INTEGRATING CDIO SKILLS BY TEAMWORK IN A SCHOOL OF ENGINEERING- ISEP

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ABSTRACT

CDIO initiative establishes a set of learning outcomes for the students to achieve upon the completion of their engineering programmes. These learning outcomes cover several areas namely scientific knowledge, personal and interpersonal skills and product, process and system building.
Teamwork is recognized to be very important in the learning process and contributes to engineering thinking and problem solving using knowledge discovery and creative and critical thinking. Besides it enhances interpersonal development since it favours individual and group interactions using communication, conflict solving and leadership.
Engineers should acquire the essential technical knowledge and also soft skills to be able to face and solve the challenges of our modern society, which require knowledge, the ability to communicate and implement solutions many times using a multidisciplinary approach. The goal of this work was to characterize and analyse the situation related to teamwork in Instituto Superior de Engenharia do Porto (ISEP), School of Engineering.
In order to achieve these goals a review of existing teamwork tasks in every course of each engineering program in ISEP was performed. In addition a survey was designed and launched online at the end of the second semester to cover all academic year. All students have access to computers and internet at school and some them also have access at home.
For the engineering programs that used teamwork as a very common tool survey quantitative and quality analyses were performed such as frequency analysis among others, in order to characterize the main aspects of their implementation.
By performing this type of analysis it was possible to detect, for example, the advantages and disadvantages of teamwork perceived by the students.
The answers given by students indicate that most of them are happy with the teamwork developed in the courses and that the support provided is enough.

KEYWORDS

Higher education, Engineering, Teamwork, Teaching-learning process, and Learning strategies, Standards: 2, 8, 11

INTRODUCTION

Engineering graduates should have several technical knowledge and skills that contribute to enhance and improve their role in business and society and that enable them to perform their

work with professionalism and success. Graduates should also have personal and interpersonal skills such as engineering reasoning and problem solving, system thinking, creative and critical thinking, working in teams and communication. These are often named "soft" as there are not considered the core subjects of an engineering graduation in opposition to the more technical subjects. All these outcomes are present in the CDIO Syllabus outcomes (standard 2) (CDIO, 2016; Zou et al., 2012). The new and global challenges/problems that exist nowadays have proven that those skills are essential to the development of an engineer's work (Crawley et al., 2011; Woods et al., 2000). Engineering programs are challenged to create innovative ways for students to learn not only core and technical subjects but also these skills. Many methodologies to enhance learning and to provide skills for future engineers have been tested and implemented such as problem-based learning and project based learning (Ríos et al., 2010). The involvement of key stakeholders that validated the learning outcomes can be very valuable to determine what should be achieved.

Teamwork is very important to the development of an engineer's work because many projects involve several professionals in a multidisciplinary approach and aspects such as leadership and communication are essential to achieve goals successfully. Teamwork can also be a very important and useful tool to enhance learning and the development of these skills. It is an active learning activity since students take on roles that follow the professional engineering practice (standard 8) (CDIO, 2016). Teamwork also promotes peer learning, which is considered by some authors very important to the effectiveness of many engaging methodologies, such as cooperative learning and problem-based learning (CDIO, 2016).

Teamwork and their assessment can help to evaluate the personal and interpersonal skills, since it is important to have effective assessment processes for measuring them as stated in standard 11 of CDIO Syllabus (CDIO, 2016).

Nowadays there is a generalized concern about the effectiveness of conventional models of teaching and learning. The engineering schools are seeking for more active and effective ways of learning to improve programs outcomes (Rodriguez-Donaire and Amante, 2012). In fact some institutions are already studying the importance of teamwork in the learning process of their students (Oakley et al., 2007; Kamarudin et al., 2011).

The goal of this work was to characterize and analyse the situation related to teamwork in ISEP, School of Engineering. To study this a review of existing teamwork tasks was done and an online survey was made to all students about teamwork developed at ISEP.

METHODOLOGY AND CHARACTERIZATION OF ISEP, SCHOOL OF ENGINEERING

To achieve the goals mentioned a survey was designed and launched online in ISEP. The questions and choices were meant to be brief with the least possible ambiguity. The survey was launched at the end of the second semester to cover all academic year. All students have access to computers and internet at school and some also have access at home.

Quantitative and qualitative analyses were performed such as frequency analysis. By performing this type of analysis it was possible to characterize the teamwork developed in the institution and to detect the advantages and disadvantages of teamwork.

ISEP is a School of Engineering of the Polytechnic of Porto that has 11 first cycle degrees in Engineering and 11 Masters in Engineering which covers almost all domains of engineering. In the academic year considered ISEP had 6502 students (table 1).

Table 1. Engineering degrees at ISEP

Bologna 1st cycle degree	Masters in Engineering
Chemical Engineering	Chemical Engineering
Civil Engineering	Civil Engineering
Computing Engineering and Medical Instrumentation	Computing Engineering and Medical Instrumentation
Electric and Computer Engineering	Electric and Computer Engineering
Electrical Engineering - Electrical Power Systems	Electrical Engineering - Electrical Power Systems
Geotechnical and Environmental Engineering	Geotechnical and Environmental Engineering
Informatics Engineering	Computer Science
Instrumentation and Metrology Engineering	Instrumentation and Metrology Engineering
Mechanical Engineering	Mechanical Engineering
Automotive Engineering	Sustainable Energies
Systems Engineering	Applied Mathematics to Engineering and Finances

Informatics and Mechanical Engineering are the courses with more students followed by Electric and Computing Engineering, Civil Engineering, Power Systems, Chemical Engineering, Medical Instrumentation, Geotechnical and Environmental Engineering and finally others courses with a percentage of students equal or lower than 1% (Fig.1). Fig.1 shows the first 10 cycles with more students.

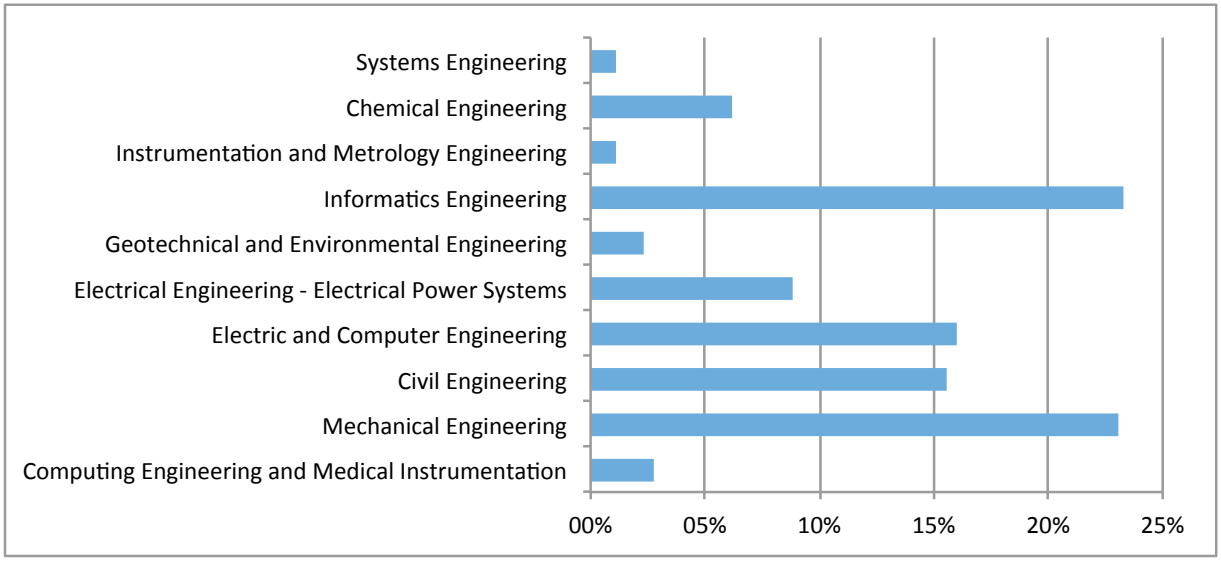

Figure 1 Percentage of students in each area of engineering at ISEP

SUBJECTS ANALYSED AND CDIO STANDARDS

The first analysis performed was to evaluate the number of courses that use teamwork as a learning tool for each engineering program. The results were compared with the integration of CDIO standards in those engineering programs. A more detail analysis was carried out for the engineering programs that used teamwork in a higher percentage.
Table 2 presents the questions asked and the corresponding CDIO standards applicable.

Table 2. Survey questions and CDIO standards

Questions	CDIO standard
1. How satisfied were you with the teamwork developed to learn the UC outcomes?	2
2. The guidance provided by the Professor was enough?	8,11
3. Is the work developed by each team member reported in any document?	11
4. Order by importance the advantages of teamwork (Maximization of the use of each member's skills, maximization of the creativity applied to the development of the project, maximization of the motivation to reach the targets, time savings considering the effort to be applied, facilitates learning, increase of the participation in the course and enrichment due to the exchange of experiences and roles)	2,8,11
5. Order by importance the disadvantages of teamwork (Decrease of personal responsibility, difficulty coordinate schedules, distraction and lack of concentration that provoke time losses, personality collisions and leadership seeking that result in conflict, lack of leadership which results in chain discouragement, confusion in responsibility attribution which results in team exhaustion and lack of productivity of some members which results in unbalanced production of the team)	2,8,11

RESULTS AND DISCUSSION

Fig. 2 shows the number of CDIO inspired/compliant courses in first cycle programs in 2008-2009 by engineering program.

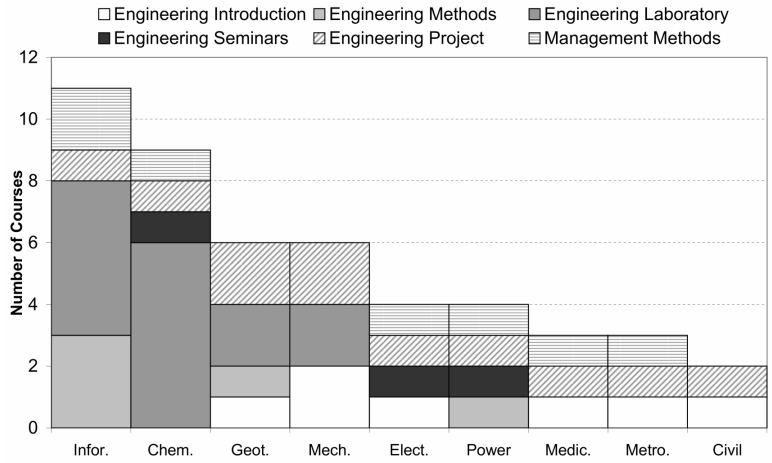

Figure 2. CDIO inspired/compliant courses in ISEP first cycle programs during 2008-2009 (Costa et al., 2010)

Comparing the results obtained with the figures available for 2008-2009 it is possible to conclude that the two engineering programs which present higher implementation of CDIO components are still Informatics Engineering (LEI) and Chemical Engineering (LEQ). It is also possible to conclude that these first cycles programs are increasing the implementation of CDIO components. For example Chemical Engineering has showed an increase approximately of 60% and LEI an increase of 36%.

In 2008-2009 System Engineering (LES) did not exist yet but it is one of the most committed engineering program in applying CDIO with 23 number of courses with teamwork besides other CDIO practices.
These three engineering programs have a capstone project/internship at the end of their cycles. They will further studied in next sections of this work.

HOW SATISFIED WERE YOU WITH THE TEAMWORK DEVELOPED TO LEARN THE UC OUTCOMES? (STANDARD 2)

Fig. 3 presents the answers given by the students, concerning the contentment with teamwork developed, of the three engineering programs that present the highest percentages of CDIO inspired courses. Comparing these 3 graphs, it is possible to conclude that almost all students seems to be satisfied with teamwork developed, because the sum of positive answers corresponds to high percentages. System Engineering and Chemical Engineering above 80% (very and reasonably satisfied) and Informatics Engineering above 55%.

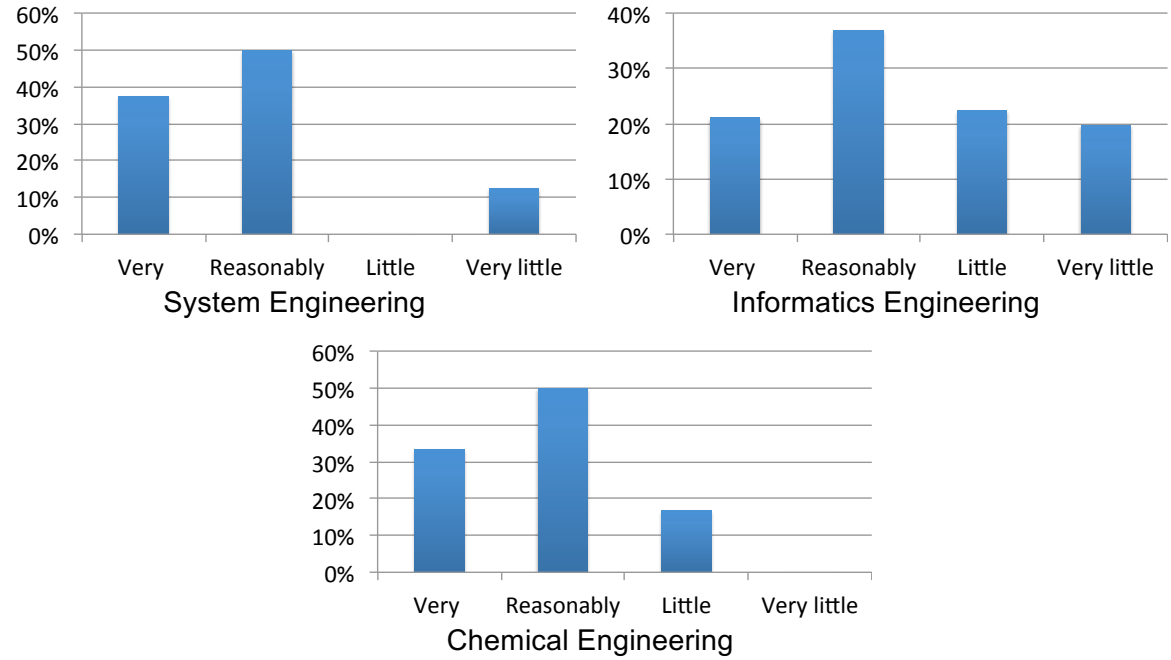

Figure 3. How satisfied were you with the teamwork developed to learn the UC outcomes?

THE GUIDANCE PROVIDED BY THE PROFESSOR (STANDARDS 8 and 11)

Fig.4 presents the answers of the students of the above mentioned engineering programs related to the guidance provided by Professors in teamwork. As can be perceived the majority of students answered that guidance was enough. System Engineering and Chemical Engineering present the highest percentages (>80%) as had happened for the previous question. In LEI only 55% of students are happy with Professor support.

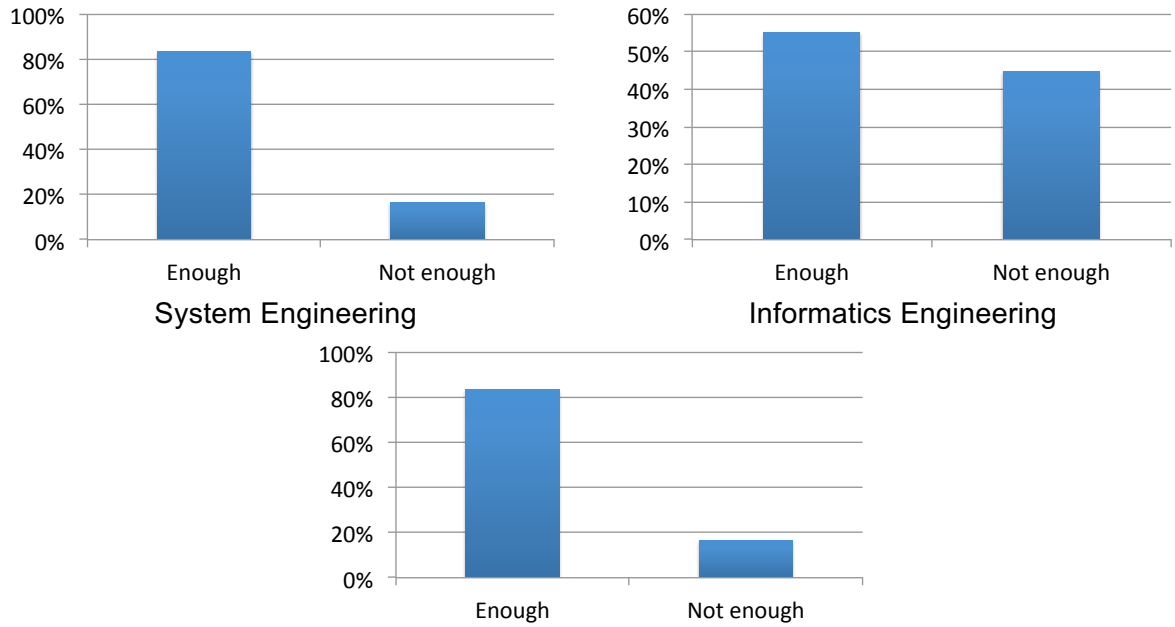

Figure 4. The guidance provided by the Professor

IS THE WORK DEVELOPED BY EACH TEAM MEMBER REPORTED IN ANY DOCUMENT? (STANDARD 11)

From Fig.5 it is possible to conclude that often the work developed by each team member is not reported in any document. According to the data this happens in all the engineering programs studied. Although, it is important to note that the percentage of students that answered not applicable corresponds to 17 to 32%.

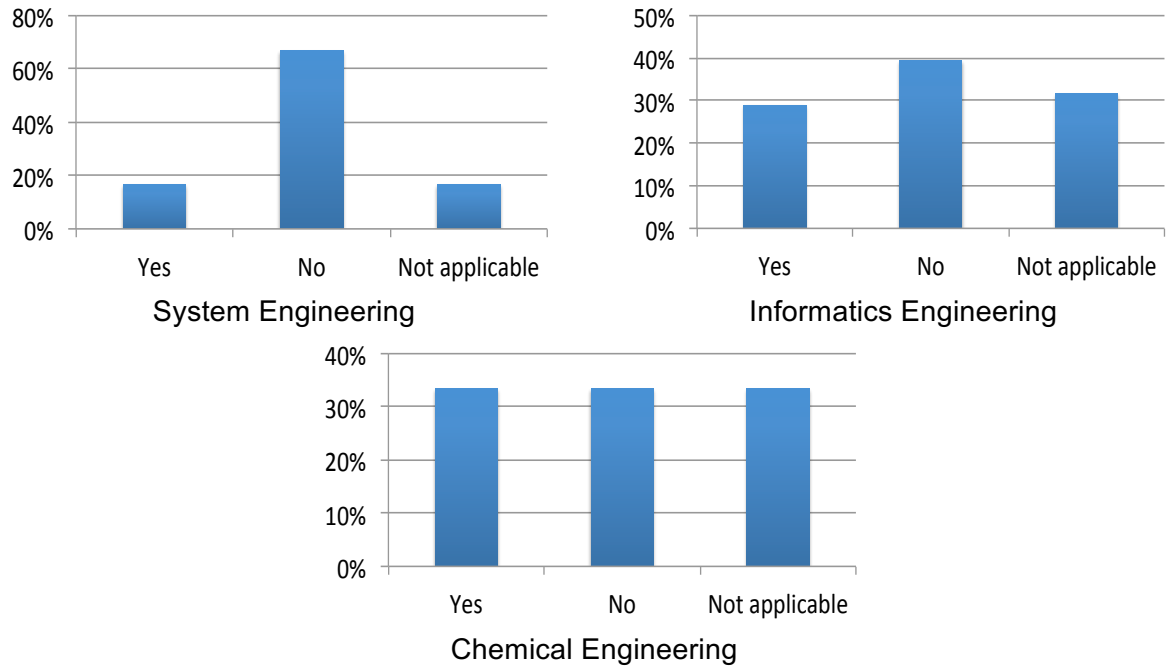

Figure 5. Is the work developed by each team member reported in any document?

ADVANTAGES AND DISADVANTAGES OF TEAMWORK (STANDARDS 2, 8 and 11)

Table 3 presents average and standard deviation for the seven advantages and Table 4 for the 7 disadvantages, the scale is between 1 (the most important) to 7 (the least important).

Table 3. Average and standard deviation for advantages of teamwork

Advantage	Average	Standard deviation
Maximization of the use of each member's skills	3.557	2.154
Maximization of the creativity applied to the development of the project	3.500	1.882
Maximization of the motivation to reach the targets	3.739	1.962
Time savings considering the effort to be applied	3.807	2.039
Facilitates learning	3.795	2.069
Increase of the participation in the course	3.886	2.065
Enrichment due to the exchange of experiences and roles	3.739	2.184

Table 4. Average and standard deviation for disadvantages of teamwork

Disadvantage	Average	Standard deviation
Decrease of personal responsibility	2.175	3.807
Difficulty in coordinate schedules	2.074	3.636
Distraction and lack of concentration that provoke time losses	2.014	3.693
Personality collisions and leadership seeking that result in conflict	1.872	3.784
Lack of leadership which results in chain discouragement	2.144	4.045
Confusion in responsibility attribution which results in team exhaustion	1.866	3.682
Lack of productivity of some members which results in unbalanced production of the team	2.171	3.000

From the analysis of data from tables 3 and 4 it is possible to conclude that most advantages and disadvantages present similar classifications, average and standard deviation. However the average values for disadvantages are slightly lower than the values for the advantages but the standard deviations are higher which indicates that for disadvantages students evaluate them more differently. Lack of leadership which results in chain discouragement, presents the highest value for standard deviation and it is followed by Decrease of personal responsibility. The advantage that presents the smallest average value is Maximization of the creativity applied to the development of the project and the disadvantage that presents the smallest average is Confusion in responsibility attribution which results in team exhaustion.

CONCLUSIONS

The results show that ISEP has engineering programs that incorporate CDIO components in the learning process in a very committed way since they have many courses with significant CDIO influence. The answers given by students indicate that most of them are happy with the teamwork developed in the courses and that the support provided is enough. Not reporting the work developed by each team member in any document seems to be a common practice. Concerning advantages of teamwork all of them present similar average values as well as the disadvantages. However the advantage that presents the smallest average value is Maximization of the creativity applied to the development of the project and the disadvantage that presents the smallest average is Confusion in responsibility attribution which results in team exhaustion.

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BIOGRAPHICAL INFORMATION

Florinda Martins, PhD in Chemical and Biological Engineering, Master in Environmental Engineering and a degree in Chemical Engineering from the Faculty of Engineering, University of Porto, Porto, Portugal, obtained in 2007, 1998 and 1989, respectively. Dr. Florinda Martins worked in industry as a process engineer and in the development of engineering projects. Further she was the director of a wastewater treatment plant. Nowadays is Adjunct Professor at Instituto Superior de Engenharia do Porto (ISEP), School of Engineering, Polytechnic Institute of Porto (IPP), Porto, Portugal. She has supervised several Master thesis and is the co-author of a book, several papers in international journals and conferences and has presented several oral and poster communications in conferences. She has also participated in several conference scientific committees. Her research interests include sustainability, environment, energy and optimization.

Eduarda Pinto Ferreira, is an Auxiliary Professor of Mathematic at ISEP - Instituto Superior de Engenharia do Porto, Portugal. PhD in Science Engineering. Chairman of 1st CDIO Iberian Workshop (ISEP), March 2011. Chairman of the 3rd ESICUP Meeting (EURO Special Interest Group on Cutting and Packing), international conference in Porto (ISEP), March 2006. Member of the Scientific Committee of JBLE-09 (Jornadas Luso-brasileiras de Engenharia), Porto (ISEP), February 2009. Attended almost all CDIO conferences since 2008. President of Pedagogical Council between 2010 and 2014. President of the NGO IPP Solidário since January 2016.

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