Success Factors in Students' Motivation with Project Based Learning

From Theory to Reality

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Abstract—One of the teacher's first goals should be to inspire students to learn. Using project-based learning (PBL) to involve students in the learning process could be a useful and powerful tool to prepare the students for their professional future. As part of a degree course in Biomedical Engineering, students were asked to look at society and identify a possible biomedical-related failure or daily-life problem. From this, the students were challenged to work towards a solution, by preparing a project and creating a prototype or a minimum viable product. In this article we present the case study of a students' team, whose project was candidate and winner of a national prize. This prize was related to health innovation. Despite the particularization of this case study case, the students considered the experience innovative, motivating, and challenging. They also underlined the added value of a project whose impact goes beyond the classroom. Therefore, this method of teaching and learning, based on projects, may have a special effect on the students and, therefore on the civil society. The PBL can help higher education institutions to have a more prominent social presence, as innovation drivers and as forces of intervention.

Keywords—Project Based Learning, Motivation, Engineering.

1 Introduction

It is a fact that universities are expected to prepare students for real world, but it is known that the teaching methods that are used not often provide the tools to be applied in the future work universe. Once academic training is complete it is not expected that students continue to take written or oral tests. Instead they will have to deal and solve complex problems that involve multiple expertise areas and apply them to real problems and needs. They will work in teams; they will deal with competition and objectives.

Teaching is a complex activity that involves several variables. Institutions and teachers should be aware of this reality as it requires multiple knowledge. This knowledge needs to be carefully prepared, analyzed, implemented, and controlled.

University teachers are usually not trained in pedagogy or teaching-learning processes, so they are solely responsible for the way of teaching their students. According to Cunha, although teaching related issues may include cognitive barriers such as methodologies, terms and others, the university pedagogy is a space for connecting knowledge and culture [1]. However, one of the teacher's first goals should be to motivate students to learn and to awake a curious perspective when facing new topics or challenges. Involving students in the learning process makes the activity easier and more effective, creating an optimal environment for students' knowledge to flourish.

The best way to improve participation is to ensure students understand the intent of the tasks to be completed, without ignoring the links to what can be accomplished in a real context [2]. According to Brookhart, such tasks, as a part of formative assessment, or learning assessment, are highly valued and can be considered more effectiveness than summative assessment [3].

While learning, by itself, could be a way of active learning, there are several innovative student-centered methods that enhance the success of learning processes.

Active learning involves learners in activity development which leads them to reflect on what they are doing. Students engaged in proposed tasks feeling motivated by developing analytical, synthesis and evaluation skills. Active learning practices could impact student performance more significantly than any other. [4].

Project-based learning (PBL) is a teaching method whereby students acquire knowledge through projects that are directly linked to daily life. The purpose is to answer a question, a challenge, or a problem. From this point, students begin a process of research, hypothesis setting and looking for resources to conduct their activity. It also involves the practical application of theorical information until a final product or a satisfactory solution to the initial question is reached. Most of the learning process takes place in groups. The idea is to work, by tasks, in small groups, to solve the identified case. By collaborating with each other, students can watch other kinds of solution strategies. Also, they can discuss the case by argument, and take responsibility for their own learning. Students are involved in the design and the problem solving [5-7].

PBL unites, to some extent, the teaching process and practice, making them inseparable. When applying it, it involves the exploration of the context, the development of ideas from knowledge and communication between peers. However, the introduction of PBL is a complex process that must involve teachers and students. This process should be open to the uncertain, creativity and communication.

Practical and experimental learning has a long history in the engineering education. Experimental learning in engineering helps students to acquire professional and practical skills [8, 9].

Engineering practice must accompany the globalization. Research, manufacturing, and development processes have been different from the past. An engineer must increasingly reveal transversal skills to succeed in a competitive work environment. It is needed that engineers show a greater capacity to adapt and respond to new challenges while being technically capable.

As this is the emerging engineering profile, more active learning is expected to approach engineering education which is strongly related to PBL [10]. In addition to technical skills, it is indispensable for an engineer to be able to exercise values and conditions of human formation essential in the contemporary world such as ethical conduct, initiative, management, entrepreneurship, communication, oral and written expression [11]. The social responsibility, also, should not be overlooked, especially for biomedical engineering students. As they will contact patients with health problems, they must be aware of the human dimension of their work.

The triple helix model of innovation refers to a set of interactions between university, industry, and government to promote economic and social development [12].

This model has the potential for innovation and economic development in a knowledge society. It resides in a more prominent role for university, industry, and government to generate new institutional and social formats for production, transfer, and application of knowledge. Teacher plays a key role in the application of the triple helix model. As mentor, the teacher develops a managerial role through activities that enhance knowledge and innovation. For that, it is necessary to understand the institution goals, the student's work and motivations, and possible development areas. The teacher has the role of launching the challenges that the students must accept and develop. Therefore, its active position allows it to occupy the central position of the triple helix model.

The university should be entrepreneurial and capable of defining strategies by formulating clear academic objectives. By concentrating knowledge and intellectual capital where students are a source of potential entrepreneurs, there must be a clear contribution to an environment conducive to innovation. This combination leads to a knowledge transformation into economic and social value.

The position played by way of the government as an agent of the triple helix version develops from its responsibility. Foster public policies that inspire the system of innovation. Promote the vital funding and formulate legal guidelines and rules that inspire the cooperation system. The main gain for authorities is the promotion of a political, economic, and institutional surroundings that encourages agencies to direct investment on science, technology, studies, and development [13].

2 Methodology

2.1 Course description and organization

Introduction to Biomedical Engineering is a course that belongs to the degree in Biomedical Engineering. The course is in the first year of the degree with very flexible theory contents (it is a three years degree complemented by an optional two years master). The course organization, inspired on the triple helix innovation model, is supported by three main development components: a) Methodological component. With the purpose to provide solid basis in methodological approaches to problem solving and scientific research. The students learn how to identify and define problems, how to search and select information, how to establish development plans and how to evaluate results; b) Professional component. Aimed to show a professional perspective on business reality and to present details about the functioning of a company. The practical and application perspectives are enhanced as well as market/client-oriented management; c) Innovation component. To showcase the most modern topics, in the limits of knowledge in the area, with the aim of covering a wide range of topics within the scope of biomedical engineering. Promising technologies and future oriented development directions have the main role. Entrepreneurship, innovation, and government support are essential topics to be covered. Understanding regulations, funding and related processes allows students to aim at feasible solutions, that can be easily implemented and that can be supported by the existing framework.

The combination of the described components, carefully integrated, can drive students' mindset and provide adequate motivation for them to observe the surrounding world from a curious and questioning perspective, willing to introduce improvements [14].

2.2 Students challenge

PBL was used in the course for the first time in 2018. This experiment was called "Applying Biomedical Engineering: from the class to the reality."

The study population consisted of fifty-two students of the first year of Biomedical Engineering, that were making Introduction to Biomedical Engineering course.

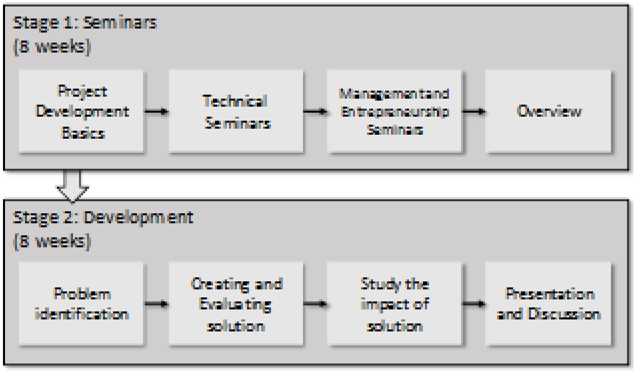

Fig. 1. Teams' motivation by intervention area

Fig. 2. Brand developed by the MedLis® team

For half of the semester (eight weeks), students attended lectures from people who works in fields that are related to Biomedical Engineering. During these seminars, students had the opportunity to understand what is being done in the biomedical area and what are the main gaps in the biotechnology market. They also could realize which area they would be most sensitive to work with.

The topics to be covered in each seminar were carefully chosen and organized chronologically so that there is an underlying logical chain. At each seminar, speakers were asked to place special emphasis on the scope of the theme, the description of challenges, methodological approaches, and technological possibilities, always from a practical and application perspective.

During the remaining eight weeks, students were asked to develop a project following a set of well-defined guidelines. The students were organized in independent teams of and each team was asked to look at society and identify possible failures in processes related to the biomedical field, to opportunities to increase a patient's life quality, and/or to enhance healthcare services performance. The teams were composed of four students [15], resulting in a total of thirteen teams. During the process of identifying failures/opportunities, students were completely free to choose the contexts of observation and analysis and had no indication of particular factors that could deserve more attention. Each team had total freedom of choice in the failures/problem's identification, although the validation of the real need and definition of the final objectives was made by the teachers.

From the identification of the flaw, the project consisted in the planning and its possible resolution. The applied steps were: (1) problem identification; (2) evaluation of possible solutions; (3) study the impact of the chosen solution and (4) presentation and discussion of the solution. In Fig. 1 we can observe a sequential pipeline of the described project development stages and related tasks. To satisfy technical requirements, all the projects should be translated into a prototype or a minimum viable product.

The students were made aware of the possible social dimension that their projects must include. With the premise "above all, doing the good", the solution should have an impact on society and increase the quality of a large group of people.

During the eight development weeks, the teams sent all the tasks deadlines by email to the teacher.

2.3 The medLis team

Considering the results obtained with the MedLis project (Fig. 2), we will proceed to its detailed description.

As well as the other teams, the MedLis team followed the methodology described above. They have identified the problem of self-administration of medications in people with visual difficulties. Then, they tried to understand and test how they could help this type of vulnerable population, solving this problem. After, they have studied the impact of potentials solutions and have discussed it with potential users. Finally, they have presented and debated their solution to tackle the problem. The proposed solution involves programming tags with NFC (Near Field Communication) technology. These tags contain the information about the medicine that was given, replacing the written guidelines that are usually provided by the physician or the pharmacist. Each tag is placed in the medicine box in an easily accessible location. As the patient approaches a mobile phone (with NFC reading capabilities) to the medicine box, the phone will read the information placed on the tag by the pharmacist. A text-to-speech system allows to produce audible audio information that is easily understood.

Engineering has an important role in society and therefore the students' endeavors and motivation to achieve optimal solutions must be presented and recognized. The final presentation of all projects was made in an out-of-class environment, open to the university community. It is our belief that to become a real project we must also have a real audience, open to dialog, open to potential users and open to investors. Providing feedback to students is an essential part of the teaching process and although the teachers feedback can be helpful to direct the project's development, a final feedback from an interested and informed audience can be quite important.

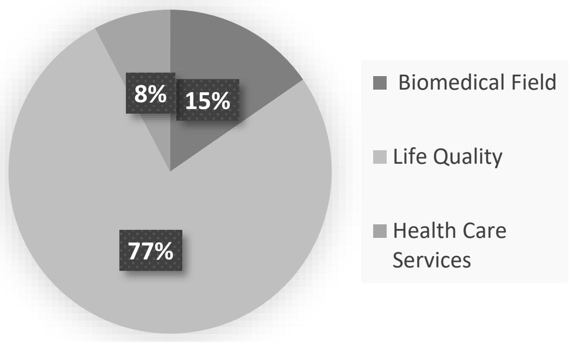

Fig. 3. Teams' motivation by intervention area.

Table 1. Summary of the projects and its purpose

Project's Name	Purpose
ADMM	Anxiety and depression medical monitoring
BEW	Wireless scalpel
GeoBand	Patients geolocation
HealthMate	Screening through app
HelpYourself	Mental disorders monitoring
MedLis	Medication management
MedO´clock	Medication management
MyPharm	Medication delivery and management
PharmaWay	Medication delivery and management
PowerSweat	Patients with pacemaker support
ProActiv	Protein drink
PartSis	Parturition simulator
SLM	Sinovial liquid simulator

3 Results

In the Biomedical Engineering area, we intend to train professionals who have transversal skills, as they represent human and technological bridges between engineering and medicine professionals. The possibility of identifying a flaw/problem in the biomedical market has enabled students to realize the potential of their education and future profession. The information exchange between students has also proved to be one of the strengths of the experience becoming a student-centered learning process.

PBL makes that the students act in everyday dilemmas, that is, in real life. As this, projects were developed just as professionals and companies, but on a smaller scale.

PBL's most quoted benefit in literature is its ability to make learning more dynamic and enjoyable, shared by students and teachers. This can do much to promote students' appreciation for study, and ultimately their desire for autonomous lifelong learning.

The experience started with the defining phase. The problem identification, the content of the project was determined by the students with the teacher's support and decision about the objectives. We have noticed that working on a project that students really enjoy and appreciate is significant. In those cases, the motivation is obvious.

At this point, it was possible to verify the teams' sensitivity to the main themes in question. Regarding flaws in the biomedical field, increasing patient's life quality and healthcare services ten teams had chosen to make something related to increasing life quality, two teams tried to identify and solve a lack in the biomedical field and, just one team dedicated their work to healthcare services.

By observing the team's motivation by intervention area, as depicted in Fig. 3, we can conclude that most students (approximately 77%) have a special concern with the improvement of patients' life quality. This ethical sensitivity and human factor perspective can be highly valued as a professional asset and constitute a motivation for solving real world challenges. Choosing the most appropriate solution to the identified problem (phase 2) was the longest and most complex phase. They needed to study the real problem and adjust the most appropriate solution. The one that best met all the needs. For students in university first year, this task could be complex. The acquired knowledge is still superficial in certain crucial areas to solve the chosen problem. But we realized that engineering projects provide the opportunity to synthesize and apply already acquired knowledge.

As PBL is designed to real-life applications, study the impact of the chosen solution or implementation phase was the most important part of all project. Students had to evaluate and understand the real application of the chosen solution. They discussed the proposed solution with stakeholders and decided what kind of solution is most appropriate to their problem.

In Table I we have a summary of the 13 projects presented and the purpose of each one. Through Fig.4 we could see that there is an extra motivation when there is a possibility of competing for a prize. From 13 teams, 4 devoted themselves to the theme of medication management, taking as their horizon the award given by the Portuguese National Association of Pharmacies.

Since each team dedicated its work to a different subject, under the global ones (flaws in biomedical engineering, patient's life quality, and/or health care services) the results were also different. The opportunity to apply to a national prize came almost at the end of the semester. The contest's theme was innovation in pharmacy, so the project that best suited was MedLis. Other projects, that achieved a mature state of development, are being directed to other competitions or conferences, allowing students to further improve their projects, and bringing additional motivation to introduce refinements towards a near-market solution.

The prize was awarded by the Portuguese National Association of Pharmacies, the Portuguese leading organization in the area. The MedLis project was the winner of the 2019 edition.

With this prize it was emphasized the importance of the presented solution and the possible positive impact in society.

In addition to the skills developed during the project preparation, others were acquired during the application process and presentation of the project to the prize jury. MedLis project is being implemented as a commercial solution in partnership with the Portuguese National Association of Pharmacies. It is expected that it will be available within one year.

Through this experience, we have been able to respond to the main goals of triple helix model. The knowledge produce by the university has been recognized by government entities and supported by industry. Given this combination, of PBL and triple helix model, we still have a way to do with students. Students can produce and present academic papers, but there is a gap about presentations with more appealing investor content. There is a need to establish a way to help students to turn ideas into products.

At the end of the semester, the fifty-two students were asked to evaluate this PBL experience anonymously in a written form. After observing the results, we can say that there was an overall satisfaction with the course's strategy, with the projects methodology, and with the teacher role. The students highlighted some of the following points:

1) The project objectives were briefly explained at the beginning of the experience
2) The basic information provided was sufficient
3) The several seminars along the first stage were decisive to the team's success
4) The teacher's communication was clear
5) The teacher, as a development facilitator, encouraged the groups to use various tools and techniques to tackle the technical issues
6) Students had feedback on their tasks all long the project duration and after the presentation
7) They have learned about projects' management and have developed their soft skills.

It was very important to conduct student's evaluation so that they could measure their performance and analyze what need to be improved. This was carefully made in several sessions, always providing detailed explanations to the students, and always working towards the defined objectives for project success. Each student also performed a self-assessment to understand, by themselves, what remains to be improved and what knowledge they still needed. If both evaluations perspectives were not fully coincident, then another meeting was arranged to understand the causes of this deviation and to reach an agreement between all the involved team members.

Authentic real-world tasks create the need to understand better the reality that is being studied. This need leads students to seek better information. Rather than teachers inducing students to go in one direction, they are involved and interested in authentic tasks.

This experience has shown that PBL could increase content retention and improve students' attitude to their own learning. As students are responsible for their own learning, their ability to apply and transfer information increases. Thus, it is natural for PBL to increase students' academic success. It makes them more autonomous and independent.

4 Application Description

After a careful collection of requirements, carried out in conjunction with health and pharmacy professionals, a native prototype application for mobile devices was developed, with ubiquitous characteristics, supporting all platforms of current devices and also ensuring compatibility with less recent devices that may exist taking into account the target audience.

It is intended that the application has an intuitive and easy-to-use interface (UI) always supporting the traditional option of tactile interaction but with particular emphasis on natural voice-based dialogue mechanisms (text-to-speech, speech recognition systems and language understanding when possible) in order to enhance accessibility and inclusion, allowing the user not to have to interact with the UI manually. Voice interaction is the most natural form of communication between humans and the interaction with devices, as part as our daily lives, should follow the same principles [16].

The introduction of gamification mechanisms is also idealized. This approach is well developed in other areas with very successful results. Its application to the healthcare area is a recent trend that can help to motivate users to best adhere to medication [17, 18]. In addition to access to the features already mentioned, the application will connect to a server to persist information and obtain results, a recommendation module, implemented as a smart chatbot for frequently asked questions, and a gamification module to enhance engagement. These mechanisms seek to reinforce the user motivation to use the application and to ensuring that the proposed application meets the needs of patients and health professionals, ensuring the effectiveness of interventions, with evidence-based practice.

The ready to market application is still under development but some details of the user interface are already in an advanced state. The user interface use already developed as well as most back-end infrastructure. In Fig. 3, on the left, we can observe the main menu which structures the application operation and allows to understand the most important functions. On the right of Fig. 3. a list of the medication is presented, showing the interaction strategies for managing the alerts and for configuring the relevant outputs.

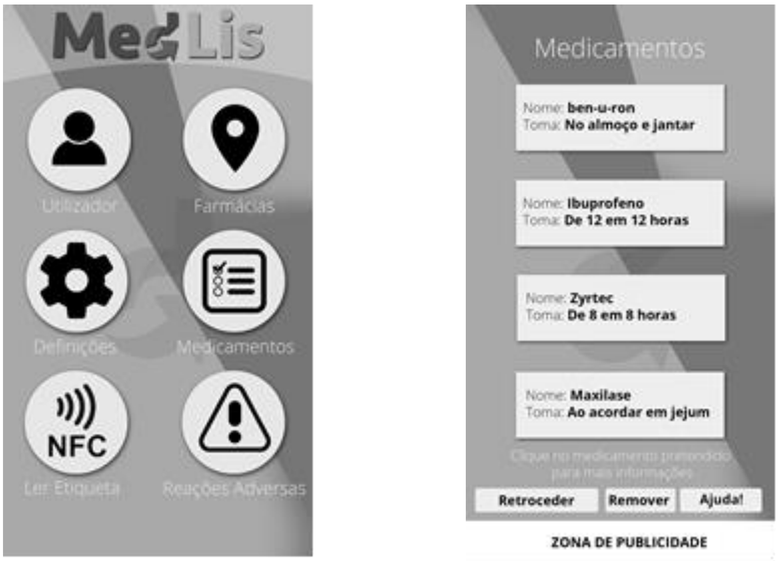

Fig. 4. Main menu for the developed mobile application

5 Conclusion

To prepare students for their professional careers, university courses should be designed to help them to acquire real problem-solving skills in addition to basic engineering technical skills. This type of teaching-learning approach requires a different way of thinking and enhances fast decision-making skills. Like others this type of ability it must be trained. Critical thinking, communication, collaboration, and creativity are examples of skills that need to be worked on. Ideation and innovation are also developed in the process.

After conducting this experiment, we should make some considerations to ensure the strength and accuracy of this type of learning process. It is paramount to to measure the impact that these activities have on student's development not only as a future professional but also personal values.

The PBL essence lies in the assignment and development of a project that may have an impact that goes beyond the classroom.

It should always be a realistic simulation of something that can be developed and applied. Utopian or impossible issues should be excluded. Is our view that the fact that students can find a solution for the presented problem makes them more motivated to face new challenges.

The fact that all the projects were translated into a workable product was crucial. This kind of research and development approach acquires a special competence in engineering education, as the companies that are dedicated to engineering need real and fast solutions.

Constant feedback is very important to ensure that all the tasks are being done. For the teacher/mentor it provides feedback on project development. For students it allows, also, a self-evaluation, within the team and with the other teams. This is an ideal tool to trainee critical arguments. Students adduced arguments in support of the criticism levelled by the other teams.

Nowadays, most of the works related to engineering involves technology. Therefore, it makes sense that some of this technology can already be accessed by students during these projects. Further, a real project cannot be accomplished without real world information, almost in real time. Because of this, is an imperative that technology makes part of this kind of education. Under the same approach, a real project needs a real audience, so we recommend that the projects' presentations should be made of the classroom, open to the public, shared with potential users and stakeholders. Be it in a poster session open to the university community, in a hospital or other entity considered most appropriate for the context.

The main students' skills evidenced by this experience were:

1) Involvement in real tasks
2) A clear increase of students' autonomy
3) A faster decision-making process
4) Awareness of ethical issues related to research and medical practice
5) Social responsibility proved by the search for a solution that adapts to a certain kind of population

This presumes an initial study of the population in question to better meet up their real needs. The previous study of the population makes the project more consistent with the reality; and (5) entrepreneurship – as a first-year course, students highlighted the importance of the first contact with entrepreneurship and how to carry out a business plan.

The most relevant students' skills forming the DELIVER framework, proposed by the authors, can be observed in Table II. Despite the particularization of this case study case the students considered the experience innovative and simultaneously motivating. They also underlined the added value of a project going beyond the classroom. Therefore, in addition to allowing them to obtain classification to the curricular unit, this type of teaching and learning could have a special impact on civil society. In fact, the assessment should not only measure the factual learning of each student. It would be interesting to find a metric to evaluate the experiences that the students had, as well as the transversal skills acquired. This metric could be done by using a system of performance indicators defined at the beginning of the project with the agreement of students and teachers. By this, the commitment is guaranteed as the experience involves all the parts from its beginning.

PBL aims to integrate different knowledge, in addition of promoting the development of skills. In fact, we could conclude that, by stimulating solutions to real-world problems, it allows teachers to control the main competences that are being acquired. Crossing PBL and the triple helix model, we are sure that future engineers will be more fully trained. In addition to technical knowledge, students learn to respond to industry needs. Partnerships between universities and hospitals or industry are recommended. The involvement of students and teachers in a challenge launched by a company or hospital will make the project more real.

As future work, we propose the direct involvement of companies or hospitals. These launch the challenge and the students, at teams, will try to respond by proposing solutions.

Table 2. The DELIVER framework for students motivation and success.

D	Decision making
E	Ethics
L	Look and Learn
I	Independence (towards team and personal autonomy)
V	Vision (Task orientation, objectives definition, planning)
E	Entrepreneurship
R	Responsibility

Biomedical engineers could have a proximity to human lives that other engineers do not have. In fact, it is imperative for a biomedical engineer to be aware and sensible for the society health problems. This is the only way for them, as professionals, to develop and respond to the real health care needs.

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