Benedita Malheiro[1,2(✉)], Cristina Ribeiro[1,3], Jorge Justo[1], Manuel F. Silva[1,2], Paulo Ferreira[1], and Pedro Guedes[1,2]

[1] ISEP/PPorto - School of Engineering, Polytechnic of Porto, Porto, Portugal
mbm@isep.ipp.pt

[2] INESC TEC - Institute for Systems and Computer Engineering, Technology and Science, Porto, Portugal

[3] INEB - Institute of Biomedical Engineering, Porto, Portugal
https://www.eps2020-wiki1.dee.isep.ipp.pt/

Abstract. Each year millions of tons of plastic end up in the oceans, lakes and rivers. In the spring of 2020, an European Project Semester team, composed of multicultural and multidisciplinary undergraduate students, decided to tackle this problem. This was achieved by designing, modelling and simulating a floating trash collector named Soaksy. The collector is expected to operate continuously and automatically on lakes at the view of everybody, becoming an educational and an environmental tool. This paper reports the team's journey from the initial studies, through the design, till the final simulation and tests.

Keywords: Engineering education · Collaborative learning · European Project Semester · Sustainability · Trash collector · Smart cities

1 Introduction

The European Project Semester (EPS) is a programme offered by several European universities, including Instituto Superior de Engenharia do Porto (ISEP). During EPS, students from various countries and study backgrounds work together to design a new product and create a prototype.

A team of Industrial Design and Engineering, Product Development, Electrical Engineering, Computer Engineering, Civil Engineering and Applied Mathematics undergraduates from Portugal, Romania, Italy, The Netherlands and Spain joined efforts to design a floating trash collector. Plastic is so light and abundant that it ends being washed down drains by rainwater or blown by the wind into bodies of water, ultimately, accumulating in the ocean at an estimated rate of 8 million tons per year [2]. To make matters more challenging, not all

This work was partially financed by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia, within project UIDB/50014/2020.

M. E. Auer et al. (Eds.): ICL 2021, LNNS 389, pp. 165–176, 2022.
https://doi.org/10.1007/978-3-030-93904-5_17

plastic is floating on the surface of the water [4]. Only less than 1 % of the plastic in the ocean floats on the surface [10]. This paper describes the floating trash collector for lakes designed by this multidisciplinary and multinational team.

This document comprises, after this introductory section, three more sections. Section 2 describes the preliminary studies, Sect. 3 details the proposed solution and Sect. 4 presents the conclusion.

2 Background

This section describes the studies on related solutions, ethics, marketing and sustainability.

2.1 Related Solutions

Collecting floating trash in natural waters can be done in different ways. The technology to collect plastic pollution from waterways, namely, macroplastics, microplastic or both, focuses mostly (59 %) on removing macro or both types of plastics [6]. These pollution capture devices can be classified as: (*i*) booms or barriers that guide debris or prevent their continued flow; (*ii*) receptacles or containers that accumulate and hold debris in a confined space; and (*iii*) watercraft vehicles, including robots, that travel on or in the water to retrieve debris [3]. The performed research targeted bins, robots and barriers.

Water Bin: The original idea of floating trash bins was first introduced by two Australian surfers in 2015. The Seabin Project (Fig. 1a) incorporates a bin, a pump, and a net. The pump makes water and debris converge into the bin, while the net ensures that only water and small particles escape. Since then, two upgrades were made in the last five years. The first one added a filter to absorb liquids other than water and the second, still under testing, includes a second bin to collect microplastic and fibres [7].

Water Robot: In 2016 the Dutch company RanMarine developed a water robot, called WasteShark [5] (Fig. 1b). This drone is modelled on the whale shark and is designed to clear plastics, bio-waste, and other debris from the water in ports and canals. With a capacity of 160 L and on-board Global Positioning System and camera sensors, the WasteShark also measures the water quality (temperature, pH, conductivity, dissolved oxygen, oxidation-reduction potential, depth, turbidity). There are two models on the market: the autonomous and the manually controlled WasteShark [5].

Barrier with Collector: In 2014, Mr. Trash Wheel (Fig. 1c) was installed by the Waterfront Partnership of Baltimore, USA [11], comprising two barriers and a collector. The two barriers, which have an underneath skirt, are placed on both sides of a river or canal and the collector is placed in the middle, facing the current. This way, the trash is guided into the collector, placed on a conveyor belt, and stored in a dumspter. This system is powered by a water wheel or, if there is not enough current, by solar panels. When the dumpster is full, it is

(a) Seabin Project [1] (b) WasteShark [5] (c) Mr. Trash Wheel [13]

Fig. 1. Water trash collectors

replaced by an empty dumpster [12]. A similar collector with barrier, called the Interceptor, is produced by The Ocean Cleanup [8].

The water bin represented by the Seabin Project is a small product that stays in place and uses a pump to suck water and debris into it. The second type is the water robot, represented by the WasteShark. A water robot is a small moving product that collects trash by pushing the trash to one location. Thirdly is the barrier with a trash collector represented by the Mr. Trash Wheel. A barrier with a trash collector is a static big product that uses the flow of the river and the barriers to collect trash.

Considering that the places closest to the populations will be the ones that are most polluted, a water bin or water bot would be ideal for lakes and community ponds. The advantage of such places is that the water tends to be calmer, making the product easier to install and maintain, when compared to places with high water flows, where the barrier products are recommended. Products for calm waters also have the advantage of lower production costs, as they are smaller than dynamic water products, leading to less visual impact on the environment. Among these products, the water bin stands out for its energy efficiency, as it does not spend energy moving when collecting floating trash, as the water robot type operates. With the benefit of greater energy efficiency also comes greater up time, since the water bin type can be powered by the mains, including renewable power sources, while the water bot depends on batteries to operate.

Based on this review, the best choice for a floating trash collector for lakes or ponds is a water bin. Furthermore, the team was confident that they could design a more affordable and easier solution than existing water bins.

2.2 Ethics

Ethical and deontological concerns are increasingly important to the society. They should be regarded as key design factors since they directly affect trade. A morally wrong case can have huge worldwide impact on the reputation of the company involved. When this happens, people lose confidence, potentially leading to a decline in sales and stock market. Although the team concentrated on the design of a solution, it also contemplated the possibility of creating an ethically aligned company to transform the proposed solution into a product. Therefore, general ethical and deontological concerns were carefully considered throughout the project, as they are key factors for any global business.

The design of Soaksy followed an ethically and sustainability driven approach to create an environmentally friendly, safe product for the people, the planet and the company. However, competition within the market inevitably leads to a clash between different players. Such clashes can sometimes lead to unprofessional behaviour, such as price competition, branding wars and the use of unfair practices. Instead, the team decided to consider ethical marketing. Ethical marketing is not a real strategy, but it is more a school of thought in which responsibility, fairness and honesty are promoted. As such, the team decided that:

(*i*) the product should have a fair price, *i.e.*, one that covers the costs and ensures a profit for the company. The goal is to keep the price and the ecological footprint as small as possible.
(*ii*) the producing company must accept its responsibilities and comply with existing laws. Therefore, the following European Union (EU) directives were strictly considered: Machinery Directive, Electromagnetic Compatibility Directive, Low Voltage Directive, Radio Equipment Directive and the Restrictions of Hazardous Substances in electrical and electronic equipment.
(*iii*) the Soaksy brand has to be registered since the registration ensures legal certainty and strengthens the position of the holder, for example, in the event of a dispute.

2.3 Marketing

The team started by analysing the market of floating trash collectors on the macro, meso and micro level. Following the market analysis, the SWOT analysis was performed to identify the Strengths, Weaknesses, Opportunities and Threats of the Soaksy company and product. The result is shown in Table 1.

The SWOT product analysis indicated that existing water pollution awareness makes it easier to get sponsors or government investment and helps gathering the high investment required to develop the product. Nevertheless, in an emerging market there is always the threat of new competitors as well of established companies like The Ocean Cleanup or The SeaBin Project.

Next, the team performed a marketing mix analysis based on the 4 P – Product, Price, Promotion and Place – to devise a marketing strategy for the floating bin. As a result, the team identified municipalities as their main target and as focus to keep local lakes free of floating trash. Product differentiation from competition should emerge from the lower price and the sustainability driven design. The product was named “Soaksy”.

2.4 Sustainability

Sustainability is a complex and fundamental concept. When applied to product design and development, it translates into creating a product to improve

Table 1. SWOT product analysis

		Helpful		Harmful
External	**S**	Sustainable and efficient	**W**	High investment needed
		Made of recycled materials		Not autonomous
		Renewable energy source		Has to be manually emptied
		Easy removable bin		Needs external power supply
		Raises awareness of water pollution		
Internal	**O**	Product is increasing in popularity	**T**	Pandemic recession
		Government investment		New appearing competitors
		Emerging market		Established competitors
		People empathise with product		Limited time and budget

living conditions. The most often quoted definition comes from the UN World Commission on Environment and Development: "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In the charter for the UCLA Sustainability Committee, sustainability is defined as: "The physical development and institutional operating practices that meet the needs of present users without compromising the ability of future generations to meet their own needs, particularly with regard to use and waste of natural resources. Sustainable practices support ecological, human, and economic health and vitality. Sustainability presumes that resources are finite and should be used conservatively and wisely with a view to long-term priorities and consequences of the ways in which resources are used" [9].

The team carried out an analysis of the sustainability of Soaksy and made choices to meet, in the best possible way, environmental, economic and social sustainability. The team decided to equip Soaksy with a solar panel as well as with traditional powering methods, making it hybrid and usable in adverse weather conditions. The solar panel absorbs sunlight as a source of energy to generate electricity. From the point of view of energy autonomy and sustainability, it is necessary to make the most of available solar energy technologies, minimising greenhouse gas emissions. Considering the envisaged building materials, although they use non-renewable resources, they are recyclable and reusable at the end of the product's life cycle. Defective products should be sent back to the factory for repair and those not repairable should be replaced, recycled or their parts or materials reused. Soaksy is to be built in countries where workers are protected and receive fair wages. The resulting slight price increase, reverts in the well-being of people and of the environment. To reduce costs, the company should adopt exclusively an online sales model and partner with a logistics company for logistics and storage. The idea is to find a central warehouse for the product from where it could be shipped globally in an effective way.

3 Proposed Solution

3.1 Concept

The initial goal was to develop a sustainable and efficient floating trash collector, involving the design, building, and testing of a prototype. However, due to the COVID-19 pandemic, it was converted into the design and simulation of a prototype. The identified project requirements were based on the state of the art, project management, marketing, sustainability and ethical considerations. The team aimed to develop a continuous operation solution, made of recyclable material, with low power consumption and easy maintenance.

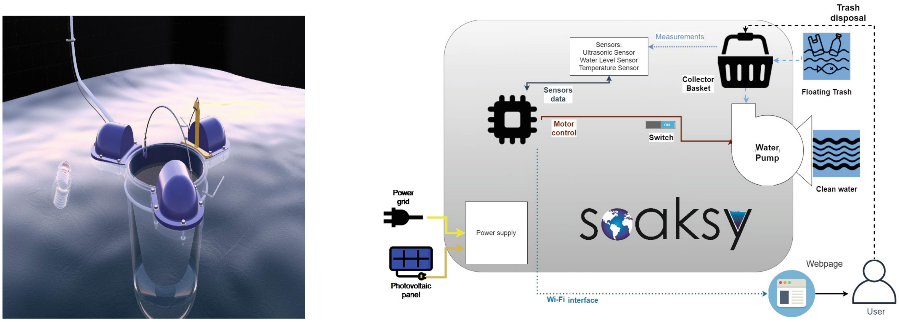
3.2 Design

The three variants analysed in Subsect. 2.1 were compared, taking into account aspects such as the type of water in which the product will operate (low or high flow), collection capacity and efficiency, power needs, price, dimensions compared to the capacity. Based on this study, the team agreed to design a fully automated solution inspired in the Seabin Project for the collection of floating trash.

The product is to float on a lake, helped by three floaters in case of small weight or water level variations. While floating, the level of the lake rises to the margin of the inner bin, allowing only a thin layer of water to enter the bin, as displayed in Fig. 2a. The water enters the system like a waterfall and is pumped out through the bottom, retaining the trash in the inner container. The system uses an ultrasonic sensor to measure the trash level, a water level sensor to measure the water level inside the bin and a temperature sensor that monitors the outlet of the pump. The data from these sensors are processed, communicated and, finally, presented to the user on a website. This continuous process, illustrated by the diagram in Fig. 2b, is interrupted when the user turns off the pump.

In terms of materials, Polyethylene terephthalate (PET) was selected for the main body because it is tough, durable, and inexpensive. The parts exposed to Sun will be in done in Ultraviolet (UV) resistant plastic, Polymethyl Methacrylate, known as acrylic, which is also most commonly used in outdoor applications. When it comes to the metal components, stainless steel will be used due to the operation environment. The mesh bag will be made of nylon.

Buoyancy is governed by Archimedes' principle, which states that any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object. There are three types of buoyancy: positive, negative, and neutral. Positive buoyancy happens when the submerged object is lighter than the fluid it displaces. The object floats because the buoyant force is greater than the weight of the object. Negative buoyancy occurs when the object is denser than the fluid it displaces, so the object will sink because its weight is greater than the buoyant force. The last type is the neutral buoyancy, meaning that the weight of the displaced fluid is the same as the weight of the object.



(a) 3D model (b) Black Box Diagram

Fig. 2. Solution

Soaksy should have a positive buoyancy overall because it always floats. However, it is necessary to ensure that when it floats, the water level stays at the very top of the inner part, allowing a very thin layer of water to enter the bin, as a waterfall. With the water level staying at the very top of the inner bin, the overall weight of the bin corresponds to the weight of the water the bin displaces. The volume of displaced water consists of the sum of the volumes of the body submerged, the pump, and of the air inside the body (where the water falls into). The volume of displaced water is approximately 47 L. The density of water changes with temperature and, very slightly, with pressure. However, its density is approximately 1 g/cm^3, meaning that 47 L correspond to 47 kg. These 47 kg need to be balanced by a body that weighs 47 kg. Without an extra weight, the product weighs approximately 16.5 kg. By adding a small body of water to allow the pump to run, another 4.5 kg are added. To balance the remaining mass, a 26 kg steel ballast was added at the bottom of the container.

The system was designed to be powered by the electric grid or by a solar panel. In the case of the photovoltaic panel, it is necessary to include a converter to regulate the voltage and, in the case of using the grid, it is necessary to convert AC from the grid to DC. Both sources have to output 12 V DC and include protection against electric current reversal.

Based on Table 2, it is possible to conclude that the system has a power consumption of approximately 6 W and can operate with water temperatures from 10 °C to 30 °C and air temperatures from −40 °C to 70 °C.

3.3 Development

The system uses three sensors to maintain a normal operation: (*i*) the ultrasonic sensor measures the level of trash within the collector; (*ii*) the water level sensor measures level of water inside the collector; and (*iii*) the temperature sensor measures the water temperature. The microcontroller uses these readings to assess the system status and notify the human operators.

Table 2. List of components for the prototype

Functionality	Name	Temperature (°C)	Consumption (W)
Pump	Velleman VMA421	−10 to +60	4.200
Ultrasonic sensor	JSN-SR04T-2.0	−10 to +70	0.150
Water level sensor	Water level sensor	+10 to +30	0.066
Temperature sensor	DS18B20	−10 to +85	0.003
Microcontroller	Espressif ESP32Dev	−40 to +85	1.650
Logical level converter	3.3 V to 5.0 V	–	–
MOSFET	BS170	−55 to +150	–

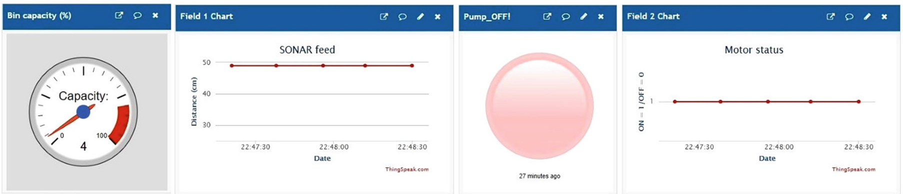


Fig. 3. ThingSpeak dashboard: instantaneous and historical data

The water pump is the most important part of the system. It prevents the inner part to fill with water, thus, allowing the whole system to function. The automatic pump control is based on the sensor information, while manual control is performed by an operator.

The IoT platform presents the system information regarding the status of the system in an intuitive and accessible way. The ThingSpeak online platform was chosen for the following reasons: free version with enough options for an intuitive and complete presentation, easy registration and sharing of dashboards, and the fact that it is the only free IoT platform able to connect to the Tinkercad circuit simulation platform. The dashboard displays the capacity of the trash bin and the status of the water pump (Fig. 3).

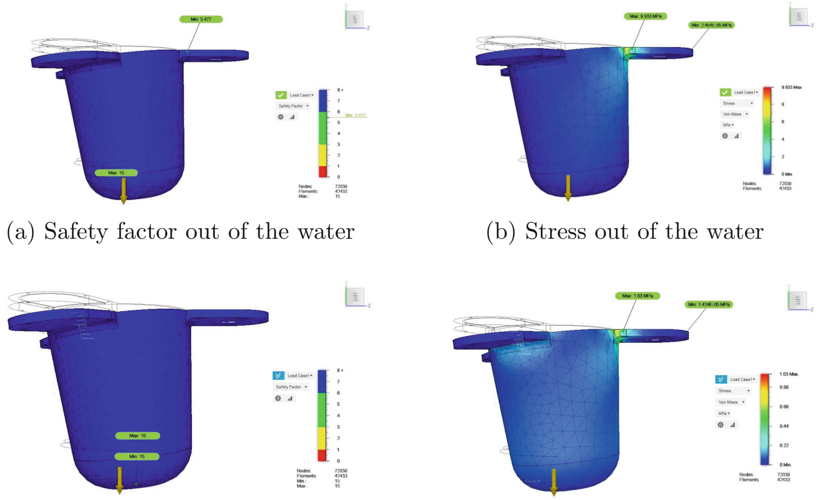
3.4 Simulation

The simulation involved two aspects of the project: the physical integrity of the system and validation of the control system.

The goal of **stress simulations** is to make sure that the main body, which carries most of the loads, resists in any circumstance. A worst-case scenario simulation eliminates any doubts when it comes to potential flaws in the design. In this case, the worst-case happens when Soaksy is hold only by one of the floaters. However, this case is unlikely to happen, because it is easier for the user to hold the main body by two folders with both hands. This can happen both outside of the water and inside. The following simulations were performed:

Stress Simulation Out of the Water. The main load that acts on the product is the weight of the stainless steel body. It weighs around 26 kg, which, as a load, is the equivalent to 255 N. To make this scenario even worse, we will consider a load of 260 N, and gravity force. Figure 4a shows the minimum safety factor that occurs in the body, and that it resists very well in this situation. Figure 4b shows the stress on the body in MPa.

Stress Simulation in the Water. The difference between the case where the body is out of the water is that there is not only the weight of the stainless steel body, but also the hydrostatic pressure. It was considered a load of 260 N, hydrostatic pressure, and gravity force. Figure 4c shows the minimum safety factor in the body, and that it has no potential to break. Figure 4d shows the stress on the body while functioning.



(a) Safety factor out of the water

(b) Stress out of the water

(c) Safety factor in the water

(d) Stress in the water

Fig. 4. Stress analysis

The results showed that the body resists to the applied loads, both in and out of the water, meaning it will not break. The system is well balanced as long as the internal tank remains with the projected water volume.

In real life, the internal volume of water fluctuates between two close levels (thanks to the water level sensor). A slight raise in the internal water volume makes the product sink a few millimetres, increasing the difference between the lake level and the inner bin edge, and augments the debit of the incoming water. Real world tests are required to fully characterise this behaviour.

The **control system simulation** used Tinkercad, an online simulation platform. The system was then integrated with the ThingSpeak IoT plataform and a dedicated dashboard was created. The simulated control circuit is shown in Fig. 5. Table 3 lists the functional tests performed.

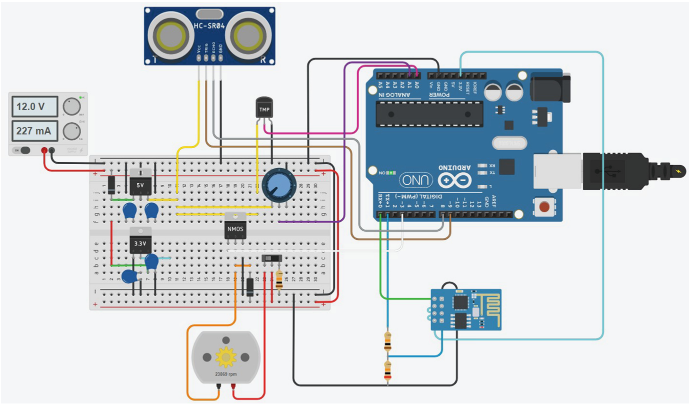


Fig. 5. Tinkercad: simulated control circuit

Table 3. Control system: functional tests

Test	Validation
Voltage regulators	Power supply
Water level and temperature sensors	Water pump
Communication with Thingspeak	Dashboard
Ultrasonic sensor	Dashboard
Inconclusive reading	Dashboard
No data available	Dashboard

In terms of **electrical and IoT results**, the dashboard displayed the simulated operation status. It provides the user with the relevant system information. Although the simulations cover most situations, there are limitations. When the ultrasonic sensor measures the distance on irregular surfaces, it can make erroneous readings. The system is prepared to overcome these situations by classifying the reading as inconclusive. Nonetheless, readings can still be wrong. Another major simulation limitation, is the absence of the ambient temperature sensor.

4 Conclusion

Considering the **project outcomes**, the team was able to design an innovative solution for the collection of floating trash in lakes. Following the preliminary studies and design thinking, the team defined the concept and designed the solution. This included the creation of technical drawings, both structural and electrical, the 3D structural model and the control system schematic. The next stage was the selection of electrical components (based on the power budget) and structural materials. Finally, simulation was used to validate the structure as well as the control of Soaksy. As future developments, the team envisaged the inclusion of sensors to monitor environmental pollution as well as filtering systems to remove microplastics and oil from the water.

Regarding **personal outcomes**, the achievers left the following testimonies on the EPS@ISEP learning experience:

António – "I entered the EPS course with the expectation of learning to develop a multidisciplinary product while working in a multicultural team. I also longed for the opportunity to live daily with my colleagues, learning about their cultures. Despite the pandemic, which forced the course to migrate online, my expectations were fulfilled. I had less interaction with my colleagues than I expected, but I am grateful for this experience. I learned a lot more than I expected, even with the online classes. I can say that I have basic knowledge in the areas of project management, marketing, study of ethical and deontological concerns and measures for sustainability, which I am sure will be useful in my professional life."

Bianca – "When I entered the EPS@ISEP programme, I knew that it was, above all, an opportunity to get out of my comfort zone, to work in a team while combining different fields of study with living and travelling in a beautiful city and country. Unfortunately, COVID-19 made me leave the country in April, after a month of staying in the house. However, it did not matter as much as what I have learnt. I have realised that it does not always matter if you do not have the knowledge or if you feel insecure. This experience teaches you on-the-go and brings out what is best in you. You only have to bring the willingness and motivation to develop on a personal and professional level."

Davide – "Participating in the European Project Semester was a wonderful experience, which taught me a lot, specially regarding time management and teamwork. Unfortunately, our experience was affected with the arrival of COVID-19 in March, leading to online lectures and meetings. However, ISEP was able to timely adapt and we managed to continue the project without difficulty. I am glad I was part of EPS@ISEP and of my team."

Evelien – "Due to the corona measures, the EPS@ISEP programme was not what I hoped for. Unfortunately, I did not get to know my team very well, one of my team members even left the team and we were unable to build the prototype together. Fortunately, ISEP really anticipated well on the corona crisis. The classes and meetings were online in no time. That way, I was still able to learn the basics of ethics, sustainability, marketing, communication, project management and even some Portuguese. Also, my team collaborated well. Thanks to the quick anticipation of ISEP on the corona crisis and the good collaboration of my team, I was able to complete the EPS@ISEP."

Laura – "I came as an Erasmus student to EPS at the ISEP campus. During the course, I learned to work and coordinate with teammates from other fields of study in the design of our product, overcoming the language barrier. Thanks to the classes and the help of project coaches, we clarified our doubts and broaden our vision of the project. In spite of the pandemic situation, that lowered our spirits and made it more difficult to concentrate, we were able to maintain the team dynamics. Overall, I can say that it has been a very gratifying experience where I have learned a lot together with my colleagues and the constant support of the teachers and the EPS@ISEP."

References

1. DrSails: Europe's first solar-powered seabin is cleaning up Spinola Bay (2018). http://drsails.buzz/projects-that-rock/. Accessed May 2021
2. Glascock, T.: The Problem of Ocean Trash (2016). https://oceanconservancy.org/blog/2016/08/22/the-problem-of-ocean-trash/. Accessed May 2021
3. Helinski, O.K., Poor, C.J., Wolfand, J.M.: Ridding our rivers of plastic: a framework for plastic pollution capture device selection. Mar. Pollut. Bull. **165**, 112095 (2021). https://doi.org/10.1016/j.marpolbul.2021.112095
4. Jacobo, J.: World Ocean Day 2019: Ocean plastics problem isn't going away, but here's what you can do to help (2019). https://abcnews.go.com/Technology/world-ocean-day-2019-oceans-plastics-problem/story?id=63324490. Accessed May 2021
5. RanMarine Technology: WasteShark (2021). https://www.ranmarine.io. Accessed May 2021
6. Schmaltz, E., et al.: Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. Environ. Int. **144**, 106067 (2020). https://doi.org/10.1016/j.envint.2020.106067
7. Seabin Project: Seabin Project - Cleaner Oceans for a Brighter Future (2021). https://seabinproject.com. Accessed May 2021
8. The Ocean Cleanup Technologies: The Ocean Cleanup (2021). https://theoceancleanup.com/rivers/. Accessed Dec 2020
9. UCLA Sustainability: What is Sustainability? (2021). https://www.sustain.ucla.edu/about-us/what-is-sustainability/. Accessed May 2021
10. Utrecht University: All about plastic soup—Plastic can be found everywhere in the ocean (2021). https://plasticsoep.sites.uu.nl/en/plastic-found-everywhere-ocean/. Accessed May 2021
11. Waterfront Partnership of Baltimore: Trash Wheels (2016). https://www.waterfrontpartnership.org/healthy-harbor/trashwheels/. Accessed May 2021
12. Waterfront Partnership of Baltimore: Mr. Trash Wheel Technology (2021). https://www.mrtrashwheel.com/technology/. Accessed May 2021
13. Wikipedia: Mr. Trash Wheel (2018). https://simple.wikipedia.org/wiki/Mr._Trash_Wheel. Accessed May 2021