PROJECT-BASED LEARNING AND SERVICE LEARNING: TOWARDS HELPFUL MEDICAL DEVICES

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ABSTRACT

This study presents an innovative teaching-learning experience, aimed at connecting project-based learning with service learning in the biomedical engineering field. This experience is planned and implemented, coordinately, in two courses devoted to the biomedical engineering field: “Bioengineering Design” and “MedTECH”. These courses are respectively included in the Master’s Degree in Industrial Engineering and in the Master’s Degree in Engineering Management respectively, both at the ETSI Industriales from Universidad Politécnica de Madrid (ETSII-UPM). These courses follow the framework established by the Industriales INGENIA Initiative, which is completely aligned with the spirit of the International CDIO Initiative. Students from both courses collaborate in teams and live through the complete development life cycle of innovative medical devices. In the current academic year, the projects from the different groups of students stand out for their extra degree of complexity and for their intimate connection with real medical needs. This has led to a higher degree of realism, motivation and social impact, as a way for continuously improving these courses. The needs and ideas for the different projects on medical devices, which can be considered services for the community, are obtained by systematic interaction with medical professionals from public hospitals, patients and social services operating in the Madrid region. Along with the medical device development projects, students from different backgrounds and with varied skills interact, not only with the group of professors but also with the entities, for which they are providing the services and designs. Besides, students are placed in contact with international initiatives, such as UBORA, a global community operating through an accessible online infrastructure and pursuing the reinvention of the biomedical industry, by promoting collaborative and open-source approaches in the design and development of medical technology. In this context several groups of our students proactively participate in the 2019 UBORA Design Competition, designing medical devices for global health emergencies, in a challenging environment and in connection with the promotion of their understanding of the relevance of engineers for achieving the Global Goals. Main benefits, lessons learned and future challenges, linked to the continuous improvement of these CDIO-inspired courses and to the strategy for connecting project-based learning and service learning, are analyzed.

KEYWORDS

CDIO as Context, Integrated Curriculum, Integrated Learning Experiences, Active Learning, Service Learning, Biomedical Engineering, Standards: 1, 3, 5, 7, 8.

INTRODUCTION

Problem-based learning, project-based learning, experiential learning, game-based learning, learning in collaborative project and environments, among others, are just different versions of highly formative and integrative learning experiences that place students in the center of the teaching-learning process, in accordance with a desire for a more holistic training for the 21st Century, especially in engineering education (Larmer, 2014). In all these project-related teaching-learning methodologies, student teams face a real life (engineering) problem, more or less simplified, and perform the specification, design, prototyping and testing of a product, a process, an event or, generally speaking, an engineering system. In some cases, prototyping and testing are achieved just virtually, but there is always a critical analysis of results and a public exposition and subsequent debate for increased learning throughout the groups of students taking part in the course or courses. Besides, creativity, decision making and critical thinking are fostered and professional resources for engineering practice (i.e. design and simulation software, prototyping tools…) are applied, so as to prepare students, as globally as possible for their professional and personal lives. Knowledge acquisition is necessary for these experiences, but the development of specific professional skills and transversal abilities, for more adequately applying the acquired knowledge to solve real challenges, is also fundamental in modern education (Shuman, 2005). These varied experiences mainly differ in the level of depth, to which the project, product, process or engineering system is specified, designed, implemented and managed or operated, and in the proposed context and desired level of realism, which depends also on the time and resources available for students living through the formative experience (De Graaf, 2003, Larmer, 2015, Díaz Lantada, 2013).

The “conceive-design-implement-operate” CDIO approach to project-based learning, in a way, encompasses all the aforementioned types of active learning experiences (Crawley, 2007). In fact, the complete CDIO cycle involves the whole life-cycle of any engineering project or system, from specification and planning, through the design, engineering and construction, towards full operation, maintenance and end of life. In addition, the CDIO model goes beyond traditional project-based learning, as the CDIO educational model involves also actuations, within the institutions and the professionals committed to “reinventing engineering education”, aimed at continuous quality improvements in all engineering education-related processes. To this end, the support of a set of CDIO standards (see: http://www.cdio.org), together with the sharing of good practices in the CDIO events, is fundamental.

Among the characteristics of CDIO educational experiences, is the permanent search for educational contexts with an increased level of realism (when compared to a more classic project- and problem-based learning experiences) and, therefore, with a higher potential social impact. In many cases, the CDIO projects are linked to real research and innovation projects or to industrial, entrepreneurial and social activities, in which highly transformative objectives are settled down and relevant human needs are addressed (Kontio, 2010, Cea, 2014, Norman, 2014, 2017).

All this links with service learning, defined by Jacobi as “a form of experiential education, in which students engage in activities that address human and community needs together with structured opportunities for reflection designed to achieve desired learning outcomes” (Jacoby, 1996). Ideally, the solutions developed in these learning experiences reach society and transform it. This project-based service learning model adds to the previously listed types of active and integrative learning experiences and is clearly within the scope of CDIO. This hybridization between service learning and project-based learning can have additional impact if open-source and collaborative approaches to engineering and its education are also involved and promoted, as recent international “express CDIO” learning experiences have put forward (Ahluwalia, 2018).

Our team, conscious of the potential of these interconnections between types of CDIO training actions, decided to improve previous experiences within “INGENIA” courses, a set of subjects following the CDIO model (Lumbreras, 2014, Díaz Lantada, 2014). To this end, we searched for an additional degree of connection with real medical needs, with patients and healthcare professionals and with actual professional practice in biomedical engineering, in courses focused on the development of medical devices and technologies, hence hybridizing service learning and project-based learning. The courses involved, the overall strategy for promoting social impact and preliminary results are presented in this study.

“BIOENGINEERING DESIGN” AND “MEDTECH” COURSES AT ETSII-UPM

The faculty of Industrial Engineering at Universidad Politécnica de Madrid (ETSII-UPM) includes a set of courses, called INGENIA” for the systematic promotion of the CDIO approach to engineering education. These INGENIA subjects are compulsory for all students enrolled in the first year of the Master’s Degree programmes in Industrial Engineering and in Engineering Management at ETSII-UPM (two-year programmes with 120 ECTS and 90 ECTS respectively, offered after a four-year Grade in Industrial Technologies or related topics with 240 ECTS). These subjects (with a similar CDIO orientation but offering different topics and projects) are 12 ECTS equivalent, which correspond to a student workload between 300 to 360 hours, distributed along two semesters with the following structure: 120 hours of supervised work plus between 180 to 240 hours of personal student work, organised usually in teams. Professor supervised part of the subjects is divided into 30 hours dedicated to adapt basic theoretical knowledge derived from other subjects to those directly related with the project, and a second set of 60 hours is devoted to practical work in the lab, with professor supervised sessions. Students also receive two seminars of 15 hours; one oriented to transversal outcomes, in particular, workshops on professional ethics, teamwork, communication skills and creativity techniques, and the other one about social responsibility issues such as environmental impact, social, political, security, health, etc. These lectures, practical sessions, seminars and workshops, are distributed along the 28 weeks of the two semesters of the first year, resulting in 5 hours per week of lectures or practical sessions in the regular schedule of students. Placing the INGENIA subjects in the first year of these formative programmesis indeed interesting, as additional 12 ECTS are devoted to the final thesis during the second year. Therefore, at least 20-25% of these programmes is devoted to project-based learning aimed at the complete development of engineering products and systems, as presented and explained in detail elsewhere (Lumbreras, 2014, Díaz Lantada, 2014).

In academic year 2017-2018 our team introduced a radical innovation to the INGENIA model, by means of the coordinated design and implementation of two courses, namely: “Bioengineering Design”, in the Master’s Degree in Industrial Engineering, and “MedTECH”, in the Master’s Degree in Engineering Management, working upon previous experiences (Díaz Lantada, 2015, 2016). This resulted in the first successful example of coordinated and complete CDIO-based experiences working across programmes, within the Industriales INGENIA Initiative, and one of the very first examples of project-based learning in the biomedical field with such a holistic approach. In fact, the positive aspects of collaboration across programmes, with students from different backgrounds, working together for the development of complex projects, and with a devoted team of multidisciplinary professors, capable of better guiding the progress of student teams, has been rewarding. In addition, it opens new possibilities and offers solutions for expanding the INGENIA model to other programmes of our university, by means of “educational joint-ventures”, in connection with trends focused on collaborative project development and with the understanding that the future of engineering is collaborative and requires from interdisciplinary collaboration for solving social challenges.

Going into details, “Bioengineering Design” and “MedTECH”, share some fundamental lessons and common topics along the two semesters, while some specific lessons also help to differentiate according to the different backgrounds and motivations of the students. Those from “Bioengineering Design” take part in the Master’s Degree in Industrial Engineering and prefer to deepen in aspects linked to design, simulation and manufacturing technologies, while those from “MedTECH” belong to the Master’s Degree in Engineering Management and are more interested in strategic and business aspects, together with topics related to the organization of production and to the supply chain management. In short, both courses advance in parallel and share several general lessons, while 30-40% of the lessons are devoted to the more specific aspects with the students from different Master’s degrees separated. Each team counts with students from both Master’s degrees and all students work together and are responsible for the successful conception, design, implementation and operation of an innovative medical device, although the different skills and backgrounds make them share and distribute tasks according to their experiences and expectations. Globally speaking, conceive and design stages are covered during the first semester and implementation and operation stages are covered during the second one, as previously analyzed and presented (Díaz Lantada, 2018).

INNOVATIONS FOR ENHANCED CONNECTION TO SOCIAL NEEDS

After the first coordinated implementation of “Bioengineering Design” & “MedTECH”, an emphasis on developing medical technology for solving real needs is placed for academic year 2018-2019: In spite of still letting students decide upon the needs to address and the related medical devices to develop in this coordinated CDIO experience, the relevance of collaborating with patients and healthcare professionals in any medical technology project is highlighted and additional efforts are given for providing students with a more realistic context. To this end, during the needs identification phase, so as to select the topics for the medical technology projects to be developed by student teams, contact with different patients associations and clinical areas has been fostered. Besides, connection to open-innovation approaches to medical technology has been supported by proposing students to join the UBORA community, to use the UBORA e-infrastructure asan open-source tool for guided medical technology development and to participate in the UBORA design competitions (Ahluwalia, 2018). Furthermore, the involvement of a team of doctors focused on organ transplants and of a couple of associations focused on physical, psychical and sensorial disabilities has been achieved thanks to the proactivity of our students. Besides, a seminar with participants from hospital innovation units, with surgeons as users of advanced medical tools, with medical technology entrepreneurs, and with experts from notified bodies, has made students more aware of the complex context of the medical industry.

All this has led to a more careful selection of medical needs and to the consequent proposal of very relevant and innovative medical technologies, to be developed during these courses. The potential impact of these technologies is increased, not only because they address more realistic needs, but also because the patients and professionals associations involved can constitute fundamental links of the chain towards eventual technology transfer, which may take place beyond the temporal framework of these courses, hence providing students also a path for professional development. In order to promote impacts and sustainability beyond the courses, students are sharing their developments through the UBORA e-infrastructure, a sort of “Wikipedia” for open-source and collaboratively developed medical devices, which also supports designers in their decision-making process towards safer and EU regulation compliant medical devices. Finally, some teams are considering spin-off creation and all students participate in the Actúa-UPM ideas challenge for technological enterprises and in the 2019 UBORA Design Competition focused on health emergencies.

IMPACTS OF THE INNOVATIONS AND PRELIMINARY RESULTS

Continuously evolving project-based learning experiences keeps them alive and is directly connected to quality improvement cycles. In the case of the educational joint-venture between "Bioengineering Design" and "MedTECH" courses, the modifications introduced in the academic year 2018-2019 for an increased connection to reality have derived, first of all, in a more global context and training. This is schematically highlighted in Figure 1, which shows the already presented structure and content of these courses (Díaz Lantada, 2018), but now surrounded by several relevant actors, especially in the needs identification phase (connection to patients and professionals associations, seminars by experts…) and as regards technology transfer (connection to international communities, local and multinational competitions…). These main innovations previously detailed, have interesting impacts in course structure, content and context, but also in the complexity and quality of the learning process and on the achieved results. The experience is resulting more multidisciplinary, with additional medical sectors involved, as also schematically highlighted in Figure 1, which the team of professors considers positive and which is proving motivating for students themselves, according to the increased attendance to lessons and in-class participation in debates and through questions, which were already high in previous editions.

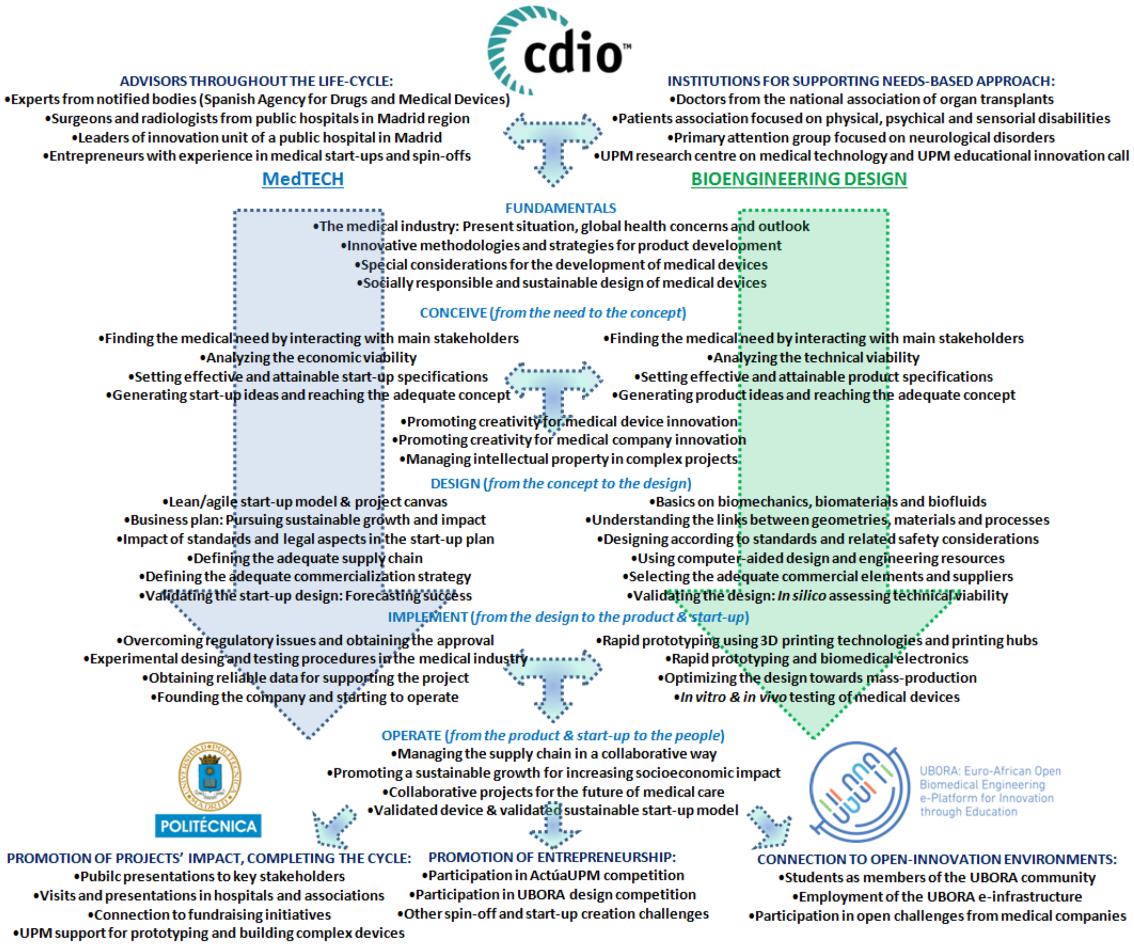

Figure 1. Collaborative scheme among "Bioengineering Design" and "MedTECH" and connections to key stakeholders for improved needs identification and social impact. The topics to the left represent the "MedTECH" track and the topics to the right the "Bioengineering Design" track, while the central topics are common. The fundamentals and conceive and design stages are *grosso modo* covered during the first semester, while implementation and operate stages correspond to the second semester.

A total of around 55 students (40 from “Bioengineering Design” and 15 from “MedTECH”) are collaborating divided in 7 teams for developing medical devices including: a pump and fluidic circuit for improved liver transplantation, a stand-up chair for children with mobility problems, a device for eyelid cleansing, an intelligent insole for detecting problems related to diabetic foot, an smart system for varicose vein massaging, a visual display for vein detection and a thumb prosthesis for children. The conceptual designs of some selected examples are presented in Figure 2. Support from UPM for hybridizing project-based learning and service learning and constructing the prototypes of the different devices has been achieved and final presentations with patients associations and healthcare professionals have been scheduled. Detailed results of the implementation and operation phases are to be presented in the CDIO 2019 Conference of Aarhus.

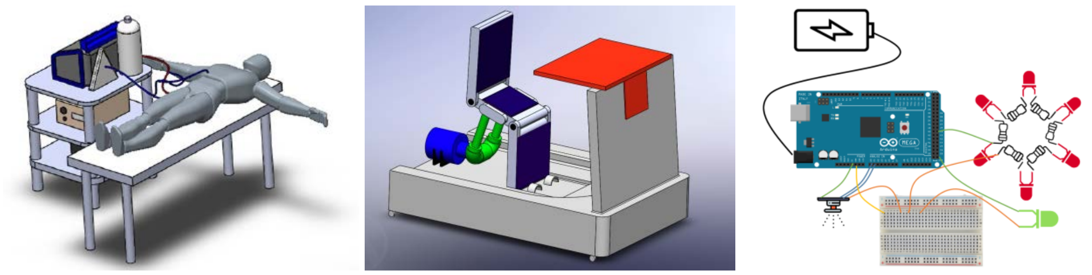

Figure 2. Selected conceptual design examples from the different projects: a) Pump and fluidic circuit from improved liver transplantation. b) Stand-up chair for children with mobility problems. c) Circuit for display for vein detection connected to a smartphone. “Bioengineering Design” and “MedTECH”, 2018-2019 academic year.

CONCLUSIONS

This study has presented an innovative teaching-learning experience, aimed at connecting project-based learning with service learning in the biomedical engineering field. This experience has been planned and implemented coordinately in two courses devoted to the biomedical engineering field: “Bioengineering Design” and “MedTECH”, included in the Master’s Degree in Industrial Engineering and in the Master’s Degree in Engineering Management respectively, both at the ETSI Industriales from Universidad Politécnica de Madrid. These courses follow the framework established by the Industriales INGENIA Initiative, which is completely aligned with the spirit of the International CDIO Initiative. In them, students from both courses collaborate in teams and live through the complete development life cycle of innovative medical devices and healthcare technologies.

Main innovations presented in this paper, which shows an evolution of these two courses working upon previous experiences, deal with: 1) the designed strategy for increased connection of student projects with real medical needs, and 2) with the promotion of social impacts, by means of more straightforward connections to entrepreneurship and other sustainability-oriented options. All this derives into more socially relevant development projects with a remarkable potential for having a real impact in the medical field, thanks to the involvement of patients and professionals associations, not just in the needs identification phase, but also in the monitoring, evaluation and search for sustainability of the proposed solutions. The results obtained motivate us to continue with this coordinated and truly holistic approach, based on hybridizing project-based learning and service learning, which will let us hopefully reach medical professionals and patients for improved social impacts in the near future.Continuous improvement is promoted by a growing community of collaborators and cases of success, which are used as teaching-learning examples.

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