Implementation of a PBL/CDIO methodology at ISEP-P.PORTO Systems Engineering Course

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***Abstract*—The earlier engineers start their creative process, the faster they can be useful to industry and economically compensated. The academy therefore has the duty to take the first step as an educational agent.**

This paper describes a teaching and learning experience for the integration of new students in Systems Engineering BSc, taught at School of Engineering of the Porto Polytechnic (ISEP-P.PORTO). This course was designed following the principles and recommendations established in the CDIO (Conceive-Design-Implement-Operate) initiative. During the first 4 weeks of the first semester, the students attend a single discipline, Engineering Labs I (LENG1), where a PBL (Problem Based Learning) methodology is implemented. The study presented refers to the 2016/17 edition, attained by 48 students, where the two projects proposed and the activities carried out by the students are described, as well as the results achieved. The comments made by the students regarding their acquired competences and their motivations are also presented.

The PBL teaching and learning methodology provided a context of design and project, an active and experiential learning in a multidisciplinary environment. Thus, students acquired a set of ethical, social and technical skills, such as teamwork, research, inter and intragroup communication and report writing, which will be useful for the rest of the course and their professional future. Projects realization were motivating for the students in order to learn different areas of engineering, to integrate students in the class, course and city and established good principles of commitment in teamwork.

Keywords— PBL; CDIO; Engineering; Prototype; Soft Skills

I. Introduction

There are many reasons to change the expository methods of teaching in engineering education. The causes are political, educational, employer pressure, regulatory or accreditation of engineering courses (Engineers Order, EUR-ACE, CDIO, ABET). In engineering education this change points towards finding alternatives to traditional programs, which contain too theoretical disciplines. This is intended to improve the quality of courses, processes and results in education, increase attractiveness for potential students, improve preparation for professional practice and contribute to a better development of innovation and job creation [1] [2].

From the various educational models that have been studied since the beginning of the 1970s, the PBL has taken on some relevance [1] in several areas of education. This model began with a preponderance of health education at the McMaster and Maastricht universities and is nowadays implemented around the world. In the PBL, the projects are the basis for students to acquire skills, technical and social, and interrelate the subjects of the various disciplines in the analysis, identification and resolution of problems. It is intended that students in an integrated way and through reflection on experimental practices gain abilities on industrial processes of autonomous learning, plan and project management, collaboration, communication and construction of collaborative inter-knowledge. These practices or projects can also help students build bridges between the phenomenon experienced in the classroom and real professional life [3].

ISEP-P.PORTO- has taken the strategic decision to certify and adopt the EUR-ACE (European Network for Accreditation of Engineering Education) quality benchmark for the school's courses, in order to align them with the others European for the accreditation of engineering education. To achieve this goal, some degrees were designed according to the CDIO model and, according to Azevedo [4] and Costa, Martins, Rodrigues and Rocha [5], their study plans must comply with a set of standards that allow the identification of high quality programs both inside and outside Europe.

Systems Engineering BSc (SE) was designed in line with the objectives of the School and the needs of the companies. The approach is to encourage critical thinking and foster curiosity through both teamwork and independent study. This is achieved dividing each semester into two parts: 4 weeks totally dedicated to a PBL integrative discipline, followed by 11 weeks where the structuring disciplines are taught. The projects/problems proposed in each integrative discipline provide the opportunity for the students to be engaged in cross-disciplinary challenges, preparing them for tackling larger problems in the next integrative disciplines (in the short term) and as engineering professionals (in the medium / long term).

This paper describes the methodology implementation in the first integrative discipline of the course, LENG1, occurring during the first 4 weeks of the course without the coexistence of other disciplines. The students had to carry out two projects, where the first of these serves in full the acquisition of soft skills and the second, more comprehensive, aims the creation of the first prototype. Both projects aim a social and technical integration in the world of engineering.

II. THEORETICAL FRAMEWORK

A. *PBL (Project-Based Learning)*

The guidelines established for the engineering education determine that the engineer training must contemplate an integral formation, which includes the acquisition of knowledge in an increasing form, parallel with the development of the professional attributes [6]. PBL methodology addresses these concerns and allows for: acquiring scientific and technological knowledge, including responses to environmental and social issues; promoting project development skills, teamwork, self and peer evaluation; valuing attitudes of ethics and responsibility towards colleagues and society.

PBL is today a tendency in teaching programs in several areas of higher education and also in engineering [6] [8]. The problem/project is the starting point for the student learning, presented in the form of a problematic situation. This issue is as realistic as possible, based on everyday social, family and professional situations, which is then adapted to the educational context. An interesting problem presents an open structure, a high challenge and serves as a cognitive stimulus. The apprentice involves more actively and collaboratively in its resolution when perceiving the obstacles to be overcome.

For Masson et al., [6] the realization of project activities, if well planned in an educational context, allows the development of an efficient and effective learning, in which students are the agents of knowledge production. The activities do not follow the rigid and pre-established pattern of content teaching but allow them to be strategically included during project development. Specific goals and content are incorporated into project management to develop skills and lifelong learning habits. The role of the teacher will be of a 'trainer' of learning, making the student aware of what he already knows and what he needs to learn, constantly motivating him to seek information in teamwork. It is up to the students to take responsibility for their own learning.

The choice of the project theme is fundamental and must be motivating in order to lead the student to new discoveries. For Masson et al. [6], monitoring and evaluating the students' teaching-learning process should be in line with the evaluation system and the Didactic-Pedagogical Project of the Course, which requires the institutional commitment and an effort of the course managers.

For Campos [9], the PBL methodology, designed for courses with a new educational vision, is an active learning strategy that does not base their curricula on disciplines that only assign routine tasks or of reduced difficulty. In this teaching model, each problem/project is a theme of professional reality. Learning takes place through an open solution problem/project, which promotes a dialogue between the members of the group, which must present a solution within a defined deadline. At the same time, the students show what they have learned in discussion with the teachers about the prototype/product developed. This educational proposal, according to Campos [9], has the general objectives of contributing to the integral formation of students as human beings, fostering their creativity and entrepreneurship, without neglecting moral, ethical and critical skills analysis. This line of intervention also develops competences for teachers in terms of new initiatives and working together with peers, promoting a more frequent exchange of ideas [7].

B. *CDIO (Conceive-Design-Implement-Operate)*

The CDIO initiative is an educational structure already implemented in several schools around the world and includes a list of concepts and associated arguments that guide the training of graduates in engineering. Concepts apply in all areas, including Mathematics and Physics.

The CDIO model tries to assist engineers to work transversal competences and interrelationships with technical, environmental, social and ethical issues. Crawley, Malmqvist et al. [8] allude that this model includes concerns regarding:

– the attributes of an Engineer, such as understanding the basic concepts of design and production, having a multidisciplinary perspective, good ability to communicate and relate, good standards of personal and professional ethics;

– the higher education institutions, whose intention is to train students who know how to conceive, design, implement and operate systems to bring added value to the companies.

The CDIO study program has a comprehensive list of learning outcomes for engineering education and has been developed by comparison with reference models such as ABET (Accreditation Board for Engineering and Technology) criteria The first level of CDIO Syllabus is composed of four general competences: (i) Knowledge and technical reasoning; (ii) Personal and professional skills and attributes; (iii) Interpersonal skills and attributes, including teamwork and communication; and (iv) Conceiving, designing, implementing and operating systems in business and social contexts [8].

To support the Syllabus construction, the consortium that manages this model has approved 12 standards that characterize and indicate what they consider to be good practices in engineering education. These standards provide the existence of project activities, usually in integrative disciplines, in teams and in environments that simulate professional practice in engineering and preferably since the first year of the course. The learning environment should lead to a design-based practice, in which students should be directly involved, and provide opportunities for social learning, in which students can also learn from each other [8].

The use of innovative and active methods leading to a practical and integrative learning with other disciplines and in the context of social interaction between the various agents of the educational process, is crucial. Problem solving should have less emphasis on passive transmission of information, engaging students in manipulating, applying, analyzing and evaluating ideas. These indicators suggest that students discuss what they are learning from each other and with others through lectures and discussion groups.

Finally, student assessment methods should consider an assessment of their effective learning with observations of student performance, reflections, portfolio, self-assessment, and hetero-evaluation.

III. METHODOLOGY

The research methodology presented in this paper is fundamentally qualitative. This choice is because one wishes to obtain "the understanding of behaviors from the perspective of the research subjects" [8, p. 16], to analyze and interpret the phenomena studied. In LENG1, occurring during the first 4 weeks of the course without the coexistence of other disciplines, a teaching and learning methodology based on PBL was implemented [1] [6], following the educational principles established in the CDIO [8] [10]. The data used refers to 48 students who enrolled in SE in the first semester of 2016/17.

The process of integrating the students in the course began in a plenary session with individual presentation of LENG1 teachers and SE management body members. Afterwards, the students presented individually to the other classmates and teachers, referring to their geographical origins, their personal tastes in music, sports, other hobbies and what were their expectations for the course. The teachers of LENG1 presented the objectives of the discipline and the tasks that the students will have to accomplish during the 4 weeks. Subsequently, 12 working groups of 4 students each were freely formed, considering these personal characteristics previously mentioned.

The working groups developed a first project for 2 weeks, which aimed the integration of the student into the classroom, school and city. For each group of students was assigned one of twelve proposed research themes (Table I). The themes were entitled "Top 5" because they required the group to identify 5 main characteristics to describe it. The mission of each group was to build a website, a video and a public presentation. This work is of low cognitive difficulty, as recommended by standard 5 (Integrated learning experiences) of the CDIO [10].

Subsequently, in the remaining 2 weeks, students developed their creative and competitive ability by performing the second project. The objectives were:

- creation of a prototype related to SE;
- use of software to simulate the actual action of the prototype;
- use of oral and panel presentation techniques;
- preparation of an article type report.

The theme of the second project was the same for all groups: the development and creation of a speedometer and distance meter for a bicycle with the help of an Arduino microprocessor. In parallel, the students developed a simulator of the real action of the prototype based on GeoGebra [11].

The development of this project included the accomplishment of a practical test, for 2 minutes, with the simultaneous demonstration of the prototype functioning in the bicycle on top of a static roller. At the end of the test, each group of students presented the following results:

- Average and maximum speeds achieved;
- Standard speed deviation;
- Distance traveled.

Besides the creation of the prototype and its test, each group of students had to make a public presentation and the elaboration of an article type report. The evaluation of this second project had a weight of 70% in the final classification and was divided as follows: performance and proof of the prototype (40%), public presentation (15%), final report (15%).

In the end, the five best projects had the opportunity to participate in the international CDIO event, held at ISEP-P.PORTO between November 15 and 18, 2016. The results were presented taking into account a documental and observation analysis [13] of written records by the students (reports and presentation slides), audio and video recordings of student activities and their public presentations. These groups then released their acquired skills and publicly received a standing ovation and their honorable mention in a certificate.

The variable under study was human behavior and its outcome was identified with contextual descriptions and reactions of participants [12]. For each group of students, the characterization and description of the intended and realized activities was considered, the results obtained (written or oral) were indicated and the comments made by the students were presented in relation to the acquired competences and their motivations.

IV. RESULTS ANALYSIS

In this section, the specificities of each of the projects are presented and the responses to the proposed tasks are analyzed.

A. *First Project*

The response to the themes (Table I) of the first project was effective, since all students were able to organize and distribute tasks among themselves to accomplish the work within the established period (9 days). In the classroom, students started their activities by searching the Web for their theme and were directed by the teacher to some simple tools that allowed them to build a website, edit and create a video.

TABLE I. THEMES OF THE FIRST PROJECT

TOP 5
A - Sustainability Measures for ISEP-P.PORTO
B - Comfort improvement measures for ISEP-P.PORTO
C - Historical facts of ISEP-P.PORTO
D - Historical facts of ISEP-P.PORTO Systems Engineering
E - Characteristics of this class 2016/17
F - Integration Tips for the New Student
1 - Leading monthly expenses for a student
2 - Best ways to do sports in Porto
3 - Low Cost Restaurants in Porto
4 - Main manufacturing industries in Porto
5 - Most visited monuments in Porto
6 - Best Port Wine Cellars

While some students in the group learned to work with the website software, others selected, analyzed, and decided upon a set of criteria needed to respond to the theme they had been assigned (Table II). Students were encouraged to seek answers within the group, but they could always pose questions to teachers and ask for guidance when they were lost.

TABLE II. ANSWER AND CRITERIA TO TOP 5 ISSUES

Tema	***Answers to TOP 5***
A	- Alteration of the ISEP-P.PORTO buildings coverage; - Reuse of waste water and rainwater; - Investment in LED lamps; - Environmental training for students, teachers and students; - Disclosure of messages and billboards. ***Criterion applied:*** - Viable sustainability measures to make ISEP-P.PORTO more environmentally, economically and socially sustainable.
B	- Hydrothermal system to optimize temperature and relative humidity; - Placement of orientation boards; - Improve parking spaces and put on parking meters with free time to use; - Electronic terminals distributed by ISEP-P.PORTO to access academic services; - Spaces intended for smokers.
C	- 1852: foundation of the Industrial Institute of Porto (IIP); - 1974: conversion of IIP into ISEP-P.PORTO; - 1998: ISEP-P.PORTO - minister two-year degrees; - 2004: ISEP-P.PORTO - one of the 8 institutions with greater employability; - 2008: 1st visit of a head of state to a polytechnic institute.
D	- Reasons that led to the opening of the SE course; - Historical evolution, nº of vacancies and access notes, from 2010 to 2016; - 1st and 2nd ISEP-P.PORTO SE Days; - Presence of SE in the current labor market; - Project accomplished by SE students – Fireman Robot.
E	- Personal hygiene; - Eating habits (breakfast, lunch); - Total and gender distribution; ***Criterion applied:*** - Using humor
F	- Praxis; - Academic Events; - Psychopedagogical Support Services; - Mentoring Programs; - University Sports.
1	- Fees; - Accommodation; - Food; - Academic and school material; - Transports.
2	- Cycling through the Porto cycle paths; - Outdoor gymnasiums; - Collective sports; - Jogging/Walking; - Sporting events organized by the Porto City Council. ***Criteria applied:*** - Total price; - Physical exercise that can be practiced in Porto; - Freedom of schedules.
3	- House Guedes restaurant - Lagostim (Crayfish) restaurant - Munchie - Pimenta Rosa (Pink pepper) restaurant - Ristorante S. Martino
Tema	***Answers to TOP 5***
	Criteria applied: - Price-quality relation - Personal experiences - Variety of dishes - Popularity index - Average price per person
4	- Bial: - CIN; - Efacec; - Unicer; - BA Vidros. ***Criteria applied:*** - Invoicing; - Number of employees; - Number of countries and export volume; - Mission/Purpose of the company
5	1- Livraria Lello (Book Store); 2- Torre dos Clérigos (Tower); 3- Palácio da Bolsa (Palace); 4- Fundação de Serralves (Foundation); 5- Estação de São Bento (Train Station); ***Criterion applied:*** - No. of visitors from 2013 to 2015
6	- 1º: SANDEMAN; - 2º: FERREIRA - 3º: REAL COMPANHIA VELHA - 4º: TAYLOR'S - 5º: CROFT ***Criterion applied:*** - Classification attributed by the wines premiums received.

Table II lists the 5 characteristics that students have considered on their website, video and public presentation, in addition to the criteria used by some groups of students. Most groups based their solutions/responses on their web searches. In the case of theme A and E, students also used interviews and questionnaires to colleagues and ISEP-P.PORTO staff to complement their answer and in theme D, the students interviewed the course director.

Most students used the existing Wix platform on the Web to create their websites. This platform is free to use, easy to manipulate and requires no programming knowledge. Students use existing templates that are easy to customize, allowing embedding videos, links to social networks and questionnaires with information requests or contacts. Only a group of students preferred to make their website programming in HTML. It was identified that most of the students (83%) exposed their videos with a link to the YouTube channel, and only 2 groups directly inserted the video (in mp4) on their website.

In the public presentations of the works, 41.7% students used the Microsoft PowerPoint tool and the remaining 58.3%, the Prezi application. It should be noted that an audioscopy was carried out on the presentations made within the scope of the first project which allowed making some correction suggestions. It should be added that students also did a test presentation before the final presentation. In both cases, weaknesses and posture errors were noted, such as: lack of initial identification of group elements, use of a cheat sheet, lack of voice placement, positioning ahead of the projected image, hands in the pockets, position themselves with their backs to the audience, lack of preparation, inclusion of too much text per slide, poor choice of background colors, wrong font size of the text, etc.

In the particular analysis of the work about theme A, the group of students promoted a set of interviews recorded in video and included in the website, http://tiago-403230.wixsite.com /5medsustisep (Fig. 1), presenting the 5 solutions that found more appropriate.

Fig. 1. Website of theme A of the 1st project.

This group of students ended their public presentation of results recommending: "With this project we hope to have captured all your attention, sensitizing students and teachers for a continuous improvement of small daily routines, that tomorrow will be the great differences for a better future!".

For the solution presented in theme D, the group of students conducted an interview with a former student of the SE course and she said: "I chose SE motivated by the polyvalence of the course... I am currently managing the quality system of a company, having implemented the ISO 9001 certification". This group of students was able to find and present footage about the events of the SE Days of previous academic years and about National Robotics Competition at the Polytechnic of Guarda,"Fireman Robot", where a team of SE students participated. This group ended their presentation by stating "In general, all goals have been achieved, thus enabling the development of a well-structured and successful work".

Another group of students chose to humorously respond to the "Characteristics of the 2016/17 Classroom" by making a video (https://www.youtube.com/watch?v=fh3mcgVotEU) with they interviewed classmates about their eating habits and personal hygiene. In the public presentation they mentioned that, to realize the video-images, they had to learn how to use various editing software. It should also be pointed out that the humorous video received a strong applause from the audience on the day of the final presentation.

The city of Porto, its architecture and gastronomy were explored through the Portuguese videos and music that the students inserted in their Websites, for example in theme 3 (Fig. 2 and http://nunomcd.wixsite.com/5restaurantes). This aspect is useful not only for the class students who arrived in the city for the first time, but also for those who want to visit it.

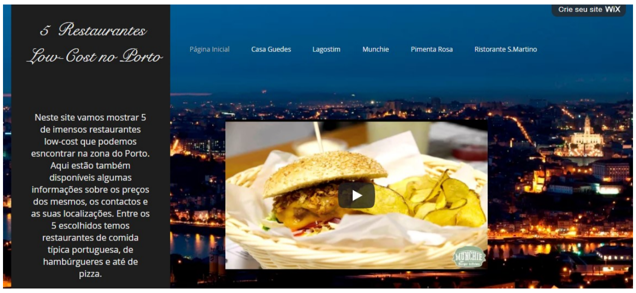

Fig. 2. Website of theme 3 of the 1st project.

The solution for theme 3 was based on: "Internet searches and magazines, which helped us to choose the 5 catering establishments. We considered the tastes of the group members' palate". The students also said that in this selection they took into consideration "that quality is not affected by the low price, the positive reviews and the good location". This group finishes their presentation recommending the Munchie restaurant because: "it is a cozy space that serves food that we all enjoy, namely their hamburgers with different accompaniments, like the French fries!".

Websites created for the themes 5 (http://1161108.wixsite.com/5monumentosisep, Fig, 3) and 6 (http://ani7167.wixsite.com/cavesvinhos, Fig. 4) are also a good example of the promotion of the pleasant places to be visited in the city of Porto.

Fig. 3. Website of theme 5 of the 1st project.

Fig. 4. Website of theme 6 of the 1st project.

For theme 5, in the Website information, students included a topic they denominated "curiosities" with descriptions of monuments, architectural type and year of construction, and presented statistics numbers of visits in pie or bars charts.

For the website of theme 6 (Fig. 4) the students chose "to create a dynamic website in which the information for each basement was simple, direct and objective". In the public presentation of results, the number of prizes awarded in each basement was announced, namely: “200 prizes for Sandeman, 100 prizes for Ferreira and 28 Real Companhia Velha”.

In summary, all groups of students were able to perform their first project activities in 9 days and from a cognitive point of view learned how to use or develop video editing/recording tools, presentation software and software/website building platform. From an ethical, social and integration point of view, the students interacted intra and intergroup, exchanged knowledge, collaborated in researches, questionnaires, interviews, videos of colleagues, therefore, reinforced their integration in the class, course and city of Porto.

B. *Second Project*

In the second project the students elaborated a prototype of a speedometer and distance meter for a bicycle based on the Arduino microprocessor. To test the prototype, students collected data through a 2-minute practice test on their bike to spin on top of a static roller. In parallel the students developed an application in GeoGebra that simulated the real speedometer's pointers from the data collected from their prototype. This application also calculated the maximum speed achieved, average speed, distance traveled and standard deviation during an established period. The performance of the students in this test, the proper functioning of the prototype and the computer application served to sort the groups and identify the best five, who were honored to participate in an international conference under the CDIO initiative.

The project activities began with the distribution of an Arduino board, a magnetic sensor and a breadboard to each group. Thereafter, it was shown, in the form of videos, some equivalent applications with the respective code for the microprocessor. Considering that, at this stage, the students had not yet contact with any programming discipline of the course, it was only intended that they were able to understand code created by others and adapt it to their own prototype.

The planning of the project involved identifying tasks and assigning them equitably by the four elements of the group. After deciding on the plan and the project management, the students made a list of necessary material, resorted to an electronics store and searched for some material of domestic use. In the classroom, young students/researchers first addressed the hardware component of the project such as installing the magnetic sensor on the bicycle frame, placing the magnet on the spokes, connecting the electronic components, LEDs, etc. (Fig.5).

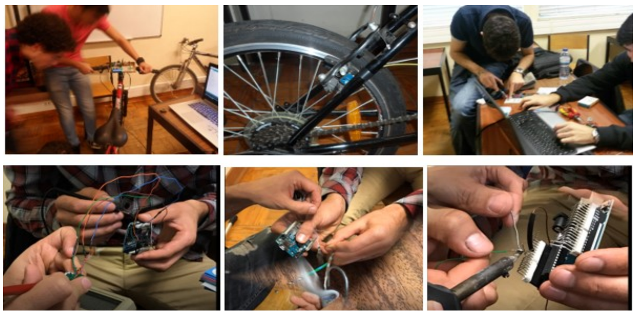

Fig. 5. Implementation of the hardware in the 2nd project.

Subsequently, they were concerned with the software component, that is, the adaptation of existing code to its prototype. Other students still had the responsibility of building an applet in GeoGebra (Fig. 6) that would simulate the movement of the real speedometer after collecting the data coming from the Arduino board.

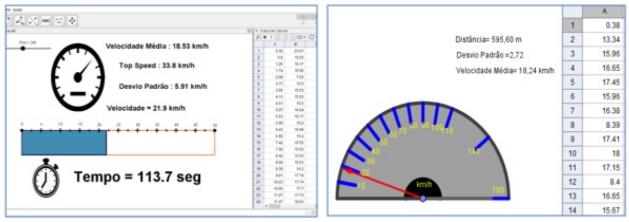

Fig. 6. Simulator of the real speedometer in GeoGebra in the 2nd project.

The final prototypes were presented with different design and construction robustness, as can be seen in the images of Fig. 7.

Fig. 7. Prototypes – several bicycle speedometers in the 2nd project.

For example: 4 groups of students inserted an SD (ScanDisk) reader/writer, 1 group inserted a Bluetooth card to communicate with a mobile application to do the data reading of the prototype, almost all the groups incorporated an LCD type display and all were able to do the reading with the free software for Arduino in PC. Regarding the total cost of the prototype, the groups reported that it was between € 34.30 and € 42.20, including the acquisition of Arduino board.

The project also included the preparation of an article type report and a public presentation of the results. The students acquired several multidisciplinary competences in an autonomous way in areas of physics, mathematics, electronics, Arduino and GeoGebra programming, cooperative and team work, report writing and oral presentation.

In relation to the article type report it was required the use of a structure that included summary, introduction, methodology and development, results and discussion, conclusions and bibliographical references. In general, the students followed the proposed structure, but they had some difficulties in the correct grammatical writing, word formatting, synthesis of quantitative results and in the highlight of the main conclusions.

Analyzing the final reports, although practically all groups pointed to the success of the project, they also described the main difficulties they have experienced, being the most significant:

- In GeoGebra's domain, a lengthy investment was required because only a few students had previous experience;
- Difficulties in programming the Arduino by the same reasons;

However, all the students were unanimous in stating that, by learning to search the internet properly and questioning / confirming with the teachers, all doubts were duly clarified. Therefore, the strengths far outweighed the weaknesses, as can be concluded from the comments included in the reports:

- The project was very important for the development of knowledge to manage the construction of a prototype;
- The effective teamwork helped to develop the spirit of mutual aid and cooperation that was established, inside and outside the group;
- Support of the teachers, who not only helped and lent materials but also encouraged not to give up when things went wrong;

The comment about cooperative work is one of the acquired skills that was most mentioned by all groups of students.

The pedagogical elements introduced by the team of 3 teachers on the Moodle-Isep platform helped to correctly manage the tasks, showing the basic concepts both at a technical level and in organizational or time management behavior. The possibility of searching for documents on the Web, viewing online videos suggested by teachers and the short theoretical sessions provided by them complemented the necessary resources. E-mail communications between students and teachers were also a mean to clarify doubts.

Considering oral communication (*Fig. 8*), in general students were a little nervous. All used slides in their presentations, as well as videos with musical records and explanatory notes of the execution and test phases.

Fig. 8. Public presentation of results obtained in the 2nd project.

In these presentations, in addition to the information contained in the reports, students had the opportunity to show their prototypes to the whole audience (classmates, other students and several SE teachers) as well as their simulator in GeoGebra and some performance charts of their test (Fig. 9).

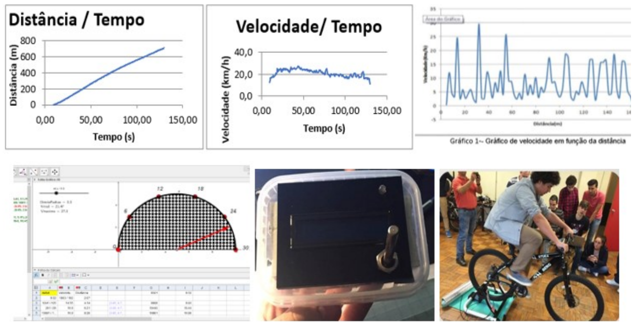

Fig. 9. Examples of results obtained in the 2nd project.

During the final presentation of group 5, for example, an electrical/electronic scheme (Fig. 10) was presented that had not been placed in the report.

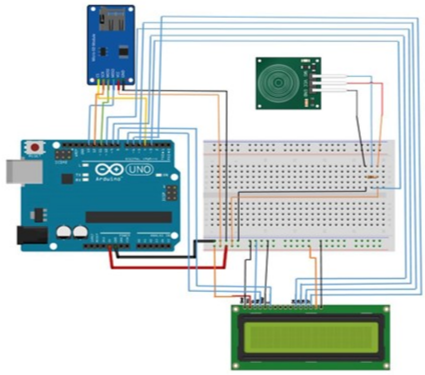

Fig. 10. Connection diagram of LCD, SD and magnetic sensor to Arduino made by group 5.

On the eve of the final oral presentation and prior to the finalization of the report, students had to test their prototypes on a two-minute bicycle official test. The students installed the prototype on their bicycle that was placed on a static roller. Each group elected a representative, who pedaled for two minutes, to achieve the highest maximum speed, the highest average speed and the lowest standard deviation (Fig. 11). The data acquired by the magnetic sensor, placed on the wheel, passes from the Arduino microprocessor to the computer through the monitor, or to the LCD and/or mobile phone to allow calculation of the physical and mathematical parameters requested in the design.

In the images of Fig. 11 besides the photos taken during the test there are also some images of the tasks of preparation for the test.

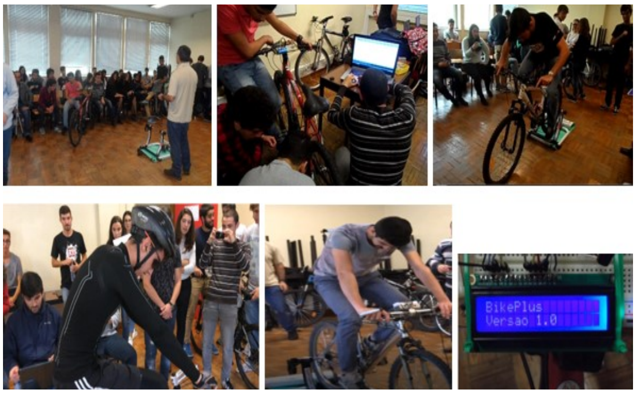

Fig. 11. Bicycle test to experiment the prototype in the 2nd project..

The robustness, design and functioning of the prototype, the results obtained in the official test and the computer application served to sort and classify the groups. In this evaluation, the following criteria and weights were used: performance and test of the prototype (40%), public presentation (15%) and final report (15%). The five best classified groups were invited to participate in a Conference (CDIO - Fall Meeting 2016) and received a certificate with their classification.

After the initial difficulties of the students, the teachers concluded that the accomplishment of this second project brought to the students a strong motivation, a sense of pride and fulfillment. The importance of doing this type of PBL activities immediately at the beginning of the course was one of the factors mentioned by most of the groups to achieve success in the integration.

According to students' reports, the accomplishment of this PBL project was important to acquire competences in the level of research and oral communication. It is also possible to conclude that, although this type of activity requires considerable effort and persistence, it motivates them for learning, working and overcoming difficulties, with ingenuity and enthusiasm, as it is reported in other studies [9], [13] [14].

In summary, the students' comments on the reports and their public presentation of results revealed the skills acquired during the execution of these projects. The students were able to integrate into the class, the course and the city and learned to apply concepts of mathematics, physics, programming and simulation. They have improved the writing of oral records and have raised the values of integrity and respect that the profession will soon require.

V. CONCLUSIONS

This paper describes the implementation of a PBL/CDIO learning/teaching methodology applied to a discipline of the first semester of Systems Engineering BSc at ISEP-P.PORTO, Engineering Labs I (LENG1). The students had to carry out two projects, both aiming a social and technical integration in the world of engineering. The PBL methodology allowed establishing a cooperation between students and teachers, fruit of the intense and sometimes unexpected work, but precisely for that reason, exciting and appealing for all. Since newly arrived students are not supposed to have major background knowledge, the theme of the engineering project is crucial to the commitment of all, where the teachers have a critical role to ensure success.

In terms of future perspectives, LENG1 will consolidate this experience/methodology and make a deeper analysis of the students' answers to questionnaires that focus on the acquired competences and the motivations.

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REFERENCES

[1] K. Edström, and A. Kolmos, "PBL and CDIO: complementary models for engineering education development", *European Journal of Engineering Education*, 39:5, pp. 539-555, 2014.

[2] S. Sheppard, K. Macatangay, A. Colby, and W. Sullivan, *Educating Engineers: Designing for the Future of the Field*. San Francisco, CA: Jossey-Bass, 2009.

[3] R Tiwari, RK Arya, and M.Bansal, "Motivating students for project-based learning for application of research methodology skills", Int J App Basic Med Res,7:S4-7, 2017.

[4] S. Azevedo, "High Level Qualifications Frameworks and the EUR-ACE Framework Standards – do they fit together?", Workshop on Overarching and Sectoral Frameworks, *European Network for Accreditation of Engineering Education*, Brussels, Fondation Universitaire, 2009. Available: http://www.ordemengenheiros.pt/fotos/editor2/eurace/comunicacaoeng.feyodeazevedo.pdf.

[5] A. Costa, A. Martins, F. Rodrigues and J. Rocha, "CDIO@ISEP: A Stairway to heaven (A CDIO contribution to EUR-ACE certification)", in *Proceedings of* the *8th International CDIO Conference*, Queensland University of Technology, Brisbane, July 1- 4, 2012.

[6] T. Masson, L. Miranda, A. Munhoz, and A. Castanheira, "Metodologia de ensino: Aprendizagem baseada em projetos (PBL)", in *XL Congresso Brasileiro de Educação em Engenharia*, *COBENGE 2012*, 3 a 6 de Setembro de 2012. Belém PA, 2012.

[7] J. Lasauskiene, and A. Rauduvaite, "Project-Based Learning at University: Teaching Experiences of Lecturers", *Procedia - Social and Behavioral Sciences*, *197* (February), pp. 788–792, 2015. https://doi.org/10.1016/j.sbspro.2015.07.182.

[8] E. Crawley, J. Malmqvist, S. Östlund, D. Brodeur and K. Edström *Rethinking Engineering Education The CDIO Approach*. Springer Science+Business Media, LLC. New York, 2007.

[9] L. Campos, "PBL (Problem/Project Based Learning): uma nova abordagem para a Educação em Engenharia", in *XVII ENCEP 2012*: *Encontro Nacional de coordenadores de cursos de engenharia de Produção*, Natal (Brasil), Maio de 2012. Available: www.abepro.org.br/.../PBL_%20LUIZ%20CARLOS%20CAMPOS.ppt

[10] J. Malmqvist, "A COMPARISON OF THE CDIO AND EUR-ACE QUALITY ASSURANCE SYSTEMS", in *Proceedings of the 5th International CDIO Conference*, Singapore Polytechnic, Singapore, June 7 – 10, 2009.

[11] "Discover Math with GeoGebra,"GeoGebra - Dynamic Mathematics. [Online]. Available: https://www.geogebra.org/. [Accessed: 30-Apr-2018].

[12] R. Bogdan, and S. Biklen, *Investigação qualitativa em educação*. Porto: Porto Editora, 1994.

[13] R. Yin, *Case study research: Design and methods* (3ª ed.). London: Sage, 2003.

[14] R. Lima, "Aprendizagem baseada em projectos interdisciplinares: Conceitos, implementação e resultados", in *XVII ENCEP 2012: Encontro Nacional de coordenadores de cursos de engenharia de Produção*. Natal (Brasil), Maio de 2012.