TAS Journal, vol. 6, n. 1, p. 27-37
ISSN 2595-1521
MARCH 2022
brunojsantos@usp.br

Monitoring a bioengineering class in a professional engineering specialization: is there concatenation of learning?

Santos BJ*§, Leão TF* and Bock EGP*

** Federal Institute of Education, Science and Technology of São Paulo, São Paulo, Brazil. § Polytechnic School, University of São Paulo, São Paulo, Brazil.*

Abstract. This paper presents the follow-up of a bioengineering class within a professional engineering specialization, whose objective is to analyze whether this integration makes sense academically. The class presents special applications of automation, being bioengineering and energy management. Its main objective is to present particular ways of applying automation concepts, their particular fundamentals (of each area) and the similarities of this kind of special project. Bioengineering refers to the application of the techniques and methods of engineering and exact sciences in the development of artificial organs and auxiliary devices of biological systems. The following analysis strategies were used: (i) ratio of grades obtained from the students of the class; (ii) impressions of two students of the class; and (iii) impression of two professors of the class. Based on the pass results, students' feedback and the report of the professors involved in the class, it is possible to state that the bioengineering class did not have any negative influence within the students' education. Moreover, it may have had a positive performance by: (i) reinforcing the assimilation of scientific methodology in students; (ii) presenting special automation applications that may have expanded the student's professional prospection; and (iii) stimulating the emergence of new engineering solutions within medicine.

Keywords. *Bioengineering; Engineering education; Postgraduate learning techniques.*

Introduction. On October 01, 2019, the Postgraduate Course (lato Sensu) in Control and Automation was approved to be applied at the Federal Institute of Education Science and Technology of São Paulo, São Paulo (IFSP SPO) (1). This course aims to provide specialized training for professionals involving and integrating the various areas of the fields of Mechanics, Electronics, Electrotechnics and Informatics of direct or indirect interest to the business sector. The specific objectives of this multidisciplinary specialisation required to carry out research and technological innovation are (2): (i) design, integrate, analyze, model, identify and control systems that bring together electronics, electrical engineering, mechanics and informatics, normally used in process control and industrial automation; and (ii) bring benefits to professors, researchers and IFSP courses by the coexistence and exchange of ideas and knowledge of professionals working in companies in the region.

The course was approved with a total workload of 370.5 class hours, divided into 7 class (not equally). The class of Special Automation Applications (I3AEA) has 76 classes (57 class hours). The curricular component of this class addresses the main aspects of bioengineering and energy management (2). In this class, there are 4 professors (2 for each topic) and the objectives are to interpret, explain, identify, apply, develop and execute projects (2): (i) in biomedical automation, bioengineering and artificial organs, via multidisciplinarity; and (ii) modernisation and automation of industrial plants, electro-electronic systems aimed at energy management, via analysis of energy bills and contracts.

Within the grid of class of the course (Methodology of Scientific Work, Production Automation, Digital Signal Processing, Control Systems, Topics of Automation and Artificial Intelligence), the class of I3AEA is the one that has more distinct characteristics of the training of the target audience (2): (i) graduates in technology in Industrial Automation, Electrical Systems, Electronic Systems, Industrial Production Management and Systems Analysis and Development; and (ii) in Control and Automation, Electronics, Electrical, Mechanical, Telecommunications and Production engineering; in addition to higher education courses in related areas.

Due to the apparent incompatibility between the students' education and the I3AEA class topics, as well as the integration of two very distinct topics in a single class, the main contribution of this work is the monitoring of the class and the students, aiming to analyse if there was a satisfactory assimilation of the topics of this class by the students. The remainder of this article is organized as follows. Section II details the I3AEA class, while Section III presents the concepts associated with bioengineering. Section IV shows the review of a conceptualized work describing the teaching application of bioengineering. Section V describes the results obtained from monitoring the students in the class and discusses them. Finally, conclusions are presented in Section VI.

Special Automation Applications (I3AEA). The development of the I3AEA class is divided into two parts, the first part (Bioengineering) with 9 class days (4 classes / 3 hours per week) and the second part (Energy Management) with 9 class days (4 classes / 3 hours per week). The programmatic content of the I3AEA class is described as follows (2):

- Bioengineering: Lesson 1 - Physiology of respiratory, cardiovascular and muscular system; Lesson 2 - Biomedical instrumentation, biomedical instruments for diagnosis, monitoring and therapy (EEG, ECG, artificial organs, cardiac pacemaker, lung ventilator and infusion pump); Lesson 3 - Principle of operation of transducers for biomedical measurements; Lesson 4 - control theory in biomedical experimentation; Lesson 5 - “in vitro” and “in vivo” tests, clinical evaluation, blood tests, use of animal model; Lesson 6 - Rehabilitation engineering; Lesson 7 - biomechanics of movement; Lesson 8 - statistics applied to the model of experimental studies; Lesson 9 - ethics in research in biomedical area, concept of Biodesign and practical framework of Biodesign; and

- Energy Management: Lesson 1 and 2 - Energy management in industrial plants, electric and electronic systems: past, present and future; Lesson 3 and 4 - Automation of electric energy management in industrial plants, electric and electronic systems; Lesson 5 and 6 - Framework of electric installations according to the criteria of the electric sector according to the current legislation; Lesson 7 and 8 - Characteristics of the commercialization processes and operations of the electric energy commercialization chamber focused on the energetic planning of the installation and its energy sources.

The I3AEA class is compulsory (without passing it, the student will not be able to obtain the diploma). The assessment instruments take into account the student's analytical and critical capacity by means of the production of academic texts, explanations and discussion. The approval criterion is the simple average of activities and assignments. The student will be considered approved if he/she obtains a grade equal to or higher than 6 (six), with a minimum attendance of 75% (seventy-five per cent) of the classes.

During the follow-up, the I3AEA class was held in the midst of the Covid-19 pandemic, and because of this, it was taught remotely as a palliative and emergency measure through the platforms: Moodle and RNP Web Conference (National Education and Research Network). The teaching methodologies and resources used were: (i) Synchronous or asynchronous activity (in adequacy to the means available by the students); (ii) Reading and production of scientific texts and academic papers; (iii) Simulation systems; (iv) Activities focused on learning autonomy and by the mediation of teaching resources organized in different supports; and (v) correction of activities and orientations.

Bioengineering. Biomedical engineering has its origin in industrial engineering, arising from the evolution of the medical-hospital, dental and pharmaceutical industry, being elevated to the condition of specialty due (3): (i) the importance of its performance in the sector; (ii) the formation of a market for high-tech products; and (iii) in the potential of engineering methods for the creation of solutions for medicine and biosciences. Biomedical engineering can be divided into four subareas (3): (i) Rehabilitation Engineering; (ii) Medical Engineering; (iii) Clinical or Hospital Engineering; and (iv) Bioengineering.

Bioengineering refers to the application of the techniques and methods of engineering and exact sciences in the development of artificial organs and auxiliary devices of biological systems (3). It was born from the pioneer effort of doctors during the initial phase of the heart transplantation era, who, used to creating tools and equipment for their specific needs, ran into technical difficulties associated with competences that went beyond the medical field such as (3): (i) management of productive industrial structures for transformation into a commercial product; and (ii) development project of monitoring and life support equipment with a high level of complexity and reliability.

The application of Bioengineering assists in branches of medicine such as Cardiology, which is a specialty developed in Brazil thanks to the importance of treating the disease that can cause early disability and is one of the leading causes of death in the world (4). Brazil is internationally recognized as a reference in the treatment of heart disease, and it is possible to highlight this ability from the beginning, given that the first heart transplant in the world was performed in 1967 and the first Brazilian transplant was performed in 1968 (5). And because of this, this science has grown and improved by necessity, extending its mission in the area of research and improvement in heart (6-10).

Bioengineering is already more than 65 years old and is consolidated in several research centres around the world, however, it is still considered to be at an incipient research stage due to two fundamental aspects (3):

- With respect to understanding the relationship between the systems that make up living organisms, which produce information-transmitting substances and communicate chemically through mechanisms not yet properly understood; and
- Regarding the cost of targeted research, which requires human, material and financial resources, imposing itself as a limiting factor to the advancement in certain areas.

Bioengineering education. The work of Coger and De Silva (11) describes the development and successful implementation of a "Biotechnology and Bioengineering" course. The structure of the course is based on the understanding that its students already have reasonable proficiency in their respective degrees (veterans). In addition, they are formally required to pass the class "introduction to physics" and "introduction to inorganic chemistry". To maximise discussion and interaction in the course, the maximum enrolment was set at 16 students for the inaugural offering. The course lasts 16 weeks with two class meetings per week lasting 80 minutes (11). The objectives of the course were (11): (i) to provide students with basic principles in biology and engineering; (ii) to give them a working knowledge of biotechnology and bioengineering applications; and (iii) to establish a climate for engineers, biologists, physicists and chemists to learn from each other.

According to Coger and De Silva (11), the course was developed and taught by a teaching team composed of a biology professor and a mechanical engineering professor, and both professors were present in all classes. To complement the theoretical classes, application classes were presented throughout the semester. To expose students to current research developments research experts from the University, the Carolinas Medical Center and the Whitaker Foundation were invited to lecture, and there was supplementation of the lectures by application lectures given by the course instructors. A website was developed and maintained by the lecturers for the purpose of managing the class resources (11).

According to Coger and De Silva (11), the Biotechnology and Bioengineering course was designed to meet several learning objectives that were assessed continuously throughout the semester (Table 1) and the class topics are described in Figure 1.

TAS Journal, vol. 6, n. 1, p. 27-37
ISSN 2595-1521
MARCH 2022
brunojsantos@usp.br

Table 1. Learning objectives and their assessment methods from the report by Coger and De Silva (11).

Learning Objectives	Assessment Method
1. Understand key science and engineering principles that are fundamental to biotechnology and bioengineering.	a. Cooperative Learning Exercises b. Homework and Quizzes c. Exams
2. Advance from the *understanding* of these key principles (Learning Objective #1) to their *application* in current Biotechnology and Bioengineering innovations.	a. Exams b. Homework c. Final Projects
3. Communicate effectively—through written and oral communication—with a cross disciplinary audience.	a. Exams b. Cooperative Learning Exercises c. Final Projects
4. Effectively participate in interdisciplinary teams.	a. Cooperative learning Exercises b. Homework c. Final Projects
5. Critically analyze biotechnology/bioengineering innovations for the need that it meets and its overall technical or social impact.	a. Exams b. Final Projects

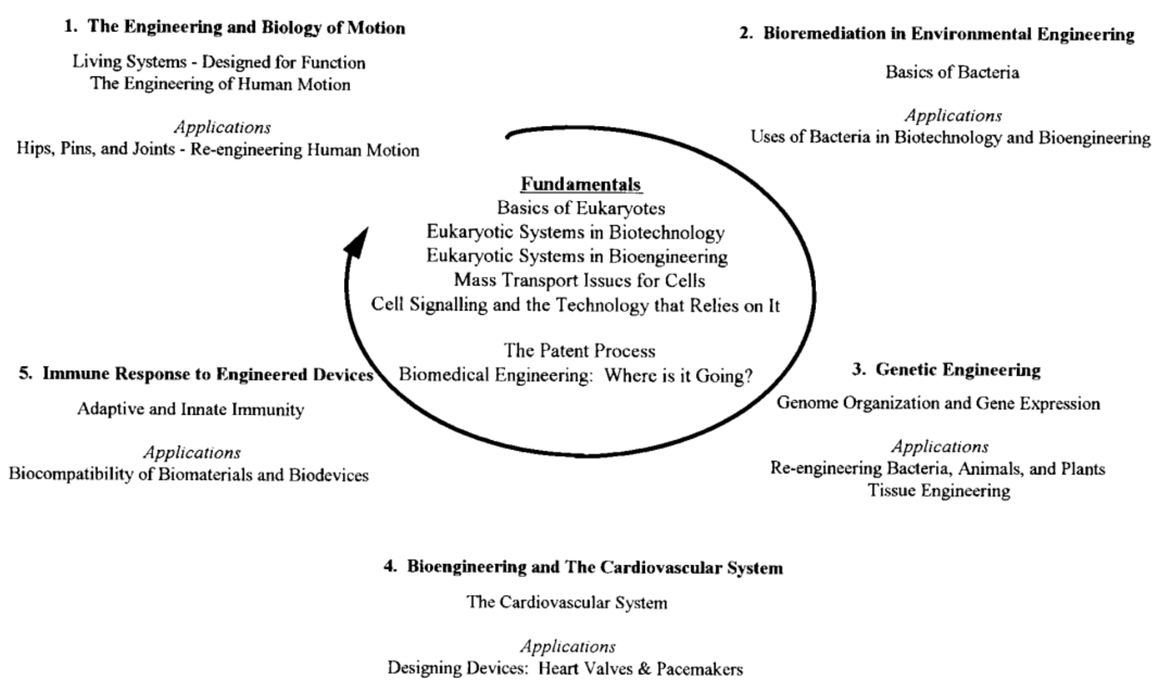

Figure 1. Scheme of the topics of the course by Coger and De Silva (11).

The final course grade for each student was obtained based on 5 main criteria: three exams (20% each), homework and quizzes (10%), class participation (10%), the final written report (12%) and the oral presentation (8%). The final course grades were based on a 0-to-10-point scale (11).

According to Coger and De Silva (11), cooperative learning exercises were effective mechanisms for reinforcing, synthesising and applying the lesson material. They also helped students begin to practice and understand the value of learning from each other. The group size of four people ensured accountability as each team member had to accept the role of (11): (i) facilitator (ensures that all team members participate in the discussion); (ii) recorder (writes down the group's answers to each question so that it can be delivered as the group's submission); (iii) fact checker (checks the group's problem solving strategy using class notes and textbook); and (iv) a calculator (calculates numerical answers) or a responder (orally reports and defends the group's results to the class for each team exercise). In addition to the in-class team exercises, each student was asked to work with a peer to critically evaluate a current innovation in biotechnology and bioengineering. Students were strongly encouraged to partner with a person from a different class to prepare a 10-page written report and a 15-minute oral presentation of the biotechnology or bioengineering application of their choice (11).

According to Coger and De Silva (11), the implementation of the Biotechnology and Bioengineering Course revealed two elements that require special attention (11): (i) biological jargon should be used as sparingly as possible during lectures; and (ii) homework and in-class exercises addressing engineering problem solving were significantly limited by biology and chemistry students' limited exposure to calculus.

According to Coger and De Silva (11), student performance and student feedback results suggest that the Biotechnology and Bioengineering Course was successful in achieving its learning objectives. The key elements for the success of the course were (11): (i) the dynamics and commitment of the course instructors; (ii) the implementation of interdisciplinary student teams at the beginning of the semester; and (iii) the inclusion of carefully selected classes on specific applications of biotechnology and bioengineering.

Results. To answer the question-objective of this work: was there a satisfactory assimilation of the topics of this class by the students? The following analysis strategies were used: (i) relation of the grades obtained by the students of the class; (ii) impressions of two students of the class; and (iii) impression of two professors of the class.

1. List of grades. The class had 18 enrolled, with the following gender distribution: 16 students (88,89 %) and 2 students (11,11 %). In the distribution of the students' education, there was a predominance of the Industrial Automation Technology course (41.7 %), followed by Electrical Engineering and Mechanical Engineering (12.5 % each), as shown in Figure 2. This distribution indicates that students with related education have more willingness to follow the same training, however, the fact of the low incidence of students with Control and Automation Engineering

TAS Journal, vol. 6, n. 1, p. 27-37
ISSN 2595-1521
MARCH 2022
brunojsantos@usp.br

education, may represent that technology students feel or are demanded by the market to strengthen their training.

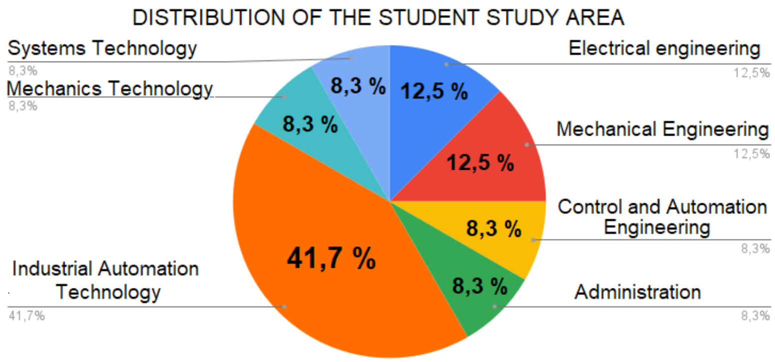

Figure 2. Distribution of students' educational background in the I3AEA class.

The marks of the students in the I3AEA class, were extremely positive: 16 approvals, 1 fail and 1 withdrawal. This approval rate indicates that students were able to assimilate and develop a work within the area of bioengineering. Due to the structure of the I3AEA class (divided into two umbrella topics), it is possible to make a deepening in the students' performance through the comparison between the grades obtained from part 1 (Bioengineering) and part 2 (Energy Management), in that there was an increase of grades between part 1 and 2 in 9 cases and a decrease in 8 cases, according to Figure 3. Because of the distribution, it is possible to state that bioengineering topics were not responsible for the failure of students and in almost half of the cases, students performed better in Part 1 than in part 2 (which has more topics associated with industrial engineering).

TAS Journal, vol. 6, n. 1, p. 27-37
ISSN 2595-1521
MARCH 2022
brunojsantos@usp.br

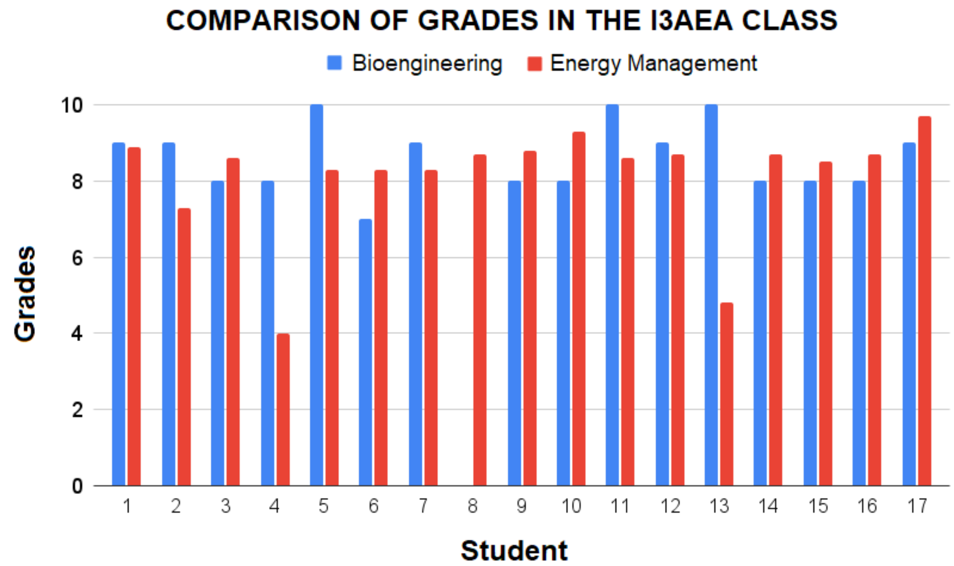

Figure 3. Comparison of grades in the I3AEA class.

2. Feedback from students. The students of the class were approached but only two students wanted to give feedback on the class. The strategy for collecting feedback from the students were: (i) to conduct a face-to-face interview in a comfortable environment. The questions were based on the questionnaire indicated by USP; (ii) from this interview the student's general impression of the I3AEA class was collected; and (iii) an integration of the interviews was performed in de intersections.

The first point to be addressed is about the remote realization of the class: (i) students reported that they felt difficulty in paying attention in class and sometimes missed passages of the content, when this happened, they felt afraid to ask and ask to repeat, feeding back the problem; (ii) they felt a lack of interest from classmates; and (iii) they reported that the veteran classmates facilitated the assimilation of the content by them, as they frequently participated in class and helped to make the class more dynamic and also asked auspicious questions that helped to rectify the confusions.

Second point, is associated with the content: (i) the students found the bioengineering contents very interesting; (ii) they did not report having difficulties associated with biological jargon; (iii) they felt that the classes should be less expository and with more dynamic contents; (iv) they liked the activities focused on reading articles, mimicking the flipped classroom strategy; (v) they liked the management of the classes via Moodle; and (vi) they did not like the class being divided into two distinct topics, they found this a gambit and bureaucratic, they would prefer one class for each umbrella.

Third point, is associated with the professors: (i) students emphasized that the professors' didactics are fantastic, they were able to easily explain very complex topics; (ii) they reported that the professors were very helpful; (iii) they reported that the professors helped in the assimilation of the scientific method; and (iv) they reported that they witnessed cases of students' insolence with the professors, mainly, when it was a female professor teaching the classes.

3. Overview of professors. Two professors reported on the experiences of the I3AEA:

- The first professor, made the following points: (i) common point between the special applications is that the project needs a multidisciplinary team and a good knowledge of the system, before any automation proposal; (ii) the students were led to reflect on the theoretical aspects of the systems and how the same automation solution has different impact; and (iii) in general the students achieved the objectives by proposing viable automation projects, considering the particularities of each system; and
- The second professor pointed out that: (i) he could not state that the post-graduation lato sensu fulfills its role, because the students are not well trained, have no professional experience and no will to learn. And he does not know if they will effectively use the knowledge for something other than having a differential in the curriculum; (ii) he does not feel comfortable talking alone and giving classes on the computer and believes that EAD only works for those who want to learn, because they have to be 100% focused and most of them are doing other things at the same time; and (iii) you cannot charge anything more complex that they students fail, whether technical, higher education or post-graduation.

Conclusion. This work aimed to analyse whether the class of bioengineering within professional engineering specialization course makes academic sense.

Based on the results of approval, student feedback and reports from the professors involved in the class, it is possible to state that the bioengineering class did not have any negative influence within the students' education. Furthermore, it may have had a positive performance by: (i) reinforcing the assimilation of scientific methodology in students; (ii) presenting special automation applications that may have expanded the student's professional prospection; and (iii) stimulating the emergence of new engineering solutions within medicine.

Acknowledgments. The authors acknowledgment Prof. Dr. José Aquiles and Prof. Dr. Osvaldo Nakao for all the support in the elaboration of this research and to the students of the I3AEA class for the collaboration.

Disclosure. The authors report no conflicts of interest in this work.

TAS Journal, vol. 6, n. 1, p. 27-37
ISSN 2595-1521
MARCH 2022
brunojsantos@usp.br

References.

(1) Ministério da educação [internet]. São Paulo: Resolução N.° 73/2019; [2019 out 1]. Available from:
https://spo.ifsp.edu.br/images/phocadownload/DOCUMENTOS_MENU_LATERAL_FIXO/POS_GRADUAÇÃO/ESPECIALIZAÇÃO/Controle_e_Automação/Resol_73_2019_Aprova_reformulação_Curso_L.Sensu_Controle_e_Automação_SPO.pdf.pdf.

(2) IFSP SPO [internet] São Paulo: Projeto do curso de pós-graduação lato sensu: especialização em controle e automação [2021 dec 2]. Available from:
https://spo.ifsp.edu.br/images/phocadownload/DOCUMENTOS_MENU_LATERAL_FIXO/POS_GRADUAÇÃO/ESPECIALIZAÇÃO/Controle_e_Automação/PPC_Lato_Sensu_Controle_e_Automacao_11.pdf.

(3) Antonio, A. M. (2004). A bioengenharia no Brasil, século XX: Estado da Arte (Doctoral dissertation, Universidade de São Paulo).

(4) Ministério da saúde [internet]. São Paulo: Doenças cardiovasculares são principal causa de morte no mundo; [2017 dec 2]. Available from:
http://www.brasil.gov.br/saude/2017/09/doencascardiovasculares-saoprincipal-causa-de-morte-no-mundo.

(5) Bock, E. G. P. (2007). Projeto, construção e testes de desempenho "In Vitro" de uma bomba de sangue centrifuga implantavel.

(6) Gonçalves, P. B., Pamplona, D., Teixeira, P. B., Jerusalmi, R. L., Cestari, I. A., & Leirner, A. A. (2003). Dynamic non-linear behavior and stability of a ventricular assist device. International journal of solids and structures, 40(19), 5017-5035.

(7) Legendre, D., Fonseca, J., Andrade, A., Biscegli, J. F., Manrique, R., Guerrino, D., ... & Lucchi, J. C. (2008). Mock circulatory system for the evaluation of left ventricular assist devices, endoluminal prostheses, and vascular diseases. Artificial organs, 32(6), 461-467.

(8) Bock, E., Antunes, P., Leao, T., Uebelhart, B., Fonseca, J., Leme, J., ... & Arruda, C. (2011). Implantable centrifugal blood pump with dual impeller and double pivot bearing system: electromechanical actuator, prototyping, and anatomical studies. Artificial organs, 35(5), 437-442.

(9) Fonseca, J., Andrade, A., Nicolosi, D. E., Biscegli, J. F., Leme, J., Legendre, D., ... & Lucchi, J. C. (2011). Cardiovascular simulator improvement: pressure versus volume loop assessment. Artificial Organs, 35(5), 454-458.

TAS Journal, vol. 6, n. 1, p. 27-37
ISSN 2595-1521
MARCH 2022
brunojsantos@usp.br

(10) Leao, T., Utiyama, B., Fonseca, J., Bock, E., & Andrade, A. (2020). In vitro evaluation of multi-objective physiological control of the centrifugal blood pump. Artificial organs, 44(8), 785-796.

(11) Coger, R. N., & De Silva, H. V. (1999). An integrated approach to teaching biotechnology and bioengineering to an interdisciplinary audience. International Journal of Engineering Education, 15(4), 256-264.

Authors ORCID (http://orcid.org/)

Bruno Jesus dos Santos - 0000-0001-5176-4711

Tarcisio Fernandes Leão - 0000-0003-4884-5638
Eduardo Guy Perpetuo Bock - 0000-0003-3962-9052