ISBN-978-989-9121-05-8
PORTO 20th International Conference on "Innovations in Engineering & Sciences"
(PICIES-22)
Porto (Portugal) May 31-June 2, 2022

Interdepartmental Research and Students Synergy in Engineering Courses

Nuno Domingues[1], Pedro Fazenda[1] , João Casaleiro[1], Carlos Gonçalves[1], Mário Assunção[2]

[1] Instituto Politécnico de Lisboa/ Instituto Superior de Engenharia de Lisboa
Rua Conselheiro Emidio Navarro, 1, 1959-007 Lisbon, Portugal
[2]Escola Superior Náutica Infante D. Henrique (ENIDH)

***Abstract*:** *The benefits of maintaining interdepartmental communication in academic and research institutions are obvious. Interdepartmental communication contributes to innovation in multidisciplinary projects, sharing of different working and research methods, knowledge, and research opportunities. Academic institutions are expected to develop and support initiatives that benefit students, teachers, researchers, industry, and society as a whole. It is a continuous challenge for most academic institutions to find projects that provide research opportunities, practical and theoretical learning, leisure, skills development, and a space for networking. Engineering students are required to learn theoretical contents, along with the opportunity to practice in laboratories. At all levels of education, laboratory work has always played a prominent role. Nevertheless, laboratory learning are mainly guides and paths that do not allow students to experiment as they would like and as they need. This article summarizes the NAMMI project, which aims to enhance students' learning by bringing them to the field and bringing practical field problems into the lab, while allowing them to define the path and approach to each problem on their own rather than following instructions provided by professors. At the broadest level, we assume two very diverse and rich engineering environments: the ocean and the land. We describe a set of projects that will be promoted in each environment and how we are setting the working conditions to encourage future students and colleagues to be involved in these projects*.

Keywords: *Education, Engineering, Experimentation, Interdepartmental Collaboration, Field Work.*

1. Introduction

According to the World Economic Forum, most companies consider that the biggest obstacle of the next decade will be the lack of talent in the market. In the next five years, half of the world's workforce will need to undergo some sort of training to keep their jobs [1]. Professionals, whether employed or unemployed, must learn the skills necessary to cope with new difficulties quickly and in ways never before envisaged in order to stay competitive. There is a widespread recognition of the importance of soft skills to personal development, employability, social development, social participation, change adaptation, among other skills that contribute for a positive and productive work environment. Academic establishments should create the appropriate conditions for young students to acquire soft skills by providing opportunities for them to actively participate in fun activities and projects that extend beyond the classroom as early as feasible in their courses. These projects should encourage learning and collaboration while also allowing for some autonomy.

It is well known that positive teacher interpersonal communication in the classroom is highly correlated with student-related academic outcomes [2]. Modern academic environments, however, are expected to provide a

degree of support to their community that goes well beyond the good teacher-student relationship that should exist in the classroom. Unfortunately, many academic institutions, we believe, do not give this level of assistance. Students either choose to stay at home and study from the resources provided, or they prefer to attend classes for the shortest period of time possible. Academic participation has decreased, and it has gotten worse since the COVID-19 pandemic outbreak, when lectures were lectured online. It is very important for academic institutions to recognize these problems and re-evaluate their key performance indicators to consider more complex models of academic success [3]. According to a synthesized definition of student success given by Kuh *et al*. [4], "…student success is defined as academic achievement, engagement in educationally purposeful activities, satisfaction, acquisition of desired knowledge, skills and competencies, persistence, attainment of educational outcomes, and post-college performance.".

Some institutions achieve higher levels of student success than others by adopting best practices for student engagement not only between students on campus but also between students and the community, opening channels for participation and involvement with academic research projects, events, and sporting activities, as well as maintaining a constant dialogue with the industry. We can look, for example, at some of the best practices for teaching and learning used by the Massachusetts Institute of Technology (MIT), which is now ranked first in the QS World University Rankings [5]. In 2001, when MIT announced its OpenCourseWare initiative, there was already a strong belief among institute stakeholders that the idea of making educational resources available to the public was one that had great potential, making university-level learning more accessible to the entire world. This initiative to make educational materials from its undergraduate and graduate-level courses freely and openly available online to anyone, anywhere, was backed up by MIT's strong belief that the value it provides to its community, from the business point of view, goes far beyond the value of those resources. Indeed, an apt metaphor known by most MIT students is that "Going to MIT is like drinking from a fire hose". This is a direct quote from Jerome Weisner, a former MIT president, describing the MIT experience and somehow representing the sheer volume of choice that students are provided not only by MIT, but also by the Massachusetts academic ecosystem. The university campus at MIT offers a myriad of clubs and activities out of the classroom that compete, every year, for new members. These include dance groups, activism groups, sports clubs, ethnic and cultural associations, musical, debate teaks, arts, gastronomy, among a wide range of activities are offered where participants can pursue personal development, networking, scientific research, and other activities in an environment that enables teachers, researchers, and the broader community to collaborate.

Most of our institutions lack the resources that MIT possesses. However, we may strive to replicate some of the MIT experience on a smaller scale by giving more possibilities for academic interest and participation. The Formula Student Competition is currently the most successful example we know of a project that students actively manage and have kept alive for several years [6]. Following this example, some lecturers from the Polytechnic Institute of Lisbon took the initiative to establish the *Núcleo de Mar e Montanha do Instituto Politécnico de Lisboa* (NAMMI) project, which is a club dedicated to ocean and mountain outdoor activities with a strong emphasis on research, innovation, and project-based learning [7] [8]. Addressing such a large sphere of interest is virtually heresy in the academy, where academics are controlled to narrow concerns and master certain disciplines of inquiry. The NAMMI project is being built assuming a top-down approach. We strongly believe that by starting with areas of interest that connect students, teachers, and other academic and non-academic participants, we will be able to create opportunities for scientific discovery while replicating part of the MIT experience.

In this article, we summarize some of the initiatives we've been working on over the past three years in an effort to bring students, teachers, researchers, and society together through fun learning and soft skill development activities. It is structured in the two parts that represent the focus areas of the NAMMI project: Ocean and land related activities. We describe some activities that are currently being developed and share ideas for future research. We finalize with discussion on the challenges we face and what are the expected outcomes.

2. Ocean Related Projects

Portugal's relationship with the ocean has a long history and relevance. Not only has Portugal been strategically connected, by ocean and language, with many other countries over the world for more than 500 years, we also share cultural and emotional bonds that make ocean relate projects appropriate vehicles for networking, research, and an opportunity for international collaboration. With ongoing projects, we have found it easy to motivate students and colleagues to participate either in the ongoing research and development that we are doing or just as a hobby. In this section, we describe some of the projects that we have been developing in this domain.

2.1. Building a Sailboat

This project, of building a sailboat at the institute campus, started with the restoration of a 100-year-old traditional *Canoa do Tejo* sailboat by a professor of the Department of Electrical Engineering, Telecommunications and Computers. The sailboat typology is a *Canoa Típica do Tejo* and is part of the *Marinha do Tejo* association and is on display on the Tagus River as a living museum supported by the navy museum. Fig. 1 shows part of the final restoration process, where the artist is painting the bow with traditional representations of flowers using the typical patterns and colours used by these traditional boats.

Fig. 1 - The restoration and sailing of a traditional Tagus River sailboat.

Over the course of three years, several other university colleagues participated in the reconstruction process on a local beach at the *Centro Náutico Moitense* nautical club. This was a great opportunity to learn ancient ship building techniques with the local craftsmen, and to participate with the community in many day-to-day operations, such as fixing, maintaining, and operating and handling sailing vessels in the river and on land. There has been a significant transfer of practical knowledge that is not easy to obtain in the academic environment. However, this connection has also been mutually beneficial in that a closer relationship with researchers and engineers has helped the local community grow in terms of club organization and digitalization, in addition to addressing other more complex engineering issues. The sailboat is currently outfitted with new sails (sponsored by the Polytechnic of Lisbon) and will be used, starting this year, to teach sailing to the

polytechnic community as well as represent the polytechnic in several events that take place near the Tagus River throughout the summer.

Throughout the restoration period of the sailboat mentioned above, the opportunity to buy a vintage wooden lifeboat was presented to our team. This lifeboat, that was once adapted to sail, is currently in the beginning of a restoration process. We immediately identified this boat as a great project for students to learn a variety of ship building skills. Fig. 2 shows the hull being transported to our campus.

Fig. 2 - The hull of a wooden lifeboat being transported to the university campus for adaptation to a sailboat.

This project includes many challenging tasks including understanding the physics of sailing, planning the dimensions of the mast, the sails, the rudder, weight distributions, engine (probably electric), and designing sails, among other practical tasks that could be of interest to students of all engineering courses.

2.2. Building a Virtual Museum

The relation with the Tagus River, its traditions and culture has led us to gain consciousness about how serious we are losing traditional knowledge due to the lack of interest, financial resources, and a lack of strategy for cultural heritage management. In the past century, most of the Tagus River traditional boats have been abandoned and destroyed, especially when a bridge over the river was built and inaugurated in 1966. Many boat topologies have vanished over the past decades and, with these boats, a huge amount of knowledge on how to build, maintain and operate them. Knowing this fact, we have found an opportunity to preserve this knowledge by creating digital identities and representations of boats and items associated with the Tagus River cultural heritage. Recently, a virtual museum is being created by students of the Informatics and Multimedia Engineering Course to preserve and make available online as much information as we can. Fig. 3 shows a picture of a 3D model of the *Muleta do Seixa*l, a fishing sailboat that has been extinct for more than a century. This peculiar sailboat was used for fishing and was rigged with a trawl net (called *tartaranha*) that was dragged laterally between the Capes *Cabo da Roca* and *Cabo Espichel*. We believe that most of the knowledge on how this fishing sailboat operated has been lost. We will now animate and reconstruct this fishing process so that people can see how fishing was done before modern motorized boats replaced them.

2.3. Building an Unmanned Surface Vehicle

Since 2019, ISEL has collaborated with *Escola Superior Náutica Infante D. Henrique* (ENIDH) to help them develop an Unmanned Surface Vehicle (USV). The collaboration enabled the creation and execution of multidisciplinary projects involving students and teachers from ENIDH and ISEL. These projects have included different areas including hardware, firmware for onboard controllers and software for remote monitoring and control. Fig. 4 shows the current prototype of the USV-enautica-I. The hull is made of polyester resin reinforced

with fibre glass. The propulsion is made using two electric motors, and the controller is made using a Raspberry Pi running the Robot Operating System. We plan to use this project in inter academic competitions (similar to Formula Student) and to scale it to be used in more ambitious projects such as ocean exploration.

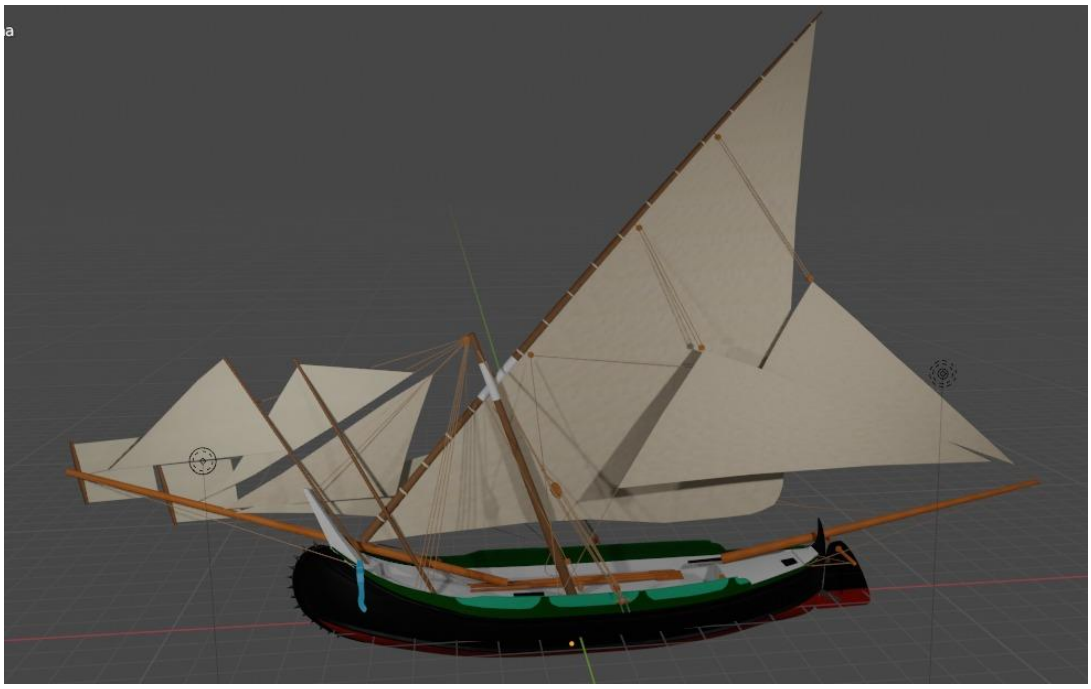

Fig. 3 - *Muleta do Seixal*, a boat that has been extinct for more than a century, modeled by the students of Informatics and Multimedia Engineering.

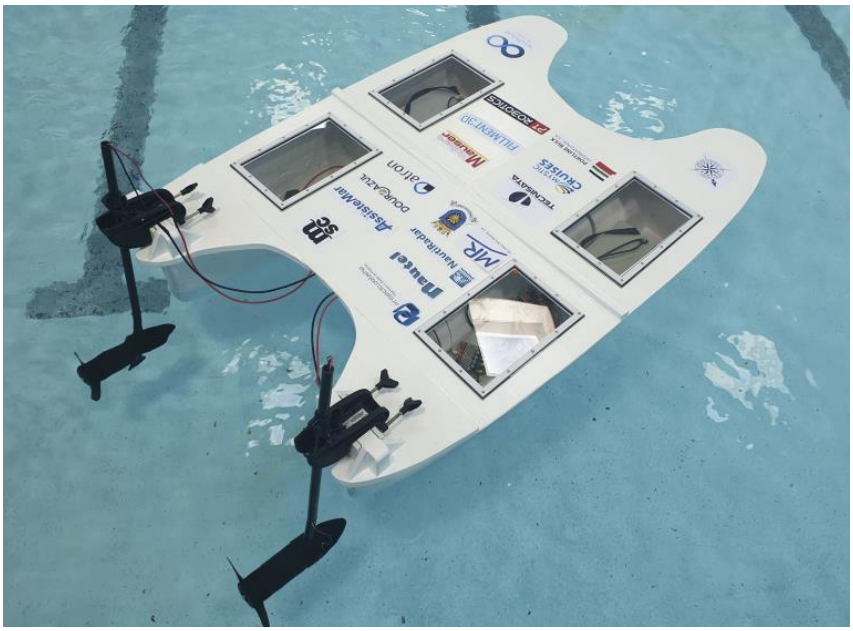

Fig. 4 - USV-enautica-I. An Unmanned Surface Vehicle build by *Escola Superior Infante D. Henrique* with the collaboration of the *Insituto Superior de Engenharia de Lisboa*.

3. Land Related Projects

There are two main activities that we have been organizing in the past four years: hiking and caving (aka spelunking). Hiking is a very popular activity that has been shown to be an excellent activity for networking and

enhancing interdepartmental communication. On the other hand, caving is a more restricted activity that is usually undertaken by a small minority of technically proficient cavers. However, the cave environment represents one of the most challenging and rich environments for engineering innovation. A range of projects from civil engineering to telecommunications, multimedia engineering, informatics, and mechanics can be beneficial to the cave community. Listed below are some projects currently underway and ideas for future projects.

3.1. Ground Penetrating Radar

One of the main goals of the caving community is to detect, explore, and document new caves. Most cavers would like to be able to observe what lies below ground. Thus, learning and implementing a ground penetrating radar (GPR) has become one of our ongoing projects for the past two years. Proposed initially as a dissertation for their degree in Electronics and Telecommunications Engineering, graduate students have developed and tested the antenna that will be used to understand the principles of a GPR shown in Fig. 5. This has been the first stop towards understanding more complex issues in the domain of GPR applications, such as, for instance, the usage of Stopped-Frequency Continuous-Wave (SFCW) systems [1], among other techniques, including information visualization and interpretation. We are currently learning and searching for opportunities to innovate, as this project becomes a good example on how we can become active users of our own research outputs.

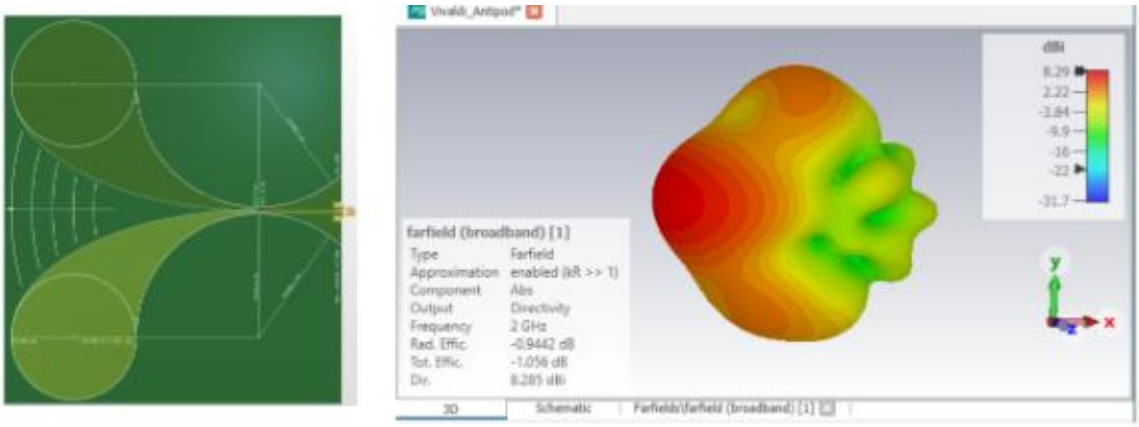

Fig. 5 - PCB antenna and simulation of the far field radiation diagram of a Vivaldi Antenna for a Ground Penetrating Radar.

3.2. Mobile Applications for Hiking and Cave Geographic Information

We have developed several mobile applications for hiking and cave geographic information as final project dissertations in informatics and multimedia engineering. Fig. 6 shows the Trails4us application that one of our students developed to store and share information for trekking, biking, and running. A current ongoing project with significant impact in the caving community, include the development of a proper cave geographic information application compatible with popular GIS software to store and share location and other information associated with the many caves that are being exposed. Although there are some GIS mobile applications in the market such as QField[1] and input[2], up to our knowledge, there are no applications in the market tailored for the caving community where cavers can easily share their location, cave location, reports, topographies, annotations on geological formations, warnings, including other metadata related to field exploration and the history of the teams that took part in that exploration. There is a huge opportunity for innovation in the cave environment. Digital twins of caves can be represented significantly using emerging multimedia engineering technologies. Knowledge representation is extremely important, and informatics engineering can help organize how

[1] https://qfield.org/
[2] https://inputapp.io/en/

information extracted from the cave environment in different ontology domains such as biological, geological, and archaeological.

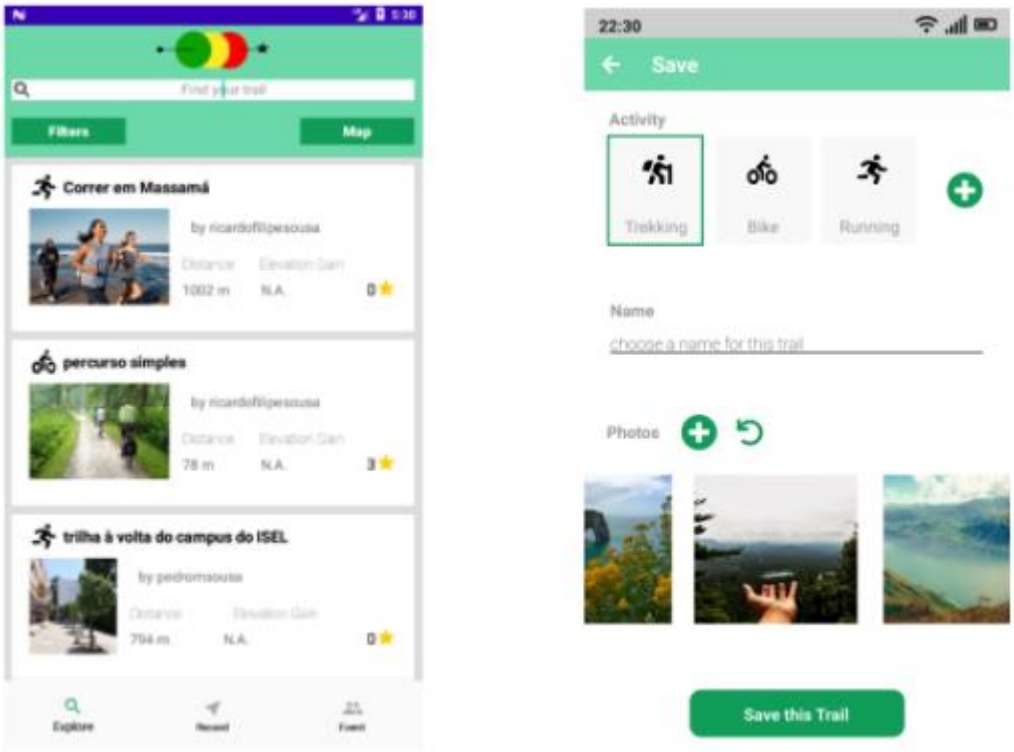

Fig. 6 - Trail4us. A mobile application for Trekking, biking, and running.

3.3. Cave Communications

As part of the multidisciplinary work that has been undertaken, an opportunity was identified for improving cave communications that are currently inexistent of very hard to implement. Students and researchers from the course of Electronics, Telecommunications and Engineering at ISEL have been involved in the research of radio coverage in subway tunnels for IoT applications using LoRa modulation. The aim of the work was to determine the coverage range of LoRa gateways considering the tunnel's propagation characteristics and the antennas installed in the tunnel's walls. The work, using the equipment shown in Fig. 7, confirms the feasibility of using low-cost devices to obtain and measure the path loss in locations and environments with difficult access and complexity for installing conventional RF measurement equipment. This year we plan to extend this work into the cave environment that is much more complex and challenging than the subway tunnel. The idea is to research the viability of using LoRa as a solution for simple cave messaging between explorers and for installing sensors and other temporary low-power systems for measuring environmental parameters.

Fig. 7- Testing LoRa telecommunication in subway tunnels.

4. Discussion

Time, human resources, and a suitable investment in equipment are, as usual, the most important resources required for the tasks detailed in this article. The amount time professors devote to these initiatives will almost always cause a certain level of unrest in the academy where there is a great deal of pressure to publish. However, we are confident that such initiatives will, in the long term, attract the critical human and financial resources required for research. Moreover, expected outcomes will, among other things, include the following:

- a reduction in the number of students dropping out of school
- making the school environment more welcoming and appealing to young students
- the creation of opportunities for the development of soft skills
- the establishment of possibilities for the development of practical engineering skills
- the increase interdepartmental communication, idea exchange, knowledge, and research opportunities
- enhancing community participation and dialogue
- assistance in generating business opportunities

ISEL has made a large conveniently isolated warehouse with a high ceiling available to support our projects, allowing us to build the sailboat and work on our autonomous surface vehicles. We also plan to make this warehouse available to the entire ISEL community as a workshop where they can utilize tools without disturbing ongoing classes. We hope that projects like NAMMI will encourage students to take charge of their own learning and develop soft skills like creativity, critical thinking, and problem solving. We also aim to counteract the trend of working from home, which we believe is particularly harmful in the academic setting. Many times, innovation emerges from informal brainstorming sessions with peers in comfortable situations. Moreover, students are also at a stage in their lives where solitude can be detrimental to their personal growth. As a result, we will continue to invest more in encouraging these students to participate in these out-of-classroom projects, as well as making NAMMI more open to new ideas and collaboration with other national and international institutes.

5. Acknowledgements

We would like to acknowledge the Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Casa da Cultura e Recreio do Pessoal do Politécnico de Lisboa and the Escola Superior Infante D. Henrique for all the support provided for the work described in this article.

References

[1] W. E. Forum, "The Future of Jobs Report," World Economic Forum, (Online, Accessed May, 2022) https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf, 2020.

[2] F. a. D. A. Xie, "A Conceptual Review of Positive Teacher Interpersonal Communication Behaviors in the Instructional Context," *Frontiers in Psychology*, vol. 12, no. doi: 10.3389/fpsyg.2021.708490, 2021.

[3] T. T. Y. a. C. G. a. S. Rankin, "Defining and Measuring Academic Success," *Practical Assessment, Research, and Evaluation*, vol. 20, no. doi:https://doi.org/10.7275/hz5x-tx03, p. Art. 5, 2015.

[4] G. D. K. a. J. K. a. J. A. Buckley, "What Matters to Student Success: A Review of the Literature," Commissioned Report for the National Symposium on Postsecondary Student Success:Spearheading a Dialog on Student Success , 2006.

[5] Q. Symonds, "QS World University Rankings 2022," (Online, Accecced May, 2022) https://www.topuniversities.com/university-rankings/world-university-rankings/2022, 2022.

[6] ISEL, "Formula Student," (Accecced May, 2022) https://formulastudent.isel.pt/, Lisbon, 2022.

[7] P. N. Johnson, "Using Project-Based Learning and STEAM to Engage Students During the Pandemic," *IDRA Newsletter*, pp. Vol. XLVIII, n 9 ISNN: 1069-5672, 2021.

[8] A. M. a. M. Aksela, "The key characteristics of project-based: how teachers implement projects in K-12 science education," *Disciplinary and Interdisciplinary Science Education Research*, Vols. 4,2 , no. https://doi.org/10.1186/s43031-021-00042-x, 2022.

[9] G. T. a. I. T. a. S. L. a. G. Catanzarit, "Comparison of pulsed and stepped frequency continuous wave (SFCW) GPR systems," in *17th International Conference on Ground Penetrating Radar (GPR)*, 2018.