# Competency-Based Assessment of Biomedical Engineering Students Through the Project-Based Learning Process

Mariana B. Rios(✉), Natalia P. Perdiz, José M. Gallardo, and Marcelo R. Risk

Carrera de Ingeniería Biomédica, Instituto Universitario del Hospital Italiano de Buenos Aires, Instituto de Medicina Traslacional EIngeniería Biomédica (IMTIB) CONICET–Instituto Universitario del Hospital Italiano de Buenos Aires, Buenos Aires, Argentina
marianab.rios@hospitalitaliano.org.ar

**Abstract.** The trainers of future biomedical engineers must provide during their studies the teaching methodologies, technological and experimental tools that motivate and bring the student closer to the professional world and acquire the necessary skills to face the labor market, increase their employability and encourage their proactivity. This paper describes the educational experience in the subject "Introduction to Research and Development Practice I" of Biomedical Engineering, applying the Project-Based Learning methodology. During the course, an exchange of students who attended this subject the previous year was proposed. The projects served as motivating axes to bring students closer to the profession, the "know-how" and enhance their vocation related to biomedical engineering, since after the covid-19 pandemic no projects were developed or have been left unfinished. The students involved in this methodology and organized in groups analyzed the transfer and finished the projects, developing a 3D printing device and two Raspberry Pi devices. The implementation of this active teaching methodology added to the use of technological tools increased the motivation and self-confidence of our students, allowing the acquisition of several skills: digital, project management, verbal and written communication, problem identification and resolution, reading comprehension, autonomy, self-regulation of learning and teamwork.

**Keywords:** Project-based learning · Engineer training · Teaching · Educational resources

## 1 Introduction

During the beginning of the Biomedical Engineering (IBM in Spanish) program, the analysis of the teaching proposals by teachers, through active learning and competency-based methodologies gave rise to the research group "Biomedical Engineering Teaching: Project-Based Learning". The aim of this group is: a) To leave traditional teaching behind and resolve the existing differences between the contents taught in universities and the


N. M. Lopez and E. Tello (Eds.): SABI 2022, IFMBE Proceedings 105, pp. 500–509, 2024.
https://doi.org/10.1007/978-3-031-51723-5_62

professional skills currently demanded by the labor market; b) To promote the teaching work developed with the students of the IBM in secondary schools, to encourage the development of early vocations towards scientific-technological careers and facilitate the transit between high school and university; c) To collaborate in the dissemination of the courses taught at the University Institute of the Italian Hospital of Buenos Aires (IUHIBA).

"New paradigms, such as the knowledge society, globalization, networks and the current economy make up a particular scenario that requires new forms of exchange and communication. The world has changed and will continue to change, and today's society demands more from the University. Not only does professional training require "knowledge", but also the provision of professional skills to its graduates, the "know-how" [1]. Currently, engineering education faces several challenges: the need of an engineering that offers innovative solutions, climate change and meeting the growing needs of society, human development and technological innovations [2]. In Argentina, engineering careers are in a process of reformulating their study plans and the necessary skills to be acquired by students to perform efficiently during their career with prospects for future labor demands [3].

The transfer of knowledge from the teacher to the student, proposed by traditional teaching, has been left behind and has given way to a methodological proposal characterized by a complex structure of functions, knowledge, abilities, skills and competences that include activities that favor the development and the potential of college students. "Act with ethics, professional responsibility and social commitment, considering the economic, social and environmental impact of its activity in the local and global context" [4], as state the social, political and attitudinal Competencies defined in the 63rd Assembly of the Federal Council of Deans of Engineering (CONFEDI) in 2018.

The IUHIBA IBM career emerged in 2019 and is the product of the technological and research developments carried out at the Italian Hospital of Buenos Aires (HIBA), which have been crowned with the creation of the Institute of Translational Medicine and Biomedical Engineering (IMTIB), result of the synergy of CONICET, IUHIBA and HIBA.

To promote learning that translates into skills, students are trained with a focus on the profession, "…from performance, from what the engineer must know and how to do it in the different areas of professional work and early years of professional performance" [1]. For this reason, project-based learning (ABPy) and competency-based learning methodologies were implemented in the course Introduction to the Practice of Research and Development I (I + D I). As it is an integrating course, it presented the students instances that included the real work of the biomedical engineer based on basic problems/challenges of the profession, in addition to being able to carry out practices in the IMTIB laboratories, to strengthen their academic training and pave their way into the labor market.

To design the subject and focus on facilitating the development of competencies, it was necessary to know, on the one hand, the Generic Competences for the Graduation of the Argentine Engineer, proposed by the CONFEDI, which are divided into: a) Technological and b) Social, political and attitudinal. And, on the other hand, the Competences for Access to University Studies [5], among which stand out: a) Basic competences: they allude to complex and general capacities necessary for any type of intellectual activity, such as reading comprehension, text production and problem solving, b) Transversal competences: they refer to key competences for higher education: autonomy in learning and general cognitive abilities, and c) Specific competences: they refer to a set of interrelated capacities that allow a satisfactory performance in the study of careers. For example, the analysis of a function or a simple physical and/or chemical phenomenon based on its graphic representation and/or mathematical equations.

Competencies are a combination of skills, knowledge, and abilities to perform an assigned task [6]. Some authors make a division between soft skills and hard skills, considering that hard skills are those directly linked to the knowledge and skills on a specific topic that allow the professional perform their job. These can be learned, are acquired primarily through formal training, and are sometimes referred to as technical skills. The fact that in order to acquire technical ability one needs to be intelligent or have good intellectual knowledge determines that hard skills are an indispensable prerequisite [6] for applicants for the IBM career. Soft skills are associated with professional behavior, social performance, leadership and emotional management in certain situations that arise at work. Both are complementary and will define whether to hire the professional. Competency-based engineering teaching finds in the Competency-based Learning and PBL methodologies a way to implement curricular activities that enhance the training of future engineers [7]. In Argentina, engineering majors are beginning to use the ABPy methodology as a way of recreating the professional practice of engineering in the university environment, following the international trend [8, 9]. This methodology allows students to identify and solve problems, work and communicate their ideas as a team and play different roles throughout the development of the project, working responsibly and confidently. Through PBL, students review an existing solution to a problem and propose a new one. Finally, they have to write a report and present it in front of the whole class (students from other groups and teachers). From this methodology, students are motivated to present ideas, make comments and ask questions [10].

This article describes the educational experience carried out during the first semester of 2022, in the I + D I course, where the context of the covid-19 pandemic demanded the reformulation of this course to a hybrid modality, which included virtual and face-to-face classes.

## 2 Materials and Methods

### 2.1 Methodology

The IUHIBA Biomedical Engineering study plan is organized into two cycles: 1) basic cycle: 3 years (2880 h), made up of 27 compulsory subjects. 2) professional cycle: 2 years (2120 h), with 20 subjects that include 7 electives and the preparation of the final project that is developed within the framework of 2 subjects (final project and final work). This last cycle also includes 200 h of supervised professional practice. The subjects are organized into 4 large areas that are considered in the standards: basic sciences, basic technologies, applied and complementary technologies, according to Resolution 1603/2004 of the Ministry of Education.

The I + D I course is given in the first semester of the third year and the aim of the subject is to introduce the student to innovation and development activities, recreating the professional practice of the biomedical engineer, based on supervised practices in the research laboratories of the IMTIB. At the end of the course, students are expected to learn to develop technological solutions applied to specific biomedical problems, working in multidisciplinary teams.

I + D I is articulated with the subject Introduction to the Practice of Research and Development II (I + D II), has an assigned workload of 8 h per week and 128 total hours, and the course regime is semester-long. The total duration of both subjects is 256 h (128 each). Both subjects are the equivalent of the *Tirocinio Esterno* (External Practice) at the Politecnico di Milano [11].

During the course, our objectives were: a) To promote learning that can be translated into skills, b) To guide professional practice towards solving problems/challenges and creating opportunities with an innovative approach competitiveness-oriented, c) To promote the ability in oral and written communication, d) To consolidate the skills of future biomedical engineers through group development of integrating and interdisciplinary projects with the technology transfer.

The knowledge acquired throughout the subject was focused on the solution of 3 (three) problems/challenges that simulated a real professional scenario that confronted the students with their future work as biomedical engineers.

Figure 1, shows an image of the technological transfer of the projects of the students who studied the subject the previous year (currently in 4th year) to the 3rd year students.

**Fig. 1.** Technology transfer of the projects.

This transfer allowed the 4th-year students to adopt a role of experts and provide collaboration to the 3rd-year students when they had questions or needed technical assistance. In addition, this experience favored the completion of projects that were left unfinished due to the social, preventive and mandatory isolation measures imposed by the government in 2021 during the COVID-19 pandemic. Many projects could not been carried out the previous year because the course was 100% virtual.

The teachers, in the role of tutors, favored the space to recreate the professional practice of biomedical engineering in the field. The tutors guided the students in the learning process to optimize the time of the subject, carry out practices to take advantage of the experience and actively participate in their learning. In addition, monitoring of documentation, budget design, oral and written presentations and, finally, the development and fine-tuning of the devices was carried out.

Rosters at the IMTIB laboratories (molecular biology, nursery, cryopreservation, histology, cell culture, microscopy and biobank) were carried out in person and were accompanied by specific classes given by prominent professors from the IMTIB laboratories called "projects leaders", for bringing them closer to the responsibilities, the way of working and the good practice standards of each laboratory.

### 2.2 Teaching Methodology

To motivate the students and to be consistent in the development of this experience, all the activities carried out during the course were under continuous evaluation and were reflected in a reasonable schedule so that the projects could be completed during the 16 weeks that the course lasted. During the projects, the students developed one device using 3D printing and two devices using the Raspberry Pi.

The course, planned under the hybrid modality, included spaces for virtual and face-to-face classes. The virtual classes were taught through video calls using Google Meet, while the face-to-face classes were held at IUHIBA or in the IMTIB laboratory intended for student internships. The students had two synchronous spaces weekly (3 h each) in which theoretical classes and project follow-up were developed. And office hours (2 h each) with engineering teachers and/or project leaders, carried out in person. This space, in the absence of office hours, was to develop asynchronous activities related to the progress of the projects.

In Fig. 2, a table is used to conveniently locate the synthesis of the intervention proposed during the course to implement our methodological proposal.

Passing the course required submission of activities in different instances of progress and feedback regarding the research work carried out, which aimed to evaluate different knowledge (Knowledge and Know-how): submission of biweekly progress and its defense, 3 (three) group deliverables, 2 (two) individual activities, the fulfillment of roles that varied during the execution of each project (interlocutor, documenter, researcher, specialist and finisher), the preparation of the budget for each project and the analysis of compliance with the regulatory frameworks of our national regulatory agent, ANMAT (action carried out together with the Ethics and Legislation course attended in the same semester by the students).

### 2.3 Integrative and Interdisciplinary Projects with Development of Technology Transfer

The aim was, through the different projects, to ensure that scientific and technological innovation/research is oriented towards applications of interest, promoting the generation of technology and its transfer.

| Project | Title | Duration (Weeks) | Didactic methodology | | | | Assessment tools | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Communication | Collaborative | TIC | Thinking | Deliverable | Deliverable | Device | Oral |
| 1 | Microscope eyepiece mount | 4 | √ | √ | √ | √ | √ | √ | √ | √ |
| 2 | Measurent system for Bioterio | 12 | √ | √ | √ | √ | √ | √ | √ | √ |
| 3 | Measurent ystem for Laboratory | | √ | √ | √ | √ | √ | √ | √ | √ |

**Fig. 2.** Summary of the proposed intervention.

With the scaffolding of the teaching staff, from the idea or concept to material realization, the students organized in groups went through different stages: a) Detection or definition of the need, b) Invention or adaptation and/or production of a concept (stage of analytical design where the basic concept is examined to make the restrictions or design specifications explicit), c) Analysis of the concept (stage of search for the deficiencies of the design and its limits through tests that allow adjusting or improving the design), d) Synthesis of the concept and production.

The teacher staff asked the students, after presenting each problem/challenge, to reflect on the possible solutions to the problem posed, for which they had to: a) Investigate the commercial options available, b) Review their previous knowledge, c) Integrate different concepts of the subject, and d) Detect the need to learn new concepts to translate them into a project following the criteria of the technological scientific report.

### 2.3.1 Microscope Eyepiece Coupling Project

Through the development of the project, the approach of the students to two relevant laboratories in the IMTIB (histology, microscopy and flow cytometry laboratory and cell culture laboratory) was stimulated. The objective was to promote knowledge of each laboratory, the activities that are carried out there and, at the same time, promote the genesis of an effective solution to the problem raised by the teachers ("Need for a coupling for the microscope eyepiece that allows microscope users to take photos with a mobile phone").

### 2.3.2 Variable Measurement System Project for a Vivarium

For this project, a theoretical introduction was carried out on general aspects of a vivarium, in order that the student knows the complexity of keeping laboratory animals with standardized environmental parameters (temperature and humidity) necessary to achieve a quality animal that can be used as a biological reagent.

### 2.3.3 Variable Measurement System Project for Laboratories/Biobank

The students received a theoretical introduction of the IMTIB laboratories (General Laboratory, Molecular Biology Laboratory and Cryopreservation Laboratory), emphasizing biosafety and quality control in the different institutional projects (e.g. Biobank).

To delay the degradation/inactivation of biological samples and reagents for different analyses since they should be stored in optimal temperature conditions (a crucial point in quality control), the student was introduced to the different preservation systems.

For both projects aimed at designing variable measurement systems, the need to have devices to verify periodically and in real time the correct operation of the storage or air conditioning equipment was raised, and, in case of failure, generation of a remote warning of the contingency.

## 3 Results

The 3 proposed projects, during this shared educational experience were completed by the students.

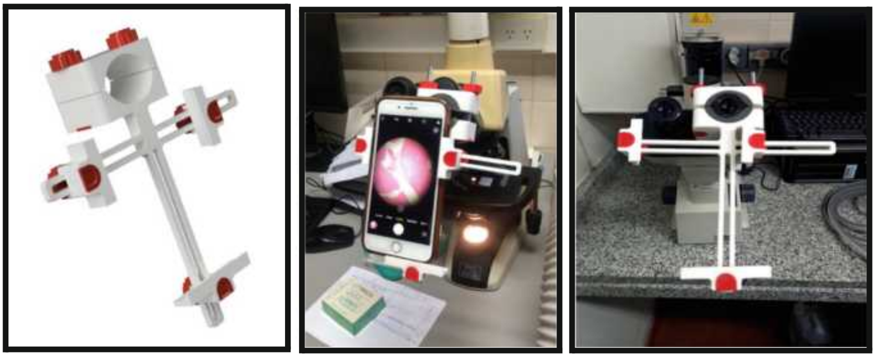

**Fig. 3.** Microscope eyepiece coupling prototype.

Figure 3 shows the prototype of the coupling for the microscope eyepiece designed by the students, its modification and assembly and finally its operation.

When carrying out the tests to determine the final adjustments of the adapter, the students detected a deficiency in the design, since the adjustment of the eyepiece bobbed, affecting its stability and correct functioning. The solution proposed was to integrate a spongy material into the coupling design that guaranteed the correct adjustment and the protection of the integrity of the microscope eyepiece. The coupling plan was made with Fusion 360.

For the variable measurement system project for laboratories/Biobank, the students, as shown in Fig. 4, developed the prototype, the alert system and 2 frontends, one for the PC and the other applications for the mobile phone.

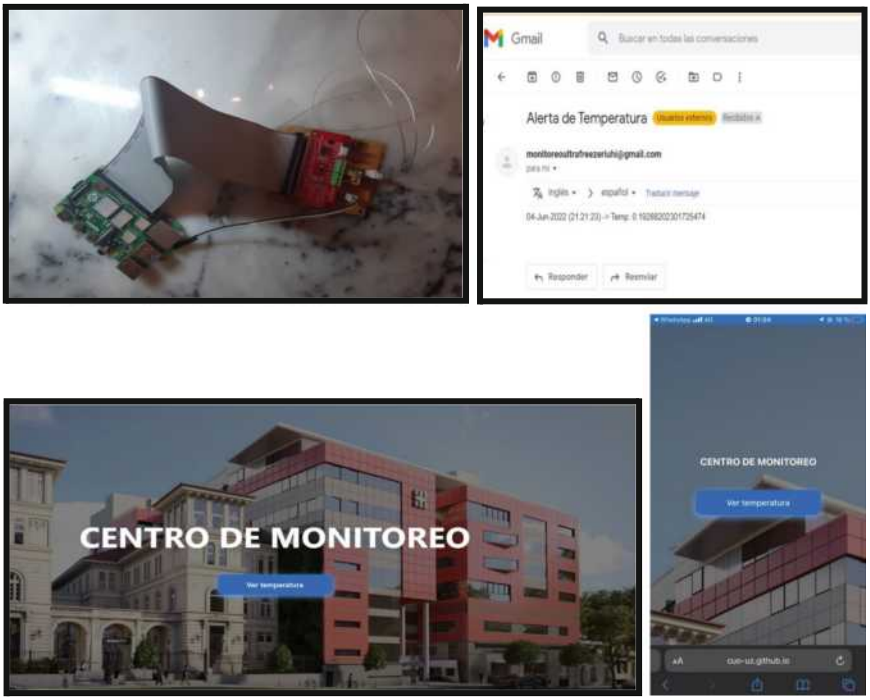


**Fig. 4.** Variable measurement system prototype for laboratories/Biobank

The students developed a frontend for the mobile phone and the alert system, for the vivarium measurement system, as shows Fig. 5.

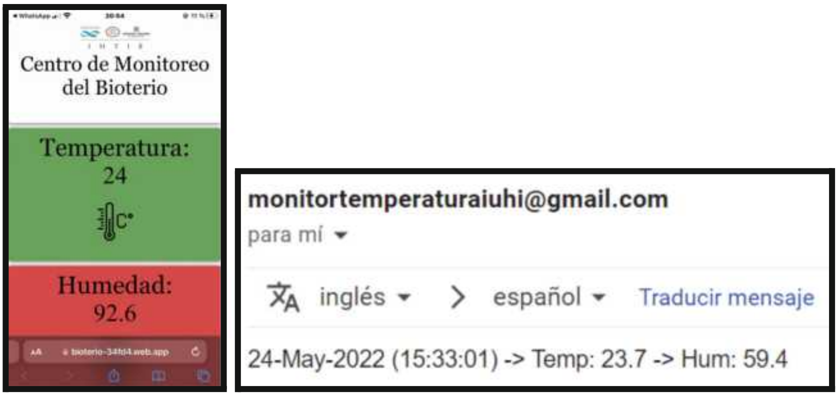


**Fig. 5.** Frontend of the Variable Measurement System Prototype for Bioterio.

Regarding software results, for both variable measurement projects, the students did the same. Regarding the preparation of the web page, the Node.js and npm applications were used for the management of packages and dependencies and javascript was used to connect with Firebase. Also, Reactsjs was used to make the interface. For the backend, a new database was generated, new rules were placed in Python, data was loaded and emails were established to receive alerts.

In this ABPy experience, students were assessed considering the written report, the understanding of the problem, the plan, its execution, the analysis of the solution, the use of disciplinary language and clear writing in their productions. In addition, from the oral point of view, the group organization and roles of the members were analyzed.

The students made their final presentation, within the framework of an IBM Conference, in front of course teachers, IUHIBA and HIBA authorities, IBM students and students and teachers from *Cristóforo Colombo* School. The passing rate for the course was high, with a final grade of 9.

This educational experience was shared by offering a workshop for high school level teachers, in response to the call to participate in the 20th International Forum on Science and Technology Education. This workshop entitled "Project-based learning: 3D printing applied to science, education and medicine" was held in May 2022 within the framework of the 46th Buenos Aires International Book Fair, at La Rural.

## 4 Conclusions

This educational proposal met the expectations through problems/challenges, simulation of a real professional scenario that brought students closer to their future work as biomedical engineers, within a motivating and creative environment.

To solve the 3 (three) projects, the students put their communication and innovation and project management skills (such as solution development, time management and planning) into play. They worked on digital competence during the programming, 3D design processes and during the search, processing, selection and storage of information. The knowledge acquired in other subjects during their training such as electronics, geometry, representation systems, ethics and legislation, among others, were of the utmost importance to advance in the resolution of the problems presented.

This experience shows that ABPy is a possible methodology to use in the training of future IUHIBA biomedical engineers because it promotes interpersonal development, self-learning, critical and divergent thinking, and increased motivation by carrying out projects in a real professional environment.

**Conflict of Interest.** The authors declare that they have no conflict of interest.

## References

1. Federal Council of Engineering Deans (CONFEDI). CONFEDI Competency Booklet (2014)
2. Lababidi, H.: Global Trends in Engineering Education, The Saudi Journal of Higher Education, 9, Center for Higher Education Research and Studies (CHERS) Ministry of Higher Education, Saudi Arabia (2013)

3. Mohamad, A., Colombo, F.: Social Commitment as a Competence in Engineering Education. Magazine #1139 (2021)
4. Federal Council of Engineering Deans (CONFEDI): Proposal of Second Generation Standards for the Accreditation of Engineering Careers in the Argentine Republic. FASTA Editions University, Mar del Plata (2018)
5. Isis, A., Gallino, M.: Generic competencies in engineering careers. Sci. Technol. **13**, 83–94 (2013)
6. Assyne, N.: Hard competencies satisfaction levels for software engineers: a unified framework. In: Hyrynsalmi, S., Suoranta, M., Nguyen-Duc, A., Tyrväinen, P., Abrahamsson, P. (Eds.) ICSOB 2019: 10th International Conference of Software Business. Lecture Notes in Business Information Processing, 370. Springer, Cham, 345–350 (2019). https://doi.org/10.1007/978-3-030-33742-1_27
7. Passow, H.J., Passow, C.H.: What competencies should undergraduate engineering programs emphasize? A systematic review. J. Eng. Educ. **106**(3), 475–526 (2017). https://doi.org/10.1002/jee.20171
8. Guerra, A.: Integration of sustainability in engineering education why is PBL an answer? Int. J. Sustain. Higher Educ. **18**(3), 436–454 (2017)
9. Herrán, C.A., Vega, C.: Use of PBL as a didactic strategy to achieve significant learning of engineering design. Eng. Educ. **1**(2), 33–44 (2006)
10. Setiawan, A.W.: Implementation of project-based learning in biomedical engineering course in ITB: opportunities and challenges. In: Lhotska, L., Sukupova, L., Lacković, I., Ibbott, G.S. (Eds.) World Congress on Medical Physics and Biomedical Engineering 2018. IFMBE Proceedings, pp. 793–796 (2019)
11. https://www.polimi.it/studenti-iscritti/attivita-didattiche-e-esame-di-laurea/stage-tirocini. Accedido el 18 abril 2022