FOSTERING DESIGN COMMUNICATION SKILLS: A CDIO INSPIRED INNOVATION ENGINEERING COURSE

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ABSTRACT

In the context of junior level courses in Industrial and Systems and computing Engineering of the Engineering Faculty of Universidad de los Andes, projects are developed seeking to strengthen the students' observation, engineering design, communication and team working skills. Throughout the semester, the students, in teams, **observe** a problem that they believe could be addressed through engineering. After that, based on their comprehension of the specific problem and specific user, they (1) **conceive** proposals, (2) **design** one of them and (3) **implement** it. Between each stage, the teams get feedback from different stakeholders in order to focus and improve their proposal. Before the end of the semester, students participate in a fair (**LaMuestra**) to show their projects (based on a prototype) to entrepreneurs, alumni, students and professors from different disciplines. This approach has led to the **Innovation Week**, a set of public events to share our CDIO activities with our stakeholders. In this paper, we present a learning methodology for the student's teams to carry out the design of an engineering solution while been challenged to innovate and have a positive impact on society. The methodology and some results of its implementation illustrate the relevance of the **o**CDIO approach.

KEYWORDS

Communication skills, Design Skills, Innovation project-based course, Standards: 4,5,8

INTRODUCTION

In order to strengthen design, teamwork, communication and innovation skills, the Faculty of Engineering of Universidad de los Andes in Colombia has been creating spaces for project-based learning. There are mainly two courses that all students must follow:

Introduction to engineering (freshman course) and *Mid-career project* (junior course). In Introduction to engineering, students develop a project in working teams and share it with the community in a fair at the end of the semester (ExpoAndes). In the mid-career space, all students work in teams (sometimes interdisciplinary teams) in the designing of an engineering proposal to solve a specific problem. Specifically, the mid-career courses of Industrial Engineering and Systems and Computing Engineering lead to the development of projects with innovation components that allow students to explore new approaches and tools to guide their emphasis in the following semesters of their undergraduate studies. We present the current state of a 15 years old course with around 1000 alumni. The different actual spaces and tools are the result of our continuous evaluation process.

THE CHALLENGE

The engineer is faced with the need to observe contemporary problems and to work in teams on the understanding of how to create possible contributions to its solution, in order to conceive, design, implement and operate technically feasible and economically sustainable proposals. In this regard, the half-career space described in this paper seeks that through the teamwork in projects, the students can develop:

- the ability to design feasible models or prototypes, in the context of a real problem
- an understanding of the need to work with engineers from other disciplines
- the need to communicate to their peers their own engineering proposals and the value that an engineering design generates in society (Ramírez et al., 2010)
- the attitude for creating innovative proposals with the potential to have an impact on society (OECD, 2004)
- the ability to be more proactive in a highly competitive environment

This model explicitly reinforces the Observation stage, seeking to improve the conception of the intervention that is sought through the engineering project. In this sense, the scheme presented starts from a CDIO approach and executes an oCDIO approach (Hernández, Ramírez & Carvajal, 2010).

THEORETICAL FRAMEWORK

Engineering as a profession has been undergoing changes in its teaching-learning models with the aim of training engineers able to face the challenges of the discipline in the 21st century (Steiner et al., 2008). Moving from the knowledge transfer paradigm to the development of professional skills is one of the most significative changes (Hernández et al., 2004; Siller et al., 2009). Examples of these changes have been reviewed by different institutions, renowned in the global context, such as the National Academy of Engineering - NAE (Siller et al., 2009) and the Accreditation Board of Engineering and Technology - ABET, in the United States of America. In Latin America, the CDIO experience has been reinforced and adopted in several universities in the region and Colombia.

However, the teaching of these skills is hard, especially for faculties seeking to generate a balance between the need to include an increase technical content in the curricula (Siller et al., 2009), and the training of engineers with the necessary skills for the adequate application of these contents. Taking into account the challenges posed by NAE (National Academy of Engineering) and ABET (Accreditation Board of Engineering and Technology), the Faculty of Engineering of Universidad de los Andes in Colombia has proposed a curricular space to develop these skills altogether with students, professors and entrepreneurs framed in an oCDIO approach.

Research has explored the need to produce alternative methods for students to develop real designing skills. Gilbuena et al. (2015) suggest the use of videos and interviews; while Kittlesson and Southerland (2004) propose the use of other tools such as self-recordings.

The researchers of this paper propose: i) to emphasize the Observation stage and ii) to reinforce the design communication through the development of systematic discussions with different stakeholders. As a contribution to the CDIO framework, a first stage of Observation has been proposed and developed within the courses: this stage seeks to carry out a careful research process based on bibliographic reviews and creativity workshops that allow the students to explore the technological conditions that surround them and make a first user-centered focus on possible problems that can be addressed from different fields of engineering. This first stage of what is called oCDIO (Hernández et al., 2010) fosters the collection of pertinent and very useful information, to begin with the conception of ideas proposed by CDIO.

DESIGN COMMUNICATION IN ENGINEERING COURSES

The oCDIO stages

To enhance the design communication skills in both engineering courses the projects developed by the working teams must be discussed with different stakeholders. The groups develop the innovative projects in the context of the six engineering stages described above: Observe, Conceive, Design, Evaluate, Implement and Operate. For instance, the three-credit mid-career course asks students to work on teams of 4-5 persons to develop an engineering project with innovation and sustainability attributes.

The students begin by a stage of Observation of the proposed problematic. In this stage, they approach it investigating with the possible people concerned by the situation, exchanging ideas with experts and researchers, exploring findings, reviewing bibliography, among other activities. Once this preliminary observation has been made, the students conceive the formulation, contextualization and a possible solution to the observed reality; this conception requires a strong emphasis on the development of creativity and innovation exercises that allow the proposal(s) to be appropriate.

The stakeholders

Although of course the course is accompanied and guided by the *teachers*, *students* have the support and following of a board of *Entrepreneurs* as *mentors* of their projects, and *technology experts* associated with each project. Along 15 weeks of the projects, students

must face the challenge of communicating the design process they are carrying out to their *specific users* and stakeholders (Mentors, TechExperts, Teachers and Students):

- In the OBSERVATION stage, they must understand the problem in dept together with an expert in the problematic situation and the potential specific user.

- In the CONCEPTION AND DESIGN stages, they must develop a dialogue with the user (continuously) an entrepreneur and an expert in technologies or solutions with social impact.

- In the IMPLEMENTATION stage, students must face presenting their MVP (Minimum Viable Product) to the end users of the solution.

In this regard, the courses have been designed with a low theoretical content and a focus on practical and debating content. What has enriched the process the most is the successful communication that the students must develop with the different stakeholders in the several moments of the semester.

In figure 1 is showed one of the mentoring session.

Figure 1. Entrepreneur board

The process

Each team (25 teams of 4 students each semester) has an entrepreneur-mentor who supports them on the project management. The group of 25 Entrepreneur-Mentors, gathered together, form a jury board that gives formal feedback on the projects' development.

At each stage of the project, the set (specific problem, specific user, proposed solution) must be tested with the specific user, and with external experts in both the problem and the technology involved.

- During the first 6 weeks, an **oCD**IO phase is carried out mainly focused on observation, Conception and a first design stage. At the end, the resulting proposal is presented to the jury board, together with a first "Oz wizard" prototype, with evidence of user participation in its construction.
- After processing the feedback from the jury board, a second oC**DIO** phase begins and, with the advice of professors and other experts and the deepening of the problem understanding, the design of a Minimum Viable Product - MVP is refined and implemented in a proposal that is taken to user evaluation and to a second round with the jury board. Some adjustments are made considering the feedback received by the teams, and the MVP is taken to an audience of professionals (alumni & entrepreneurs) at a fair called *LaMuestra* (The Exhibition).

In figure 2 is showed the process with the main communication points:

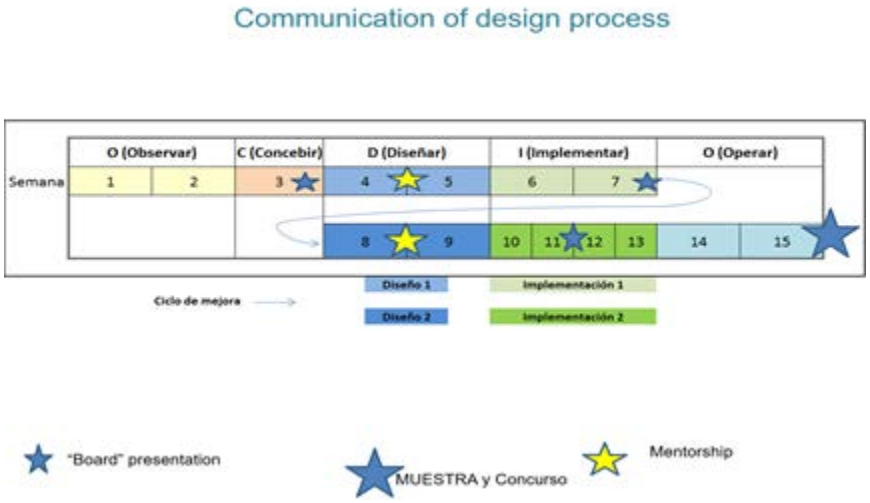

Figure 2. Communication of design process

The spaces devoted to communication during the process are:

-The four moments of validation with the specific user (twice in the Observation, Conception, Design and Implementation stages and once on the Operation one). These activities follow the guidelines proposed in "Running lean" (Maurya, 2012).

- An interview with the problem expert and one with the technology expert, following again the guidelines of "Running lean" (Maurya, 2012).
-Two presentations before the jury board in the Observation/Conception and Design/Implementation stages, consisting of: a jury of 5 members external to the University, a 7 minutes pitch, 3 minutes of feedback and an immediate verdict.

-Two videos that are published in the YouTube channel that is held for this purpose:

- The first takes place at the end of the first Design/Implementation iteration, presenting: problematic, user, proposal and preliminary engineering design. This video is addressed mainly to other engineering students of different disciplines at the junior level. Each student must analyze two projects from other disciplines and send feedback directly to the team responsible of the project:
    - A review of the project based on what was understood after having "explored" its video (maximum one page). This aims to the building of "mirrors" showing the result of their communication effort.
    - Three suggestions that could enrich the project. This furthers a reflection on the possibilities of contributing from their own discipline to the formulation and design of such engineering solutions.
- The second takes place at the end of the second Design/Implementation iteration, presenting: the project, its context and its MVP (Minimum Viable Prototype). This video is addressed to professionals and businessmen. These videos are part of the invitation to alumni and entrepreneurs to visit LaMuestra, an exhibition space in a fair format that takes place during the 15th week of the academic semester. Approximately 140 projects from different disciplines are exhibited and approximately 300 visitors external to the University are received.

-LaMuestra, where each team has a stand to present its project, supported by a poster and the display of the MVP. The public is mainly alumni and entrepreneurs community (aprox. 300). It takes place during the 15th week of the academic semester. Our 25 teams take part of LaMuestra with approx. 140 junior projects from different disciplines. In figure 3 is shown a set of student teams.

-A written report, or a paper to submit to an international congress of innovation in engineering, should be delivered by each team at the end of the term.

Figure 3. La Muestra- Final presentation

CONCLUSION AND FURTHER RESEARCH

An oCDIO space for carrying out engineering innovation projects in teams of students on their 3rd year (junior level) was presented. In this space, a special effort is made towards the development of communication skills, with emphasis on engineering design.

The presence and intervention of actors external to the traditional environment of the engineering school are highlighted. This effort to present the projects and listen to the reactions and suggestions of potential users, connaisseurs of the problem addressed, technology experts and entrepreneurs, has proved to be very enriching for all participants in this process. The use of different media (interviews, videos, pitch, fair, paper) expose students to communication challenges that they will face throughout their future as engineers. Also, an interesting aspect of this exercise is how students learn to listen to the reaction of the different stakeholders of their initiative, especially that of their peers, around the engineering proposals that are being elaborated in the projects.

An additional aspect to highlight is the point in the curriculum in which this exercise is carried out. This type of spaces usually has place towards the end of the career (Capstone project). This proposal, which has been implemented over the last ten years, is done at the junior level so that it can impact on the way students approach their last three semesters of undergraduate studies. Particularly the choice of electives and the orientation of the final engineering project.

A challenge in this process is a longitudinal evaluation of its impact, currently in implementation, both in the students' skills and the attitude towards innovation and communication in the first years of professional life.

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BIOGRAPHICAL INFORMATION

José Tiberio Hernández is currently professor in Systems & Computing Engineering at Engineering School of the University of Los Andes (Bogota) and director of the IMAGINE visual computing R&D+i team. His research interests are focused on visual computing, and Engineering Education. He is involved in different projects with industrial&academic partners, and in Science and technology-based innovation&entrepreneurship initiative in the University of Los Andes. He is at the origin of international scientific collaborative projects of the engineering school and the visual computing team (IMAGINE). He is former Dean of the Engineering School at University of Los Andes (1997-2005). He received his Ph.D. in 1983 in Computing Engineering (ENSTA-Paris), and Computing Engineering Bs. and MSc from UniAndes (Bogotá) in 1979.

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The courses that form the Engineering Communication Program provide for critical awareness-raising of community issues such as ethics, sustainability and gender, English for academic and professional Engineering purposes for both English as an Additional Language (EAL) and English background students and advanced research communication for postgraduate students.Â According to Najar (2001) communicative competence, including teamwork and professional writing skills for example, the ability to â€—research, write and format basic research reportsâ€˜ as well as developing formal oral presentation skills is important to prepare students for both â€—academic success and the workplaceâ€˜. Application and Development of CDIO Engineering Education Mode in Undergraduate Science Program. Chengdu University of Information Technology, P.R. China J. Zhou. Enlightened by successful implementation CDIO (Conceive, Design, Implement, and Operate) in Engineering Program, CDIO is applied to undergraduate science program in Chengdu University of Information Technology.Â The results show that the adaptation of CDIO can inspire the interests of study as well as the practical ability of students in undergraduate science program. Key words: CDIO, Undergraduate science program, Training standard, Curriculum system, Course designation, Process assessment. 1. Introduction Established in 2004, engineering. The collection of skills could be grouped together and described as â€œinnovation skillsâ€ since all are vital to developing and launching an innovation. It takes creative problem solving, leadership, strategic thinking, and effective communication. Bloomberg also has an interactive tool where you can see which skills are more/less desired and common by industry.