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Developing Professional and Entrepreneurship Skills of Engineering Students Through Problem-Based Learning: A Case Study in Brazil*

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Engineering courses are currently experiencing a high dropout rate. At the same time, the industry is changing, following the evolution of big data systems, the internet of things, artificial intelligence and machine learning, and today's engineer therefore needs to develop new skills to achieve success as a professional. The purpose of this article is to present a teaching methodology that is organised in the form of a programme, and is based on a set of active methodologies such as project-based learning and hands-on activities. This program is called ARHTE, and provides a set of pedagogical actions for the elaboration of interdisciplinary activities, with the objective of overcoming the fragmentation of knowledge in engineering and the lack of a relationship with professional practice. In the ARHTE program, the first four semesters of a course involve students working in teams and applying cumulative knowledge to a comprehensive project. The ARHTE program has been applied within numerous engineering programs, including environmental, civil, computer, production, electrical, mechanical, automation and chemical engineering. One of the main universities in the state of Bahia, Brazil, has been using the ARHTE program, with 1,209 students enrolled in the second semester of 2018, and the results are presented in this paper. Evaluation surveys of students revealed that the proposed methodology was effective in terms of enhancing their interest in engineering. This study demonstrates that action that is coordinated among different university departments can result not only in improved learning but also in better preparation for the job market, participation in regional, national and international academic competitions, patent registration and the founding of new technology-based companies (startups). Standardised tests show that a significant improvement in scores was seen after this new learning methodology was introduced. The increased retention rate during the initial periods of the engineering programs is also an indicator of the effectiveness of the proposed methodology.

Keywords: active learning; project based learning; hands-on activities; interdisciplinarity

1. Introduction

Engineers play an essential part in the growth and change of the economy in every country. A good engineering education is the key to providing qualified engineers who can develop innovative products and services, for the optimisation of processes and to ensure high quality and productivity [1].

As described by UNESCO [2], engineering is a profession that relates to the development, acquisition and application of technical, scientific and mathematical knowledge of the understanding, design, development, invention, innovation and use of materials, machines, structures, systems and processes for specific purposes. Engineers use a knowledge of both science and mathematics to create technologies and infrastructure that address human, social and economic issues. Fig.1 illustrates the relationships between science, technology and engineering.

Higher education institutions (HEIs) are constantly undergoing changes to their curricula and teaching methodologies, and need to adapt to these changes to reflect ongoing discoveries in the world beyond academia [3]. Since the earliest times, educational institutions across the world have always dealt with processes of transformation, and engineering education is no exception. New approaches

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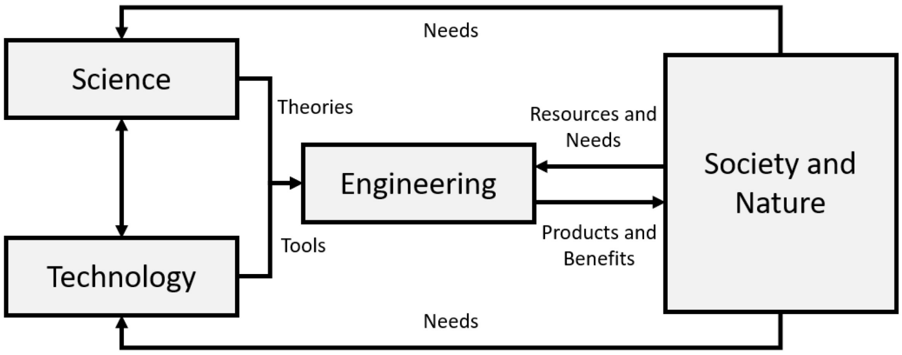

Fig. 1. Relationships between science, technology and engineering (source: [2]).

to the teaching and learning process in engineering have been tried in numerous HEIs around the world. The major focus of these proposals is to empower the student in "learning to do", i.e., studying, researching and creating "something". Projects that are carried out in teams and which integrate practical activities with the theoretical knowledge introduced in expository classes have been reported more frequently in recent years [3–5].

Interdisciplinary projects and active learning have increasingly been used in undergraduate engineering programmes to promote practical applications and a hands-on approach [6–8]. Problem-based (PBL) and challenge-based learning (CBL) methods are known to be particularly effective in various areas of education [9, 10]. The PBL methodology promotes learning through problem solving [11–15]. In this methodology, students are grouped into teams, and problems with appropriate degrees of difficulty are tackled [9]. In addition to solving a problem, the CBL methodology provides the opportunity to test ideas, skills and results among teams of students who have access to the same infrastructure, tools and level of knowledge [16].

Several HEIs have developed programmes to promote interdisciplinary and real problem solving, involving students working in teams and applying cumulative knowledge to a comprehensive project. Examples include the Senior Capstone Program in Engineering (SCOPE) and the CDIO initiative (Conceive, Design, Implement and Operate). SCOPE is heavily used by Olin College of Engineering, and promotes a hands-on approach through solutions to open-ended problems in the real world [17]. The CDIO methodology was conceived at MIT, and involves integration between product design and development, with the implementation and life cycle of a product forming an appropriate context for engineering teaching [16]. As stated in the CDIO methodology syllabus, engineering education should provide graduates with the ability to "*conceive, design, implement and operate complex value-added engineering systems in a modern team-based environment*" [18].

In most engineering programs, students have difficulties with the relationship between the components of the curriculum and their practical applications [8, 19]. Furthermore, approximating industrial reality to engineering courses is a constant challenge in academic activities [20, 6], and didactic aspects may end up damaging "learning", due to teaching methodologies that primarily consider the question of "how to teach" rather than "how to learn" [21]. It is noticeable that several courses forming part of an engineering program are not easily understood by the students due to a lack of a physical/mechanical view of the real situations under study. This gap between theoretical idealisation and practical application, which can be represented by a broken or compartmentalised Kolb's learning diagram, often creates a distance between the student and the course. This may compromise their technical and scientific training, motivation, interest and performance when starting out in their professional vocation [8].

As observed in the Inova Engineering Study [22], engineering curricula have been developed under the influence of the industrialisation process. Initially, the skills required of an engineer were highly technical, but as industrial processes became increasingly varied and sophisticated, scientific qualifications became required. In addition to these areas, industry now requires soft skills such as teamwork, written and oral communication, project management and leadership [23].

The skills needed by engineers in order to succeed in industrial practice have already been presented in several studies. The ability to communicate effectively, to apply mathematical, scientific, and engineering knowledge, to work in multidisciplinary teams, to understand the impacts of engineering solutions in global and social contexts, to demonstrate lifelong learning and leadership, and to recognize and adapt to change are some of the skills required of graduates from engineering programs. The skills required of engineers according to [5, 22, 24, 25] are listed below; these studies were carried out with academics and industry professionals, and the following list summarises the relevant competences identified in these works:

1. Ability to design and operate complex systems;
2. Knowledge of computing environments and programming languages;
3. Ability to apply knowledge of mathematics, physics and science;
4. Logical and objective thinking;
5. Written, oral and graphic communication;
6. Ability to work in multidisciplinary teams;
7. Management, leadership, negotiation and decision-making skills;
8. Ability to share information and cooperate with co-workers;
9. Ability to adapt to ever-changing work environments;
10. Ability to acquire new knowledge in an autonomous and independent way;
11. Social conscience, ethics and professional responsibility.

These skills are reinforced by the Engineering Accreditation Commission [26], which defines the general criteria for accreditation of engineering programs, including the student outcomes that prepare graduates to achieve the educational objectives of the programme. Among the student outcomes are an understanding of professional and ethical responsibilities; a recognition of the need for, and an ability to engage in, life-long learning; a knowledge of contemporary issues; the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; the ability to apply knowledge of mathematics, science, and engineering; the ability to function within multidisciplinary teams; the ability to design and conduct experiments, as well as to analyse and interpret data; the ability to design a system, component, or process to meet certain needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; and the ability to identify, formulate, and solve engineering problems, to communicate effectively, to understand the impact of engineering solutions in a global, economic, environmental, and societal context, and to use the techniques, skills, and modern engineering tools necessary for engineering practice [26].

According to a study published by the World Economic Forum called "The Future of Jobs", seven million jobs will cease to exist by 2020 in the 15 largest economies of the world [27]. Engineers will therefore have to develop new skills due to this change in order to achieve success in the market. The World Economic Forum Study identifies the skills that professionals will need to acquire in this new scenario, among them the ability to coordinate their actions with those of others, the emotional balance that can allow professionals to weather a crisis with serenity and without losing their "fighting spirit", decision making in highly complex environments, the ability to create or use different sets of rules to combine or group things in different ways, clear communication, and the ability to ask the right questions, recognise the problem behind the problem, and to be creative [27].

To meet these demands from industry, current engineering education needs to adapt and adjust. The traditional courses included in an engineering program should be increasingly supplemented with interdisciplinary content whenever possible [8]. The study also finds that the theory presented in the classroom should be coupled with the solution of real problems via which the required skills of the new generation of engineers can be improved, such as creating and producing ("making something happen"); working in teams to manage deadlines, financial and human resources, and exercising leadership; knowing how to communicate effectively, both orally and in writing; and, finally, knowing how to assimilate new knowledge and skills ("learning to learn").

The purpose of this article is to present a teaching methodology based on a set of active methodologies such as PBL and hands-on activities. This methodology is implemented with the support of (mostly free) software applications and web-based innovative education tools designed for the management of students' progress, the utilisation of laboratories, and the certification of professional skills developed through interdisciplinary projects and training tracks. The proposed methodology has been applied to several engineering programs, including environmental, civil, computer, production, electrical, mechanical, automation and chemical engineering, in one of the main universities in the state of Bahia, Brazil.

This paper is organised as follows. Section 2 presents the proposed methodology, online tools, and the results, as applied to several engineering programs in one of the main universities of the state of Bahia, Brazil. Section 3 presents the results of the survey and discussions with students enrolled in programmes using the proposed methodology. The paper concludes with some suggestions for the further evolution of engineering education.

2. Promoting Practical Application and Problem-Solving Skills from the Start

The dropout rate in Brazilian higher education is high, and this is cause for concern in terms of the organisation of curricula and learning methodologies used in higher education. According to data from the National Institute of Educational Studies and Research Anísio Teixeira (INEP) [28], the proportion of enrolled (82%), incoming (50%) and graduates (97%) in engineering, production and construction significantly increased in Brazil between 2010 and 2016.

Enrolment in engineering programs more than doubled between 2010 and 2017 [28] due to promotion via the Pro-Engineering Program (Support Programme for Education and Scientific and Technological Research in Engineering), which until 2013 promoted an increase in the number of engineering programs vacancies in the private sector of higher education institutions, reflecting the priority of engineering in the FIES (Student Financing Fund) and Science without Borders programmes.

Although the proportion of total enrolments and new enrolments per 10,000 inhabitants in engineering, production and construction in Brazil have surpassed those of the OECD (Organisation for Economic Cooperation and Development) countries by 60% and 61%, respectively, the proportion of these students graduating in Brazil is still 33% lower, even compared with 2014 OECD data [28].

In Brazil, this lack of interest in engineering programs can be related to the relatively low competence of students in science and mathematics, as demonstrated by the outcome of the Program for International Student Assessment (PISA) [29]. In the three areas assessed by PISA in 2015 (science, reading and mathematics), Brazilian students performed below average compared to students from other OECD countries.

The challenge for engineering programmes is to combine active methodologies with hands-on laboratory activities and practical engineering experience [19]. As pointed out by The New Media Consortium (NMC), in Brazil [30], online education is becoming a viable alternative for face-to-face teaching, as it facilitates access to courses as well as integrating technological resources with pedagogical ones.

The NMC study identified nine trends and twelve technologies for the Brazilian university scenario, for the short (one to two years), medium (three to five years) and long term (four to five years). In the short term, it was shown that hybrid education models, which involve a trade-off between face-to-face and online methods, will be explored. Over the medium term, it was shown that the production of online educational and pedagogical resources in open source format will become more important. A wide range of content is already available on platforms such as the Khan Academy [31] and TED conferences [32], and MOOCs such as Coursera [33], OpenCourseWare [34] and Veduca [35], among others. The use of learning analytics, remote and virtual laboratories, social networks for academic subjects, flipped classrooms, games/gamification and mobile applications will also increase in the medium term, according to this study. In the long term, augmented reality, the internet of things and virtual assistants [30] will play a role.

With the aim of encouraging the practical application of the theoretical concepts introduced in the classroom, making the course more interesting and challenging for the students, and to increase their attention and reduce dropout rates, an interdisciplinary programme of semester-length projects was developed and implemented in Brazil for engineering courses[1]. This proposal assumes that the student has the central role, and can plan and acquire knowledge and skills through "learning by doing" [36].

This programme is called ARHTE[2], and provides a set of pedagogical actions for the elaboration of interdisciplinary activities with the objective of overcoming the issues of fragmentation of knowledge in engineering and a lack of relationship with professional practice. The ARHTE program began in 2008 and was implemented gradually, culminating in the current format introduced in 2016. This was based on SCOPE and the CDIO initiative, and provides students and teachers with opportunities for discussion, reflection and execution of interdisciplinary projects, encouraging research in topics related to technology and promoting an entrepreneurial spirit. From the first semester, the programme has created an atmosphere in which theory can be applied in practice, combining the concepts of entrepreneurship and the technical and commercial viability of new ideas with a professional attitude towards the preparation of proposals (drafts and projects) and presentations (to the examining board). In this context, the factor of time is decisive, and this necessarily implies the

[1] The implementation experience takes place at Salvador University (UNIFACS), a private HEI in the state of Bahia, Brazil.
[2] The name of the programme matches the meaning of the word ARTE in Portuguese, which according to the dictionary means: (i) the human capacity for creation and its use for a certain result, obtained by various means; . . . ; (iv) ability; cleverness; (v) craft (especially in the manual arts). The term "to make art", characteristic of the Brazilian Northeast, is related to disorder or mischief, e.g., doing something that goes against order. The spelling of the program (ARHTE) is an acronym referring to (and in tribute to) Archimedes, Robert Hooke and Thomas Edison.

importance of team organisation and the management of the project.

In the ARHTE programme, the courses in the first four periods involve students working in teams and applying cumulative knowledge to a comprehensive project. Another similarity between the ARHTE programme and CDIO is the verification of learning in each class, using active learning methodologies and ICT tools. In this way, the teachers can see whether the students are having problems, and the students themselves can evaluate their understanding of the content. At the end of the cycle, students will have been introduced to the creation, design, implementation and operation of systems or products. ARHTE is a compulsory curricular activity for all students in the first to fourth semesters of the programmes of environmental, civil, computer, production, electrical, mechanical, automation and chemical engineering at the Salvador University, UNIFACS, Brazil.

There are four steps in the programme, each of which takes one semester. In each subject area of engineering, progressively, the students undertakes a design project, prototype construction and a feasibility study related to the creation of a startup. Special attention is paid to the first semester, in which students take online courses in entrepreneurship, creativity and the relevance of environmental issues. The Introduction to Engineering course is essential as a basic overview of the interdisciplinary program and to change the students' attitudes towards engineering. In addition to ethics, social and environmental responsibility, and professional practice, this course must contain content related to design, entrepreneurship, innovation and patent registration. Fig. 2 illustrates the four steps of the ARHTE programme.

In addition to the Introduction to Engineering course, courses in all four semesters are fundamental in guiding the operation of the ARHTE interdisciplinary program. In parallel to the traditional curriculum, these courses must include the utilisation of free tools such as TINKERCAD for design, 3D printing, circuit modeling and embedded programming, as well as cheap electronic prototyping platforms such as Arduino and Nodemcu ESP8266, which are used to develop projects that enrich the student portfolio.

TINKERCAD is an online tool that aims to create computer-aided 3D (CAD) designs and models as well as simulating analogue and digital electrical circuit designs. It is offered by Autodesk, and is a free program that works entirely in the cloud via any browser, with a download option [37]. TINKERCAD software works by simulating circuits with a large quantity of electronic components, such as resistors, capacitors, switches, inductors, integrated circuits, multimeters, and buttons, among others. Using this software, it is possible to create electrical circuits, to program microcontrollers such as Arduinos, and to simulate their operation [37].

NodeMCU is a development kit with open source firmware that combines the ESP8266 chip, a USB interface and a 3.3 V voltage regulator. The ESP8266 microcontroller, designed by Espressif Systems, is notable for the presence of integrated Wi-Fi. Manufacturers such as Adafruit [38], SparkFun [39], Wemos [40] and Espressif [41] have developed modules that integrate the ESP8266, a USB converter and connector, a voltage regulator and GPIO [42] on a board. One of these modules is the open source NodeMCU development platform [43]; in addition to the ESP8266 microcontroller flash memory, this includes a voltage regulator, a USB-TTL converter, a USB connector and additional circuits. The ESP2866 microcontroller is based on a 32-bit T10 L106 processor. By default, the clock frequency is 80 MHz, and can be set to 160 MHz, as it is generated by an internal oscillator and an external crystal with a value of 24 to 52 MHz. It integrates a controller and two types of ROM and SRAM, of sizes 32 K for instructions and 80 K for user data. Although it does not have a programmable ROM memory, an SPI flash memory with support for up to 16 MB can be used. It integrates a 2.4 GHz transceiver based on IEEE802.11b/g/n and TCP/IP standards, the WLAN MAC protocol and

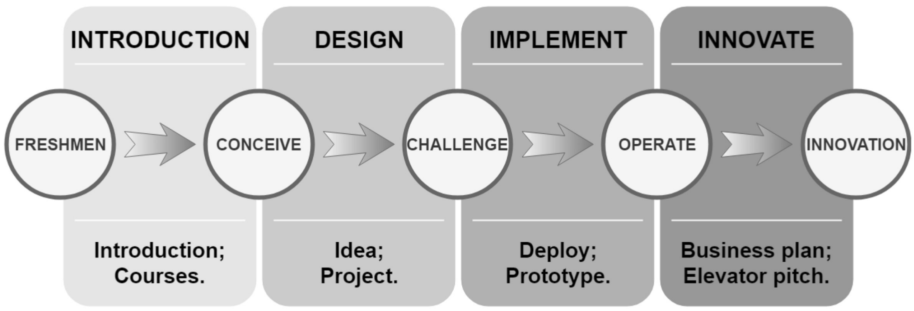

Fig. 2. Steps of the ARHTE program between the first and fourth semesters. Source: authors.

Wi-Fi direct specification. It was designed to support the development of Internet of Things (IoT), wearable mobile and electronic equipment, and has advanced power management with three modes: active, suspension and deep sleep. In addition to input and output, the ESP8266 has 17 GPIOs that can be programmed with various functions, such as SPI, I2C, I2S, UART, PWM, IR and ADC [42].

In all courses in the programme, active learning methodologies are used to verify real-time learning. Free tools such as Kahoot (kahoot.com), Plickers (plickers.com) and Gradepen (gradepen.com) have proven effective for checking learning and each student's understanding of the content.

Kahoot is a free game-based e-learning tool, which was developed in 2006 at the Norwegian University of Science and Technology (NTNU) [44]. Teachers use this tool to prepare multiple choice online questionnaires, discussions or exams, and as a learning game conducted in the classroom with the students [45]. Teachers typically launch the quiz in a web browser displayed on a large screen. The teacher takes on the role of host, and the students use their own mobile devices to connect to the quiz as players, using a game pin and nickname, to give their answers. After each question, the distribution of answers is shown on the large screen, and the teacher can then discuss the results. Before the next question, a scoreboard of the five best players is shown with their nicknames. The students get individual feedback on their own devices after the question has been completed. At the end of the session, the first, second and third best scores are shown on the screen [44, 45].

Plickers is a free application that is also used to prepare multiple choice online questionnaires, discussions or exams, and is played as a learning game in the classroom with students. Teachers use a web-based application to create their own classes, uploading questions and associating each student with a specific Plicker, a four-sided QR code printed in the centre of a paper sheet [46]. The teacher launches the host application in a web browser, displaying the questions on a large screen in the room. The students hold up a QR code on a paper sheet, oriented to the desired answer, so that the teacher can scan all their responses simultaneously using a cell phone camera and the downloadable Plickers app. The answers are transmitted in real time to the web-based application, allowing teachers to check whether their students have understood the content properly. The students are able to see their answers immediately on the screen, while the answers are kept anonymous. Plickers also stores the responses online [46].

Gradepen is a web-based application for the preparation of objective assessments that allows for the automatic shuffling of questions and response options [47]. Evaluations are printed using a QR code and an answer sheet. The teacher uses the mobile application to identify the test and check for the correct answers and errors using the camera of a cell phone. When the corrections are complete, the results are saved online. Another feature of the application is a collaborative network of questions in which teachers can make their questions public so that they can also be used by other teachers. Teachers can use Gradepen free of charge to correct up to five questions and five items, while for larger tests, low-cost packages can be purchased.

In the second and third semesters, students are organised into teams, and are asked to think of an idea, build a prototype and present it. In the fourth semester, the teams draw up business plans for their prototypes in the CANVAS format and post two-minute videos in an 'elevator pitch' style. The three stages involve mandatory meetings with guiding teachers, participation in lectures with topics related to each stage (e.g., project preparation, writing articles) and a presentation to the examining board.

In addition, each student must complete a series of (extra) training courses over the first four semesters. In the first semester, this involves 21 hours of online training, providing an introduction to entrepreneurship, creativity and environmental issues. This training aims to develop entrepreneurial attitudes, awaken the creative potential to overcome problems and raise awareness about biosphere care and sustainable development. In the second semester, there are 22 hours of online games related to algorithms, which aim to teach the student various programming skills, including loops and functions with parameters. The third semester involves 15 online hours of training in microeconomics, which aims to introduce the student to the core ideas of this field, including supply, demand and balance. In the fourth semester, there are 22 hours of online training on innovation, entrepreneurship and patents. The aim of this is to present the main aspects of entrepreneurship, including how to create innovative business models and understand the fundamentals of modeling using CANVAS, and presenting innovation as a factor in the success of a business. The student will also be able to identify the constitutional basis for the protection of patents in Brazil, as well as the principles of industrial property law.

The use of free software and online training offers students free access to tools and training at their own pace. These characteristics are important, as the constraints of time and space can be avoided, while encouraging the student to practice and deepening the subjects studied and researched.

The use of simulators is important in promoting the PBL methodology, and is associated with face-to-face meetings in which guidance teachers propose challenges and projects to connect previously presented theory with the use of the proposed tools. Studies have shown the benefits of online tools in improving the quality of education [48–50], as well as the integration of technology to improve student learning [51, 52].

There are also face-to-face group orientations that use an interactive, expository classroom methodology. These group orientations are carried out in a differentiated classroom, with innovative technological resources such as network-connected projectors for simultaneous projection, differentiated acoustics, interactive projection, and notebooks connected to high-speed Internet, allowing the teacher to interact dynamically with the groups. Four major orientations are promoted for students, provided for ARHTE program: (i) project preparation; (ii) entrepreneurship, innovation and the future of jobs; (iii) CANVAS modelling; and (iv) the importance of portfolio creation with online tools.

The management of training and the issuance of certification are carried out in the student space that exists on the ARHTE portal. Guidance teachers accompany students throughout the certification process, and ensure that compliance with the planned steps is demonstrated.

The laboratories were reorganised and reformed using an interdisciplinary approach in order to encourage the involvement of students from different programmes within the same team to develop interdisciplinary projects. To facilitate these projects, free student access to the laboratories and other resources of the institution was provided outside of regular class hours. Trained personnel were available in laboratories (technicians and monitors) to allow for monitoring and guidance in the use of equipment. The laboratories were equipped with flexible computer-controlled equipment and tools for the manipulation of different materials. A Fab Lab[3] is the most appropriate model for use in this interdisciplinary program.

The scheduling system (available from www.gmr.unifacs.br/lab) can be used by teachers and students for course-based practice, research, scientific innovation and the ARHTE interdisciplinary program. This system allows any teacher or student to view the availability of both the laboratory and the technician, and to schedule a booking using an online booking form. The methodology promotes the intensive use of laboratories.

Two days of the academic calendar were exclusively reserved for the evaluation of the teams and their presentations, in the form of a technological fair. The aim of this evaluation, which uses the form of an examining board, is to enable and familiarize the student with the common requirement for given presentations as part of a conference, dissertation or thesis. Numerous aspects of this form of communication are evaluated, such as the professional posture to be adopted by the student, the way they dress and speak, how to conduct a presentation and how to convince the public of the quality of their "product".

Participation by teachers is required in terms of the orientation of the projects developed by the students. Part of the teachers' time may be assigned to this guidance process, for example being available for inquiries both in person and online, recommending books and references, best practices, other teachers, and companies and professionals in the area, and introducing the reasoning and practical application of the necessary theories for the execution of the projects by the students. These guiding teachers maintained weekly attendance hours in the labs to meet with students, and the teachers' agenda was available on the ARHTE website.

In addition, it is important to have an ecosystem of innovation to support the longer-term orientation of the teams that stand out in the fourth stage of the programme. These teams should be guided by a business incubator and innovation agency, as part of an entrepreneurship and innovation center (CEI in Portuguese) that promotes the emergence of new technology-based startups.

All guidance teachers and the course coordinator were trained in entrepreneurship, innovation and industrial property, with a total of 30 hours of immersion. In addition, they were trained every six months on pedagogical aspects. The training in entrepreneurship and innovation was carried out by the CEI of the HEI (UNIFACS) and used the methodology of the Brazilian Service to Support Micro and Small Enterprises (SEBRAE), through an institutional partnership under the National Program for Entrepreneurial Education (PNEE) [53]. The proposal aims to allow teachers to identify and promote entrepreneurial behavior, market opportunities, innovative business models and ideas, culminating in the construction of startups, through prototyping and the use of a minimum viable product (MVP).

The ARHTE program provides two intermediate certifications in order to provide proof of certain skills and the development of a portfolio. After fulfilling the steps set for the first and second

[3] A Fab Lab is a technical prototyping platform for innovation and invention, which provides stimulus for local entrepreneurship. A Fab Lab is also a platform for learning and innovation, a place to play, create, learn, mentor and invent. More information is available at www.fablabs.io.

semesters, the student is certified as a "Technological Project Assistant", indicating that he or she is able to write academic papers, disseminate new technologies in the areas of engineering and information technology, recognise their implications for sustainable development, and develop optimised algorithms using logical and mathematical reasoning in problem solving. After fulfilling the steps set for the third and fourth semesters, the student is certified as an "Analyst in Entrepreneurship and Technological Innovation", meaning that he or she is able to conceive, design, implement and operate innovative prototypes, identify business opportunities, work in multidisciplinary teams, and apply these technologies to create commercial solutions.

The implementation of the ARHTE program in Brazil has been encouraging in terms of the preparation of students for the job market, helping students to win prizes in regional, national and international competitions, register patents with the National Institute of Industrial Property in Brazil and found new technology-based companies (startups). The average attrition rate of engineering programs was reduced by 9% for the first and second semesters and 2% for the second and third semesters in 2017 compared to 2016.

The results gained by engineering students in the National Student Performance Exam (ENADE in Portuguese) have improved in every cycle. ENADE is a test applied by the Ministry of Education (MEC) for students from higher education programs, which integrates the National System for the Evaluation of Higher Education (SINAES in Portuguese) and aims to measure each student's performance in relation to the knowledge and skills necessary for their profession. All HEIs in Brazil receive a MEC grade for each program, and this is composed of the results of ENADE and other relevant tests. Although ENADE is held every year, not all courses are evaluated at the same time. There are three large groups of programs that are examined alternately each year, meaning that each course is evaluated every three years.

The ENADE grade is made up of the weighted average of two sets of questions: questions about general education have a weight of one, and questions about specific components have a weight of three. The averages obtained by the students are then standardised according to the Brazilian average and standard deviation, giving grades ranging from one to five. Fig. 3 details the ENADE results for each engineering program for the cycles of 2011, 2014 and 2017.

Except for environmental engineering, which only began to be evaluated in 2014, the results of each programme improved between 2011 and 2017. On average, the results improved by 40.4% between 2011 and 2014. In particular, improvements were seen in the results for civil engineering (145.95%), production engineering (102.17%) and computer engineering (75.46%). Between the cycles of 2014 and 2017, the average improvement in the result was 60%, with the best improvements in civil engineering (66.5%) and control and automation engineering (347.6%). Between the 2011 and 2017 cycles, the average improvement in the results was 134.6%, with overall improvements in the results of civil engineering (440.5%), computer engineering (145.4%) and production engineering (117.4%).

The next section describes a student survey on the ARHTE interdisciplinary program, including the method used, the results, a discussion, the limitations of the survey and suggestions for the future.

3. Evaluation Methods, Survey Results, Discussion, Limitations and Implications

In order to characterise the study using a representative sample [54], the questionnaire was made available to all students enrolled in the programme.

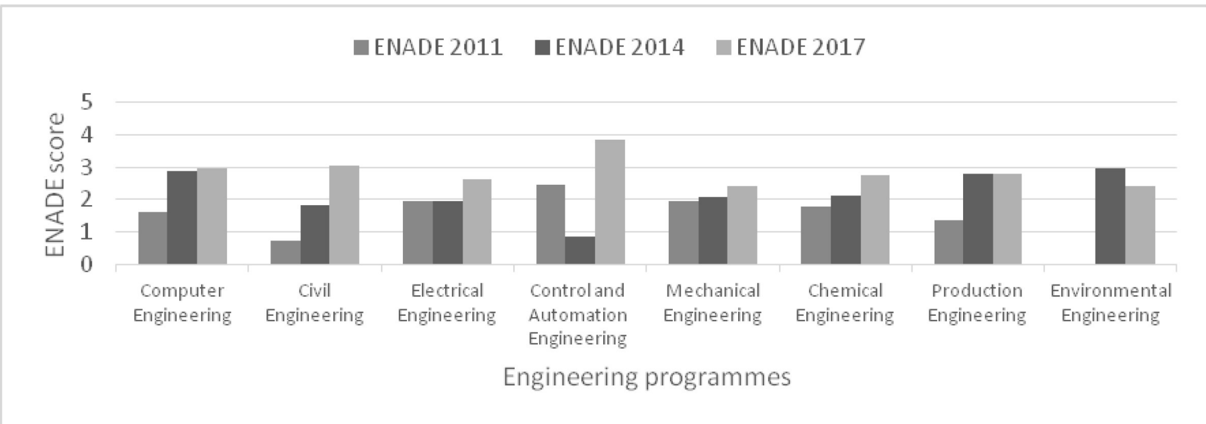

Fig. 3. ENADE results for engineering programmes in Brazil between 2011 and 2017. Source: [28].

A survey questionnaire was applied online during the technological fair at which students presented their research and were evaluated. Students accessed the survey via their mobile devices using a QR code. At the end of the second semester of 2018, this anonymous and voluntary survey was presented to 1,209 students enrolled in the ARHTE interdisciplinary program, of which 447 participated.

Using a table of sample sizes [55] and a sampling strategy of a 95% confidence level and a 4% confidence interval, the sample size needed was a minimum of 400 respondents. There are several web sites that offer sample size calculation services for random samples [55], and two of these were used for this research sample calculation: Creative Research Systems (https://www.surveysystem.com/sscalc.htm) and Macorr Research Solutions (http://www.macorr.com/sample-size-calculator.htm). These offer a service in which the researcher inputs the desired confidence level, confidence interval and population size, and the sample size is calculated automatically. For a confidence level of 95%, confidence interval of 4% and a population of 1,209 people, both services calculated the minimum sample size needed as 401 respondents. The conclusions of this study did not involve generalising for subgroups [54]. The Likert method [56] and net promoter score method [57] were used to evaluate the levels of engagement and satisfaction and the students' opinions about the methodology implemented. It was important to measure student satisfaction, since this is an index that is directly related to the facilitation of the learning process. Student satisfaction indicates a greater acceptance of the learning process and decreases the likelihood of dropping out, especially in engineering [58].

This survey had three sections: in Section 1, numerical and binary ratings were used to evaluate the satisfaction, experience and institutional support to the students; in Section 2, numerical and binary ratings were designed to evaluate the effectiveness of the proposed methodology in facilitating students' learning and skill development; and in Section 3, a binary question was used to evaluate the student's knowledge of ARHTE's rules, and written feedback was required that included three open-ended questions asking students to list the aspects they did and did not like about the proposed methodology and to provide suggestions for further improvement. In addition to information on the course and semester of each student, their responses were characterised as regular {3} or dissatisfaction {1, 2}, as well as negative in binary questions {not} more detailed information was collected, in all sections.

As shown in Table 1, Section 1 of the survey included seven questions. Questions 1 and 2 were used to evaluate the students' satisfaction level, while Questions 3 to 5 were designed to evaluate institutional support, and Questions 6 and 7 were designed to evaluate the students' experience. Fig.4 illustrates the results, showing a 71.1% overall satisfaction with the interdisciplinary ARHTE programme, i.e. an average of 3.8 out of 5, and a 78.5% overall satisfaction with the resources available (courses, guidance, labs and tools), i.e. an average of 3.9 out of 5. The results for Question 3 show that about 85.2% of the students were satisfied with the support provided by the university to the ARHTE interdisciplinary programme, i.e. an average of 4 out of 5. The results for Question 4 show that 76.7% of the students needed to seek clarification or assistance from the coordinators of the ARHTE interdisciplinary programme at some point, i.e. an average of 4.1 out of 5, and of these, 86.9% were satisfied with the support they received (Question 5). Question 6 shows that 92.2% of the students felt that the interdisciplinary programme offered an engaging/immersive experience, and an average of 7.5 out of 10 would recommend the ARHTE interdisciplinary programme to other people with the same

Table 1. Section 1 of the survey, which was designed to evaluate the satisfaction, experience and institutional support for the students

Questions	**Extremely unsatisfied to extremely satisfied**
Rate your overall satisfaction with the interdisciplinary ARHTE programme.	① ② ③ ④ ⑤
Rate your overall satisfaction with the resources available (courses, guidance, labs and tools).	① ② ③ ④ ⑤
How would you rate the overall support provided by the university to the ARHTE interdisciplinary programme?	① ② ③ ④ ⑤
Did you find it necessary to seek out clarification or assistance from the coordinators of the ARHTE interdisciplinary programme at any point?	{No} {Yes}
Did the answer from the coordinators of the ARHTE interdisciplinary programme meet your expectations?	{No} {Yes}
Did the programme offer an engaging/immersive experience?	{No} {Yes}
On a scale of 0 to 10, how likely would you be to recommend the ARHTE interdisciplinary programme to other people with the same academic and professional goals?	① ② to ⑨ ⑩

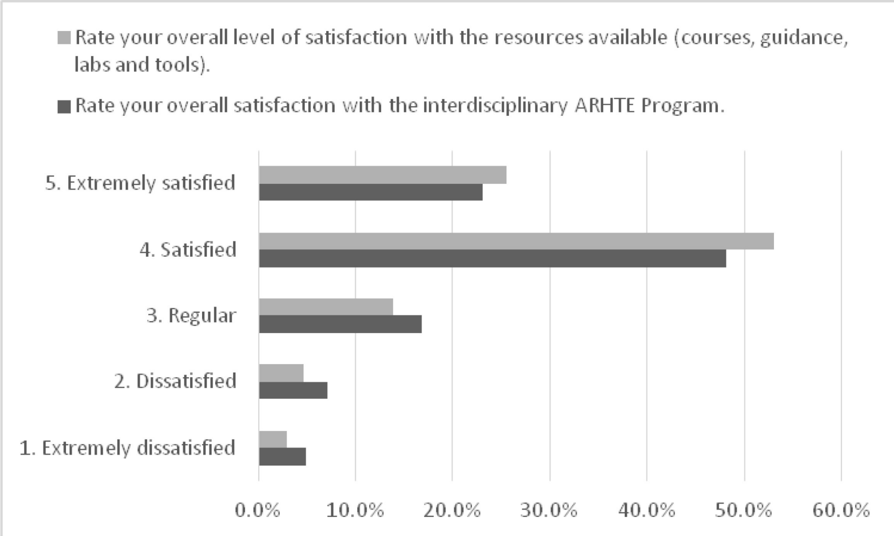

Fig. 4. Overall satisfaction with the interdisciplinary ARHTE programme and the resources available.

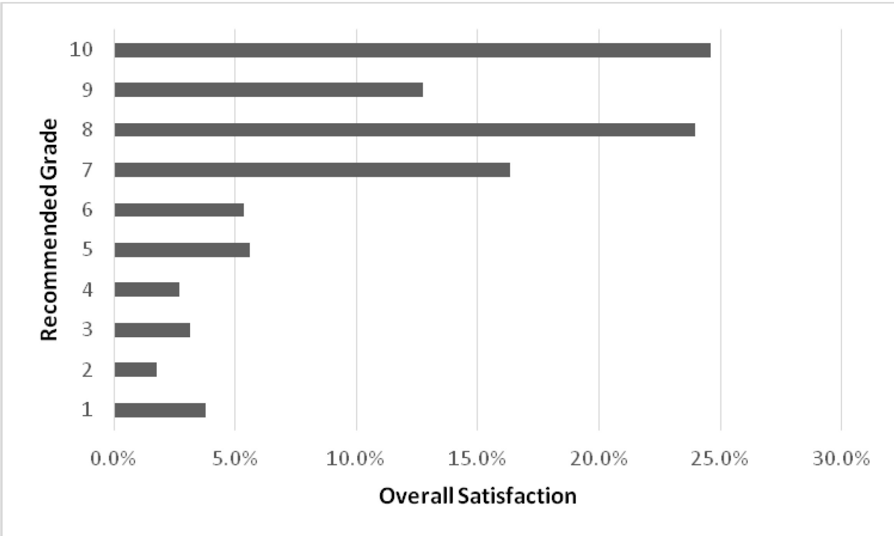

Fig. 5. Students' ratings of the ARHTE interdisciplinary programme on a scale of 0 to 10.

academic and professional goals (Question 7), as shown in Fig. 5.

As shown in Table 2, Section 2 of the survey included five questions that evaluated the effectiveness of the proposed methodology in terms of facilitating the development of learning and skills. Question 1 was used to evaluate the programme organisation as a way of facilitating learning, while Questions 2, 3 and 4 were designed to evaluate whether the courses and guidance offered helped the students to develop skills and the ability to apply the theory in practice, and to understand the use of intermediate certifications as a differential in the curriculum. Question 5 was designed to evaluate how many hours per week the students dedicated to the programme. The results of Question 1 showed that 85% of the students felt that the way the programme was organised facilitated their learning. Of the 15% who answered this question negatively, their reasons were related to the short time allowed for the development of the project and a lack of information on the ARHTE portal. Fig. 6 shows an 89% overall satisfaction with the guidance offered by teachers, laboratory technicians or monitors, i.e. an average of 4.1 out of 5. The results of Questions 3 and 4 showed that 85% of the students felt the courses helped them to develop skills, the ability to apply theory in practice, and critical thinking, i.e. an average of 4.1 out of 5. In addition, 85.2% of the students felt that the intermediate certifications promoted by the ARHTE programme provide a differential in curriculum, i.e. an average of 4 out of

Table 2. Questions in Section 2 of the survey, which were designed to evaluate the effectiveness of the proposed methodology in terms of facilitating students' learning and skill development

Questions	Extremely unsatisfied to extremely satisfied
Did the way the project was organised facilitate learning?	{No} {Yes}
Was the guidance offered (teachers, laboratory technicians or monitors) sufficient?	① ② ③ ④ ⑤
Did the promoted courses (online or face-to-face) help you to develop skills, the ability to apply theory in practice, and critical thinking?	① ② ③ ④ ⑤
Will the intermediate certifications promoted by the ARHTE programme provide a differential in your curriculum?	⓪ ① ② ③ ④ ⑤
In general, how many hours per week did you dedicate to the programme?	{1–2} hours; {3–4} hours; {5–6} hours; 7 or more hours

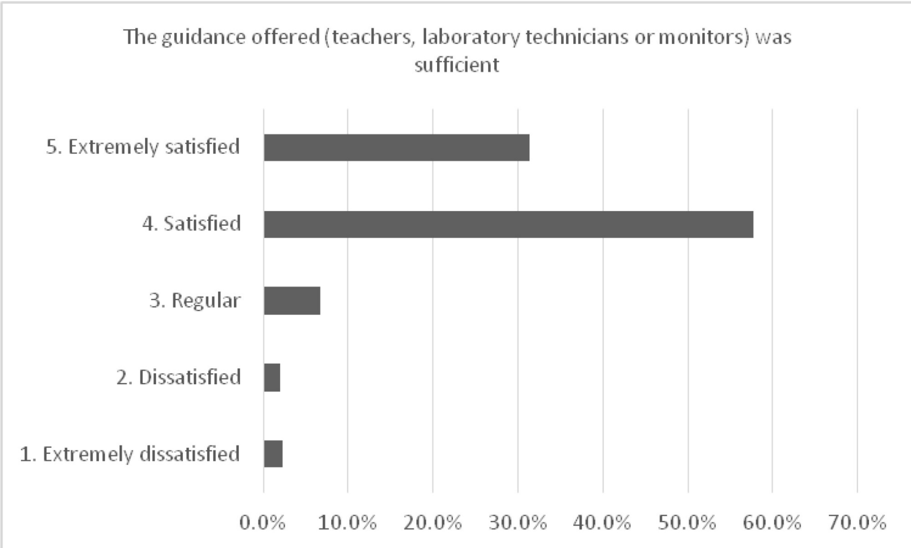

Fig. 6. Satisfaction with the guidance offered (teachers, laboratory technicians or monitors).

5. It is important to note that 2.2% of the students reported not knowing about the intermediate certifications, since they had not read about these on the ARHTE portal or because they claimed that the teachers did not discuss them in the classroom.

As shown in Table 3, Section 3 of the survey included four questions that were designed to evaluate the students' knowledge about ARHTE's rules, and which asked about the aspects they did and did not like about the proposed methodology and suggestions for further improvement. The results of Question 1 showed that 92.8% of the students knew the rules of the ARHTE interdisciplinary programme. The remaining 7.2% of the students reported not knowing the rules of the ARHTE interdisciplinary programme because they had not read about it on the ARHTE website or because they claimed that the teachers had not discussed it in the classroom. Question 2 was an open question on what the students most liked about the ARHTE interdisciplinary programme, and the written feedback was summarised by key-

Table 3. Questions in Section 3 of the survey, which were designed to identify the aspects students did and did not like and to gather suggestions for further improvement

Questions	Open-ended questions
Do you know the rules of the ARHTE interdisciplinary programme?	{No} {Yes}
What did you most like about the ARHTE interdisciplinary programme?	Written feedback
What do you dislike about the ARHTE interdisciplinary programme?	Written feedback
Feel free to comment or suggest proposals for improvements to the programme.	Written feedback

word in order to better understand the students' answers. Comments on teamwork appeared in 21.2% of the contributions, innovation appeared in 17.1%, obtaining knowledge appeared in 11.1%, prototyping appeared in 10.3% and presentations appeared in 7.6% of their answers. Question 3 was an open question on what the students disliked about the ARHTE interdisciplinary programme, and the written feedback was also summarised by keyword to better understand the student's answers. Comments relating to time (i.e. the time allowed to develop the project) appeared in 26.4% of the contributions, disorganisation in 14.8%, guidance in 11.6%, communication in 10.5% and mandatory in 5.1%. Question 4 related to the students' suggestions for further improvement, and the results included increasing the project development time, improvements to the ARHTE portal and the rules manual, and more schedules time for guidance.

New formats for engineering education that are aligned with existing and developing technologies are necessary to attract and retain students and to train them better as professionals who are prepared for the market, which is in a state of constant evolution. The traditional courses that are included in engineering programmes should whenever possible be supplemented with interdisciplinary content. It is also crucial that the theory introduced in the classroom is coupled with the solution of real problems that involve the skills required of the new generation of engineers, such as creating and producing (''making something happen''), working in teams, managing deadlines, financial and human resources, exercising leadership, knowing how to communicate both in writing and orally, and, finally, knowing how to search for new knowledge (''learning to learn'').

Innovative practices, including the use of ICTs, should be adopted for undergraduates in order to promote contact with real problems occurring in professional life, to increase students' interest in engineering and to reduce attrition. In addition, the engineering curriculum should focus on innovation through optional courses with an emphasis on technological innovation, industrial property, entrepreneurship and project management. Teaching and learning should promote portfolio building, forcing the student to obtain practical, ''hands on'' experience.

The challenges arising in relation to the adoption of trends and technologies in higher education should also be mentioned. ''Learning by doing'' can be expensive, in terms of both the manpower required and the facilities used when compared to traditional methods of delivery in large lecture halls. Institutional support is also important in improving student engagement, planning and stress reduction [59]. The low digital fluency of teachers is a concern for educational institutions. Constant training and the sharing of good practices are necessary.

In addition to promoting a continuous increase in the number of graduates in engineering programmes, current concerns are to reduce the dropout rate and to significantly increase the quality of engineering training using new pedagogical approaches. In this sense, innovative approaches have contributed to innovative engineering education.

4. Conclusions

We propose an active interdisciplinarity learning methodology for beginning engineering students, which can be adapted to various undergraduate engineering programmes. This methodology combines hands-on laboratory activities with engineering practical experience, thus promoting problem-solving skills and portfolio creation. The results of a survey indicate that this methodology can enhance students' interest in engineering, and can train them in the development of innovative prototypes and technological startups. The survey also indicates a high satisfaction level of the students and good understanding of an engaging/immersive experience.

Our experience with the implementation of the ARHTE interdisciplinary academic programme has proven successful in terms of student participation in regional, national and international academic competitions, continuing education through Masters' and doctoral programs, patent registration, preparation for the market and the foundation of new technology-based companies (startups). The reduction of attrition in the initial periods of the programme is also an indicator of the effectiveness of the proposal methodology in increasing interest in engineering. Each year, as the programme progresses, further analyses will be carried out to enable adjustments and to prove its effectiveness.

The focus of the ARHTE programme is on the first four semesters of engineering courses, and on improving interest in engineering careers and decreasing the dropout rate in the first few semesters of these courses. In future work, we propose the organisation of specific interdisciplinary tracks by modality of engineering, to use the professional program's semesters. In this way, more in-depth skills and content can be addressed in areas such as control and automation, machine learning, artificial intelligence, chemical and industrial processes, construction, mechanics and materials, operational research, and environmental management. With the continuity of the interdisciplinary program focused on specific vocational training tracks, we intend to develop new projects and deepen technical and industrial knowledge, thus increasing the number of open startups.

The proposal of interdisciplinary projects has become more important following the implementation of new National Curricular Guidelines (NCGs) for engineering courses, which were approved by the Ministry of Education in Brazil on April 24th, 2019. The new NCGs recommend that from the outset of courses, activities should be implemented that promote integration and interdisciplinarity, in line with the axis of curriculum development, in an effort to integrate the technical, scientific, economic, social, environmental and ethical dimensions. In addition, these new NCGs for engineering programs encourage academic activities such as interdisciplinary and transdisciplinary projects, teamwork, prototype development, participation in business incubators and other entrepreneurial activities. They also propose that the use of active learning methodologies should be encouraged in order to promote a more student-centered education.

Suggestions for improvements to the ARHTE interdisciplinary programme are being implemented. The ARHTE portal is being redesigned, and planning for communication at the beginning of the semester has been carried out. Special attention will be paid to the information required to begin the development of the projects, as well as the guidance provided by the teachers.

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References

1. F. M. Schaf, D. Müller, F. W. Bruns, C. E. Pereira and H.-H. Erbe, Collaborative learning and engineering workspaces, *Annual Reviews in Control*, **33**(2), pp. 246–252, 2009.
2. UNESCO, *Engineering: Issues, challenges and opportunities for development*, UNESCO, Paris, France, 2010.
3. C. M. Christensen and H. J. Eyring, *The Innovative University: Changing the DNA of Higher Education from the Inside Out*, Jossey-Bass, 2011.
4. K. Edström and A. Kolmos, PBL and CDIO: Complementary models for engineering education development, *European Journal of Engineering Education*, 2014.
5. F. Schnaid, *Engineering Education: From Positivism to Building Change for the 21st Century*, UFRGS, Porto Alegre, Brazil, 2006.
6. P. Ponsa, B. Amante, J. A. Roman, S. Oliver M. Díaz and J. Vives, Higher education challenges: Introduction of active methodologies in engineering curricula, *International Journal of Engineering Education, Special Issue: Instructional Technologies in Engineering Education*, **25**(4), 2009.
7. D. Marcos-Jorquera, M. L. Pertegal-Felices, A. Jimeno-Morenilla and R. Gilar-Corbi, An interdisciplinary practical for multimedia engineering students, *IEEE Transactions on Education*, **60**(1), pp. 8–15, 2017.
8. P. Venkateswarlu, Establishing a "Centre for Engineering Experimentation and Design Simulation": a step towards restructuring engineering education in India, *European Journal of Engineering Education*, **42**(4), pp. 349–367, 2017.
9. D. Boud and G. Feletti, *The Challenge of Problem-Based Learning*, St. Martin's Press, New York, 1991.
10. E. Poikela and S. Poikela, The strategic points of Problem-Based Learning – organizing curricula and assessment, in E. Poikela and S. Poikela (eds) *PBL in Context, Bridging Work and Education*, Tampere University Press, Tampere, 2005.
11. A. C. Alves, F. Moreira, C. P. Leao and S. Teixeira, Tutoring experiences in PBL of industrial engineering and management program: Teachers vs students, *Proceedings of the ASME International Mechanical Engineering Congress and Exposition*, **5**, 2018.
12. J. P. Chen, F. Gao, L. L. Kong and L. Cui, Study on teaching methods of fundamental electrical courses in Engineering education, *2018 5th International Conference on Industrial Engineering and Applications (ICIEA)*, 2018, p. 515–519.
13. P. Etchepareborda, M. E. Bierzychudek, L. Carducci, F. E. Veiras, F. G. Zacchigna, E. Corbellini, S. G. Marra, M. Iglesias, M. M. Teggia, J. I. Alvarez-Hamelin and R. A. Veiga, A project-based learning method applied to an introductory course in electronics engineering, *2018 IEEE World Engineering Education Conference (Edunine)*, pp. 212–215, 2018.
14. M. K. Noordin and M. S. Nordin, Project-based learning (PjBL) framework in developing non-technical skills for engineering students, *Advanced Science Letters*, **24**(6), pp. 4515–4518, 2018.
15. P. Taheri, Project-based approach in a first-year engineering course to promote project management and sustainability, *International Journal of Engineering Pedagogy*, **8**(3), pp. 104–119, 2018.
16. A. Piironen, CDIO concept in challenge based learning, *WESE '09 Proceedings of the 2009 Workshop on Embedded Systems Education*, Grenoble, France, pp. 27–32, 2009. ISBN: 978-1-4503-0021-6.
17. Senior Capstone Program in Engineering (SCOPE), United States, 2018, http://www.olin.edu/collaborate/scope. Accessed 17 January 2019
18. E. Crawley, The CDIO Syllabus v2.0 – An updated statement of goals for engineering education, *Proceedings of the 7th International CDIO Conference*, Technical University of Denmark, Copenhagen, June 20–23, 2011, http://www.cdio.org/files/project/file/cdio_syllabus_v2.pdf.
19. J. B. Lopes, C. Viegas and J. P. Cravino, Improving the learning of physics and development of competences in engineering students, *International Journal of Engineering Education. Special Issue: Methodology for the study of PBL in Engineering Education*, **26**(3), 2010.
20. M. V. Americano da Costa and J. E. Normey-Rico, An interactive tool to design controllers for processes with dead time, *IFAC Proceedings*, **42**(14), pp. 189–194, 2009.
21. V. F. Oliveira, A proposal to improve the teaching/learning process in civil engineering courses PhD Thesis, Federal University of Rio de Janeiro (UFRJ)/COPPE, Brazil, 2000.
22. IEL/SENAI: Inova Engineering proposals for engineering education innovation in Brazil, Brasília: IEL.NC/SENAI.DN, 2006. ISBN 85-87257-21-8

23. C. Alvarez, M. Nussbaum, M. Recabarren, F. Gomez and D. Radovic, Teaching communication, interpersonal and decision-making skills in engineering courses supported by technology, *The International Journal of Engineering Education, Special Issue: Instructional Technologies in Engineering Education*, **25**(4), 2009.
24. M. F. Cox, Engineering professionals' expectations of undergraduate engineering students, *Leadership and Management in Engineering*, **12**, pp. 60–70, April 2012. ISSN 1532-6748 (online): 1943-5630.
25. WEF, *The Future of Jobs Report 2018 – Centre for the New Economy and Society*. World Economic Forum, Switzerland, 2018. ISBN 978-1-944835-18-7, https://www.weforum.org/reports/the-future-of-jobs-report-2018. Accessed 17 January 2019.
26. ABET, Engineering Accreditation Commission: Criteria for Accrediting Engineering Programs – Effective for Reviews During the 2018-2019 Accreditation Cycle Incorporates all changes approved by the ABET Board of Delegates Engineering Area Delegation as of October 20, 2017. 415 N. Charles Street. Baltimore, MD 21201, http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/. Accessed 17 January 2019.
27. WEF, *The Future of Jobs - Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, World Economic Forum, REF 010116. January 2016, https://www.weforum.org/reports/the-future-of-jobs. Accessed 17 January 2019.
28. INEP, 2018. *Census of Higher Education 2018: Dissemination of Main Results*, Board of Education Statistics – Deed (in Portuguese), Ministry of Education, Brazil, 2018.
29. PISA 2015. Brasil no PISA 2015: Analyses and reflections on the performance of Brazilian students/OECD – Organization for Economic Cooperation and Development, Santillana Foundation, Sao Paulo, 2016, http://download.inep.gov.br/acoes_internacionais/pisa/resultados/2015/pisa2015_completo_final_baixa.pdf. Accessed 17 January 2019.
30. L. Johnson, A. Adams Becker, M. Cummins and V. Estrada, NMC technology outlook for Brazilian universities: A Horizon Project regional report, New Media Consortium Austin, Texas
31. S. Khan, *The One World Schoolhouse: Education Reimagined*, Hodder & Stoughton Ltd, 2013.
32. TED Conferences LLC, Technology, Entertainment, Design: Ideas worth spreading, New York, US 2018, https://www.ted.com/. Accessed 17 January 2019.
33. Coursera Inc. online education company, https://www.coursera.org/. Accessed 17 January 2019
34. Massachusetts Institute of Technology OpenCourseWare, Cambridge, United States, 2018, https://ocw.mit.edu/index.htm. Accessed 17 January 2019
35. Veduca Edtech online education platform, São Paulo, Brasil, 2018, https://veduca.org/. Accessed 17 January 2019
36. S. Dormido, Control learning: Present and future, *Annual Reviews in Control*, **28**(1), pp. 115–136, 2004. ISSN: 1367-5788.
37. Tinkercad: an online application to support design, 3D printing, and simulation of electronic circuits, 2018, https://www.tinkercad.com/, Accessed 17 June 2018.
38. ADAFRUIT. Adafruit Industries open-source hardware company, New York, 2018, United States, https://www.adafruit.com/. Accessed 17 January 2019.
39. SparkFun electronics retailer, Colorado, US, 2018, https://www.sparkfun.com/. Accessed 17 January 2019.
40. WEMOS, IoT products company, China, 2018, https://www.wemos.cc/. Accessed 17 January 2019.
41. Espressif Systems – Fabless semiconductor company. Shanghai, 2018. China, https://www.espressif.com/. Accessed 17 January 2019
42. N. Kolban, Kolban's Book on the ESP32 & ESP8266, ePub format, 2016. Texas, USA, https://leanpub.com/ESP8266_ESP32 Accessed 17 January 2019
43. NodeMCU – Connect Things EASY, An open-source firmware and development kit that helps you to prototype your IOT product, 2018, http://nodemcu.com/index_en.html. Accessed 17 January 2019.
44. Y. Chaiyo and R. Nokham, The effect of Kahoot, Quizizz and Google Forms on the student's perception in the classrooms response system, *International Conference on Digital Arts, Media and Technology (ICDAMT)*, Chiang Mai, 2017, pp. 178–182.
45. H. Bicen and S. Kocakoyun, Perceptions of students for gamification approach: Kahoot as a case study, *International Journal of Emerging Technologies in Learning (iJET)*, **13**(02), p. 72, 2018.
46. M. G. McCargo, The effects of Plickers as response cards on academic engagement behavior in high school students, Master's Thesis, University of Southern Mississippi, 2017, https://aquila.usm.edu/masters_theses/300. Accessed 17 January 2019
47. GRADEPEN, tests preparation, 2018, https://www.gradepen.com/. Accessed 17 January 2019.
48. D. Becking, S. Thomas, B. Bertemieux, G. Filedmann, G. Rademacher and T. Schlageter, Web-based practical trainings at the Virtual University: A breakthrough in distance education, 2003 World Conference on E-Learning in Corporate. Arizona USA, 2003: Healthcare & Higher Education.
49. M. A. J. Lopez, Web-based remote learning of communication systems: A successful experience, *International Journal of Electrical Engineering Education*, **40**(3), pp. 169–174, 2003.
50. V. Petridis, S. Kazarlis and V. G. Kaburlasos, ACES: An interactive software platform for self-instruction and self-evaluation in automatic control systems, *IEEE Transactions on Education*, **46**(1), pp. 102–110, 2003.
51. A. Davidovic, J. Warren, E. Trichina and M. Lakes, Learning benefits of structural example-based adaptive tutoring systems, *IEEE Transactions on Education*, **46**(2), pp. 241–251, 2003.
52. P. S. Shiakolas, V. Chandra and J. Kebrle, Environment for engineering design, analysis, and simulation for education using MATLAB via the World Wide Web. I. Environment description and development, *Computer Applications in Engineering Education*, **10**(3), pp. 99–108, 2002.
53. SEBRAE, Brazilian Micro and Small Business Support Service, National Entrepreneurial Education Program – PNEE, Brazil, 2018, http://www.sebrae.com.br/sites/PortalSebrae/Programas/programa-nacional-da-educacao-empreendedora-pnee,2c7cd24a8321c510VgnVCM1000004c00210aRCRD. Accessed 17 January 2019
54. X. López, J. Valenzuela, M. Nussbaum and C.-C. Tsai, Some recommendations for the reporting of quantitative studies, *Computers & Education*, 2015.
55. L. Cohen, L. Manion and K. Morrison, *Research Methods in Education*, (7th ed), Routledge, Abingdon, UK, 2011.
56. J. Murray, Likert data: What to use, parametric or non-parametric? *International Journal of Business and Social Science*, **21**, 2013.
57. G. Muller, Systems engineering research methods, *Procedia Computer Science*, **16**, pp. 1092–1101, 2013.
58. A.-B. González-Rogado, M.-J. Rodríguez-Conde, S. Olmos, M. Borham and F. J. García-Peñalvo, Key factors for determining student satisfaction in engineering: A regression study, *The International Journal of Engineering Education, Special Issue: Emerging Technologies to Enhance Engineering Education*, **30**(3), 2014.

59. D. Bédard, C. Lison, D. Dalle and N. Boutin, Predictors of student's engagement and persistence in an innovative PBL curriculum: Applications for engineering education, *International Journal of Engineering Education. Special Issue: Methodology for the Study of PBL in Engineering Education*, **26**(3), 2010.

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