A CONCEIVE-DESIGN PROJECT IN THE FIRST SEMESTER OF THE ENGINEERING PROGRAMS AT METHODIST UNIVERSITY OF SÃO PAULO

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ABSTRACT

A conceive-design project is presented. The project runs over the first two years of the engineering education programs at the Methodist University of São Paulo, and the paper focuses on the first semester of the Computer Engineering Program. The projects are carried out in teams of students from different programs and the results are presented to a board of faculty members and sometimes participants from our partner companies, at the end of each semester. There are around 200 students involved in total. For the first semester, students are required to conceive, design and document an environmentally-friendly product or service. The conceive-design project is integrated with surrounding modules is the curriculum, such as Entrepreneurship and Innovation and Economics, Society and Environmental Issues.

KEYWORDS

Introductory course, conceive-design experience, environmental aspects, business aspects, Standards: 4, 5, 7, 8

INTRODUCTION

Design-implement experiences of various complexity are important components in modern engineering education. This is also reflected in the CDIO framework, where such activities play an important role. Some examples of previous work will be given below. The purpose of this paper is to present a conceive-design project which is part of the curricula of a set of engineering programs at Methodist University of São Paulo, Brazil. The project has several important aspects that can be pointed out:

- The project runs over the first two years of the engineering programs involved. To the best of the authors' knowledge there are very few examples of project with such long duration. The focus of this paper will however be on the first semester and hence on the conceive and design steps.
- From the very beginning the students need to consider both environmental and business aspects in the conceive-design process, including for example estimates of the cost for office space, electricity, and other resources needed to run the project.

- The project is tightly integrated with the surrounding disciplinary modules.
- The project, concerning both the result and the process, is assessed continuously using a variety of methods, by both faculty members and representatives from industry.

The outline of the paper is as follows. Initially a summary of the CDIO framework is given, and references to some previous work are given. Then a general presentation of the structure of engineering education in Brazil will be given, followed by a description of the Methodist University of São Paulo and the various engineering education programs offered at this university. The next section will describe the conceive-design project in detail, concentrating on the activities the first semester. The following section will discuss how the project connects to the various sections of the CDIO Standards. Finally, the paper ends with some conclusions.

CDIO BACKGROUND

The CDIO framework is a powerful tool for design and management of engineering education. The framework relies on four key components:

- A definition of the role of an engineer.
- Clearly defined and documented goals for the desired knowledge and skills of an engineer (The CDIO Syllabus).
- Clearly defined and documented goals for the properties of the engineering education program (The CDIO Standards).
- An engineering approach to the development and management of education programs.

According to the CDIO framework, see Crawley et al (2014), the goal of engineering education is that every graduating engineer should be able to:

Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.

Adopting the definition, it is natural to design and run an engineering education program with this is focus. The CDIO Standards (2018), which can be found and explained in detail via the CDIO web site, is a set of twelve components that are necessary to design and run an engineering program that enables the students to reach the desired knowledge and skills. The twelve standards are:

1. The context
2. Learning outcomes
3. Integrated curriculum.
4. Introduction to engineering.
5. Design-implement experiences.
6. Engineering workspaces.
7. Integrated learning experiences
8. Active learning.
9. Enhancement of faculty competence.
10. Enhancement of faculty teaching competence.
11. Learning assessment.
12. Program evaluation.

The conceive-design project has connections to several of the CDIO Standards, and a more detailed discussion of these connections and how the learning activities are connected to the sections of the CDIO Standards will be given later in the paper. Since the project described here starts directly when the students enter the education it is an example of Standard 4, Introduction to Engineering. According to the CDIO web site the rationale for introductory courses is as follows:

Introductory courses aim to stimulate students' interest in, and strengthen their motivation for, the field of engineering by focusing on the application of relevant core engineering disciplines. Students usually select engineering programs because they want to build things, and introductory courses can capitalize on this interest. In addition, introductory courses provide an early start to the development of the essential skills described in the CDIO Syllabus.

Numerous examples of introductory courses have been presented over the years. One example is from the Applied Physics and Electrical Engineering Program at Linköping University, and a thorough description is given in Box 4.4 in Crawley et al (2014). The course contains a set of lectures about e.g. communication, group dynamics, project management. The main part is a design-implement experience, and the course ends with a project conference. Via the Knowledge library at the CDIO web site many other examples from different countries and contexts can be found. Some recent examples are Schrey-Niemenmaa and Piironen (2017) and González Correal et al (2016). A common aspect of these examples is the high degree of active learning, i.e. Standard 8. This is also a key feature of the conceive-design project presented in this paper.

Also, for the type of design-implement experiences referred to in Standard 5 there are numerous examples presented in literature, both within and outside the CDIO community. One example is presented in Svensson and Gunnarsson (2012), in which experiences from more than ten years operation of a design-implement project is presented. The paper stresses the importance of clearly defined learning outcomes, a well working course organization, the importance of using a project model for carrying out the project, sufficiently challenging project tasks, and access to suitable workspaces and equipment. Additional examples are given in e.g. Bragós et al (2012). This paper discusses the role and properties of a course related to where in the curriculum it is places, examples of tollgates and deliverables, and methods for assessment. An additional example is Van Torre and Verhaevert (2017), where also various methods for presentations of the project results are given, including for example written and oral presentations, and demonstrations.

THE METHODIST UNIVERSITY OF SÃO PAULO

The Methodist University of São Paulo is maintained by the Methodist Institute of Higher Education and is in São Bernardo do Campo, an important city in São Paulo's Greater ABC industrial belt. Its history began in 1938, when the Theological College was created and since then, degree programs in Humanities, Health Science, Communication, Management and Business, and Engineering started their activities.

The School of Engineering, Technology and Information is one of the five units of the Methodist University of São Paulo, and its first Engineering program was created in 1999 in response to socio economic changes in the Greater ABC area, demanding more qualified professionals for industrial positions. The Computer Engineering program was followed by

Environmental and Sanitary (2011), Industrial (2014), Civil and Electronics (2017) engineering programs.

In Brazil, engineering programs are organized in 5-year education programs and their pedagogical projects are structured according to Law nº 9394 Brazil (1996) and specific directives for engineering programs Brazil (2002), with a minimum of 3600 hours, with subjects organized in 3 main areas, as follows:

1- Basic Components (minimum of 1080 hours)**:** includes mathematics, physics, scientific methodology, language and communication, informatics, mechanics, transports phenomena, chemistry, materials sciences, electricity, management, economics, environmental issues, humanities, social science and citizenship.

2- Professional Components (minimum of 540 hours): each program choses a subset in a group of 53 subjects according to the engineering program. For example, in computer engineering, software analysis and modeling, programming languages and digital and analogical electronics are considered in this subset, among others.

3. Specific Components (remaining hours): are related to the professional components, in a deeper approach, and consider regional and institutional research interests.

Considering that the directives are clearly defined for all engineering programs, each institution must choose a way to have their students better prepared to engineer, or in other words, be prepared to create and develop new products, services and systems. As Engineering Education researches have a fundamental role in this context, Methodist University was motivated to change the pedagogical model of its engineering programs and decided to do this based on CDIO framework. During their 5-year education, undergraduates of the Engineering programs (namely, Computer, Industrial, Environmental, Civil and Electronics), are expected to take part in a project, which runs over two years and become increasingly and gradually more demanding every semester. These projects are carried out in teams of students from different programs and the results are presented to a board of faculty members and sometimes participants from our partner companies, at the end of each semester. There are around 200 students involved in total and the details of these projects will be described in the next session.

THE CONCEIVE-DESIGN PROJECT

Since 2008, the Computer Engineering program at Methodist University involves its students in activities related to the development of short projects that lasts one semester. In 2016, considering the accumulated experience, the project approach was changed, and the students must take part in a project of two years, divided in four semesters and developed in teams of four or five students.

The aim of this section is to describe the activities developed by Computer Engineering students, in the first semester of this conceive-design project, when they are required to conceive, design and document an environmentally-friendly product or service. The different tasks required to complete this project are described, in details, in a “Manual” the students are given in the first day of the semester. In parallel to the project, students are enrolled in three modules, Introduction to Engineering (I2E) with 8 hour-classes per week, being 1 for the project, Economics, Society and Environmental Issues (ESE) with 6 hour-classes per week and Entrepreneurship and Innovation (E&I) with 6 hour-classes per week (1 hour-class has 50 minutes).

I2E module offers the students basic tools for project management, including the organization of the tasks that are to be executed to meet the project needs and their relationship with other activities (WBS and workflow), instructions on how to identify and calculated project costs and ROI.

E&I module is responsible for a first training on assessment and self- and peer-evaluation, and on self-organization related to time and tasks.

ESE module discusses socioenvironmental responsibility and the fundamentals of economics.

Considering the students just arrived at the University and they are (mostly) not familiar with the educational dynamics, they are given a set of documents for orientation. These documents include templates for project directives, pair evaluation directives, project plan, meetings, status report, time plan, among others. Completing this documentation, throughout the semester, there are lectures about teamwork, project management, process, meeting, and other related issues. The activities related to the project are distributed in 18 weeks and have four main steps.

The first step is the organization of the groups with 4 or 5 students in each team. These teams represent "companies" that are being stablished to offer specific service or product that is to be defined until the 3rd week of the semester. This "idea" of product or service must be approved before the group move to the next step.
The deliverable of the first step is composed of:

1 – Names of the students in each team;
2 – Company name;
3 – Product or service (initial idea);

In the next step, the teams must get information about what is a business plan, identify the better business opportunities for the company, and create its visual identity. This information is part of a document that includes the project goals and motivation, the project scope and theoretical information about the product or service, and its description. This document must be approved until the 9th week of the semester, before the group move to the next step.

The third step is mainly a refinement of the last step and some additional information related to the business, including the project scope, operational plan (company layout, IT resources, main processes related to the project), and additional information about necessary investments to start the company, the business risks, and a market analysis.
This information completes the document approved in the 2nd step and, if approved, enables the team to focus on the prototype and presentation. Usually, this step ends between the 13th to 15th week of the semester.

The last step is dedicated to finish the solution prototype, prepare the material and make the oral presentation to a board. In general, the team have 3 to 5 weeks to finish this step.

The organization of the orientation material, project definition, and relationship between the four steps is part of a continuous improvement process that involves many faculties. Activities related to this process is part of a faculty development program that occurs every semester.

At the end of 2nd and 3rd steps, students receive a worksheet, based on Lingard (2010), where they are expected to assess their teammates and to self-assess themselves regarding engagement to the project, commitment to the goals, meetings, tasks, and results. Lectures on meeting organization, conflicts resolutions, distributions of tasks, responsibilities & roles, and status reporting are offered the students to help them on this assessment.

CONNECTIONS TO THE CDIO STANDARDS

The presented conceive-design project is connected to a majority of the twelve CDIO Standards, and these connections will be discussed in some detail. Since the students immediately face the task to conceive and design a product or service they are directly put in the context of engineering as formulated in Standard 1, i.e. "*Adoption of the principle that product, process, and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education".*

As mentioned earlier the project connects to Standard 4, Introduction to engineering in an obvious way since it starts during the first semester of the education programs. However, since the project runs over two years and the aim of the work is a product it also has strong connections to Standard 5, Design-implement experiences, for which The CDIO Standards (2018) states "*A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level*". In addition, considering the mutual support offered by all the courses in the semester, Standard 3, can be easily considered in this program. Standards 4 and 5 lead in a natural way to Standard 6, Engineering Workspaces, defined as "*Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning".* Students involved with these projects can use computer labs (from 7 am to 11 pm), electronics labs (from 1 pm to 7 pm) and a workshop with some tools, including screwdrivers, saw, drill bench, among others. The workshop and electronics labs are available upon schedule.

Like other learning activities of this type, see e.g. Svensson and Gunnarsson (2012), the project relies on a high degree of Active learning, i.e. Standard 8, for which CDIO Standards (2018) states *Teaching and learning based on active experiential learning methods.* In the project presented here the students are expected to spend, on average, 5 hours per week on the project, and it is the responsibility of the students to plan and organize the work within the given time frames. In a similar way the project is tightly connected to Standard 7, Integrated Learning Experiences, where the description from CDIO Standards (2018) states "*Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills".*

Integrated learning, as defined in Standard 7, and specific detailed learning outcomes, as defined in Standard 2, makes in necessary to use various assessment methods to assess the different types of knowledge and skills that are formulated as learning objectives. In this case CDIO Standards (2018) says "*Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge."* In the conceive-design project presented here, several different methods for assessment are used and their operationalization are discussed during the faculty organization meetings that occur prior to the beginning of every semester.
Assessing individual student's teamwork skills is difficult, so we must use different approaches to have a more effective assessment. Along the semester, individual observation and specific student contributions are considered. In addition, information given by the

students in the peer assessment contributes to the general evaluation of the students individually. The adequate use of these assessment tools is part of a course offered the faculty annually that is close related to the Standard 10, "*Enhancement of Faculty Teaching Competence*".

CONCLUSIONS

A conceive-design project at the Methodist University of São Paulo has been presented. The project runs over the first two years of the engineering education programs, and the paper has focused on the first semester of the Computer Engineering Program. The projects are carried out in teams of students from different programs, and the results are presented to a board of faculty members and sometimes participants from the partner companies, at the end of each semester. The paper presented an overview of the process in the first semester of the program, the faculty preparation and course integration, tools for the self and peer assessment of the students, and teamwork skills development associated to the process.

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Carlos Eduardo Santi, is Professor in Software Engineering at Methodist University of São Paulo, Brazil. His main research interest is Engineering Education. He is also the Dean of the School of Engineering, Technology and Information at Methodist University. In the last 3 years (2015, 2016 and 2017) was in the Organizing Committee of the International Annual Seminar on Engineering Education at University of São Paulo.

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