A CDIO-ORIENTED TECHNOLOGY PRODUCT DEVELOPMENT COURSE FOR ELECTRONIC ENGINEERING STUDENTS

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ABSTRACT

This paper describes a one-semester course, given to third-year Electrical and Electronic Engineering (EE) students at Shenkar College of Engineering, Design and Art, since 2011. The course was developed in accordance with CDIO standards. This integrative course is delivered by two co-teachers, one from the EE Department and the other from the Industrial Design Department. Each year a different topic is chosen for the course. Throughout the course, students plan, research, design, develop, implement, and present a product prototype. The prototype must be a physical and functional model that effectively communicates the proposed idea. Students are expected to use the tools and experience gained during course sessions, including basic aspects of industrial design and prototyping. The course provides an opportunity to implement both theoretical and practical knowledge acquired through previous EE core courses along with elements of industrial design. In the course, students integrate interdisciplinary knowledge elements to conceive, design, implement, and operate real-world systems and products. Looking forward, this active learning experience forms a basis for carrying out challenging capstone projects, and for future successful integration into the engineering industry.

KEYWORDS

Design Thinking, Engineering Problem Solving, Teamwork, Innovation, Industrial Design, Standards: 1, 2, 3, 5, 7, 8

INTRODUCTION

The typical engineering curriculum nowadays still consists, essentially, of a multitude of frontal lecture courses, augmented with a capstone project that is carried out during the last year of study. However, this way of knowledge transfer is insufficient: it is often too abstract, and in many cases, lacks on aspects of knowledge implementation. These limitations motivated the development of the CDIO framework some two decades ago (Crawley, Malmqvist, Lucas, & Brodeur, 2011). The CDIO approach emphasizes the importance of learning experiences where products that meet customer needs are developed through a process of conception, design, implementation, and operation (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014).

The current paper is about a CDIO-oriented course (module), named "Technological Product Development" (TPD) that was developed and is being taught in the Electrical and Electronic Engineering (EE), at Shenkar college in Israel, since 2011. The course is a single-semester, project based, interdisciplinary, knowledge-integrative course, guided together by two teachers- one from the EE department, the second from the Industrial Design (ID) department. As such, this concept (to be detailed below) is aligned with the institutional mission and vision at Shenkar College, in which engineering and design studies co-exist, with an aim to find joint areas of activity. In fact, the course was inspired by an annual Hackathon-like event at Shenkar, called MERKACHA (jam, in Hebrew), in which students and staff from the Engineering and Design departments collaborate on projects, within a specific, common, pre-defined theme, which changes each year. We have written about this Engineering-Design “fusion” event, and some of its implications on engineering education, in previous papers (Furman, & Weissman, 2019), (Furman, & Weissman, 2020).

The need for such a course, and its suitable position within the curricular flow of knowledge transfer, has become clear over the years of teaching engineering, EE in this case. As illustrated in Figure 1, the course follows several core EE courses, in which students accumulate theoretical knowledge in variety of subjects, particularly in electronics and coding. These courses are followed by a series of EE labs on various subjects, in which the main theoretical subjects are demonstrated in a pre-defined set of experiments, using a suitable dedicated lab equipment. Notably, these labs include subjects such as electronic circuits, communication techniques, micro-controllers, and others.

These courses and labs provide sufficient basis for building simple systems, but they often lack the provision of a wider context to the proper way to use the acquired knowledge in the process of developing these systems. Thus, it became clear that what was further needed is a project-based learning (PBL) course, at about midway of the study path (beginning of 3rd year), that would precede the capstone project, would provide context, and would interconnect the theoretical subjects with the practice of designing products. This is where the course discussed here fits in.

The product development process generally involves skills and competencies that are beyond the core topics of EE theory, so engineering education must fulfil many and varied tasks dictated by modern trends. For example, technological innovations, changes in business models, and changes in consumer habits require not only business trend awareness, but also innovative practices of self-management, time management, teamwork and problem solving (Eppinger, & Chitkara, 2007). Added to this is the transition from a traditional learning methods to an attitude of creativity, design, and planning of new alternatives (Zika-Viktorsson, & Ritzén, 2005). In addition, based on the various approaches on design thinking, common basic principles have been identified that successfully allow dealing with contexts such as: user focus, problem framing, visualization, experimentation, and presentation (Leavy, 2010). These additional skills and competencies, which are part of the CDIO syllabus (Crawley, Malmqvist, Lucas, & Brodeur, 2011), enable future graduates to be more competitive in the labor market. Studies on preparing engineering graduates for industrial careers appear often in the industrial and academic literature (Cerezo-Narváez, Bastante-Ceca, & Yagüe-Blanco, 2018). As shown in Figure 1, three additional competencies are reflected during the course: Acquaintance with principles of design thinking, b. development of soft skills, c. experiencing prototyping tools, particularly the use of 3D printing.

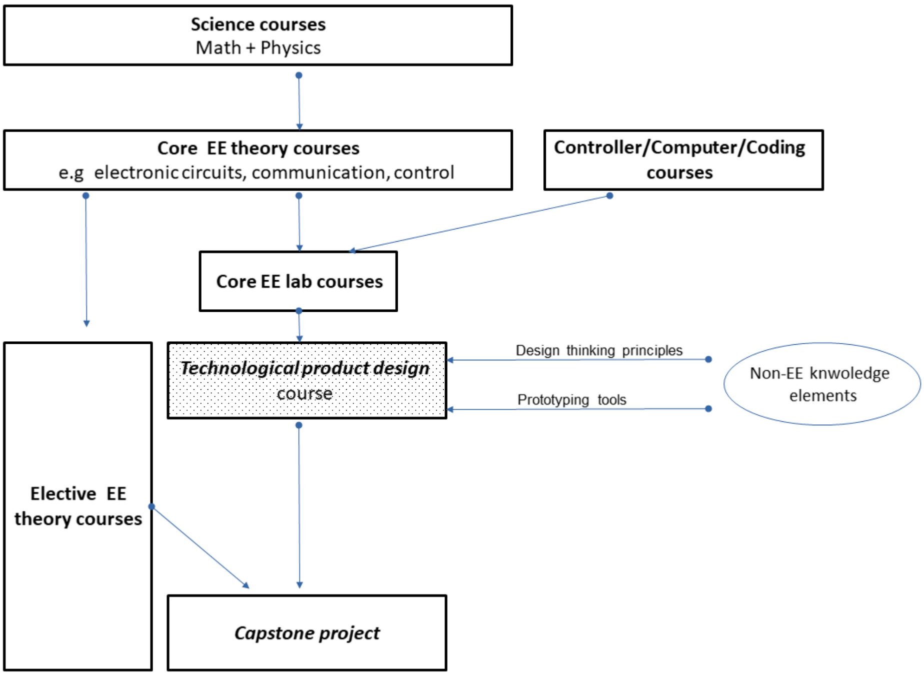

Figure 1. The curricular structure at the EE department. The dotted-pattern course is the subject of the current study

The methodology of integrating all these components into a useful course is detailed in the following section. The aim of this study is to describe the design and process of this CDIO-oriented course and reflect on their impact on the EE curriculum and on its pedagogical effectiveness.

COURSE DESCRIPTION

As indicated above, the course (or module) is normally taught during the first semester of the 3rd year. Each year, before the semester begins, a theme is chosen by the two co-teachers, one from the Electrical Engineering (EE) department and the other from the Industrial Design (ID) department. The theme is broad enough to facilitate a sufficient variety of feasible products. The theme should match the common knowledge of a typical 3rd year student. Two examples for such themes in recent years are energy harvesting devices, and innovative musical instruments.

Upon course debut, the students are assigned into teams of 2-4 participants. The aim was to try and ensure a reasonable balance between teams, and in particular disperse the most talented students equally among all groups.

The next phase is brainstorming for ideas. After the brainstorming session in the class as a whole, each team would be free to choose a product based on the ideas raised in class.

Once the teams had chosen an idea, they are asked to conduct a short market research. Throughout this research, they have to explore three similar products and conduct focus group interviews (as commercial companies regularly do, as part of their market research). The interviews take place within the classroom, and the focus groups are their peer students.

At this stage, the groups have gathered enough insight and can start defining a functional specification – main product features and use case scenarios.

The next phase is hardware design. Based on EE core knowledge acquired throughout their studies thus far, each team prepares a block diagram containing the electrical components which are needed to build the prototype. In order to save precious delivery time, components are borrowed from the college or bought in local electronics stores, rather than being ordered online.

From this time on, the course proceeds to the "Practical, Hands-on" phase. This takes place during the second half of the course and lasts seven weeks long. The work format in this phase is that of a workshop: Each student team works separately, and the co-teachers guide the groups, one by one.

As soon as the main components are acquired, the ID team moves into a higher gear. The ID team is led by the ID co-teacher, and a 4th year ID student, who helps with building the physical 3D models, into which the electronic sub-system is inserted.

In parallel, each team assembles its respective electronic circuit and starts coding the software that would run on the embedded microcontroller, which constitutes the core of most systems designed in the course. Software writing skills, as well as physical assembly of electrical circuit skills, are acquired in previous core EE courses.

Then, all the elements are integrated into the final model, which is to be presented in front of the class in the last lesson of the course. Alongside the functional prototype, the students are requested to prepare a one-pager, and a PowerPoint presentation.

The final presentation is held during the last lesson of the semester, the forum being the students, the co-teachers, and a "jury". The jury is comprised of staff members from Shenkar College and of external visitors from the hi-tech industry.

Several examples from recent years are shown in Figure 2. In Figure 2a, an electric fin is shown, which is a surfboard that powers LED stripes with the energy of sea waves. Figure 2b shows a milk saxophone, in which a standard milk carton is used as a resonance box. Figure 2c shows a solar sunflower, that absorbs solar energy during the day and turns on LED lights during the night. Finally, Figure 2d shows an electronic Hang, an electronic version of the acoustic hang musical instrument.

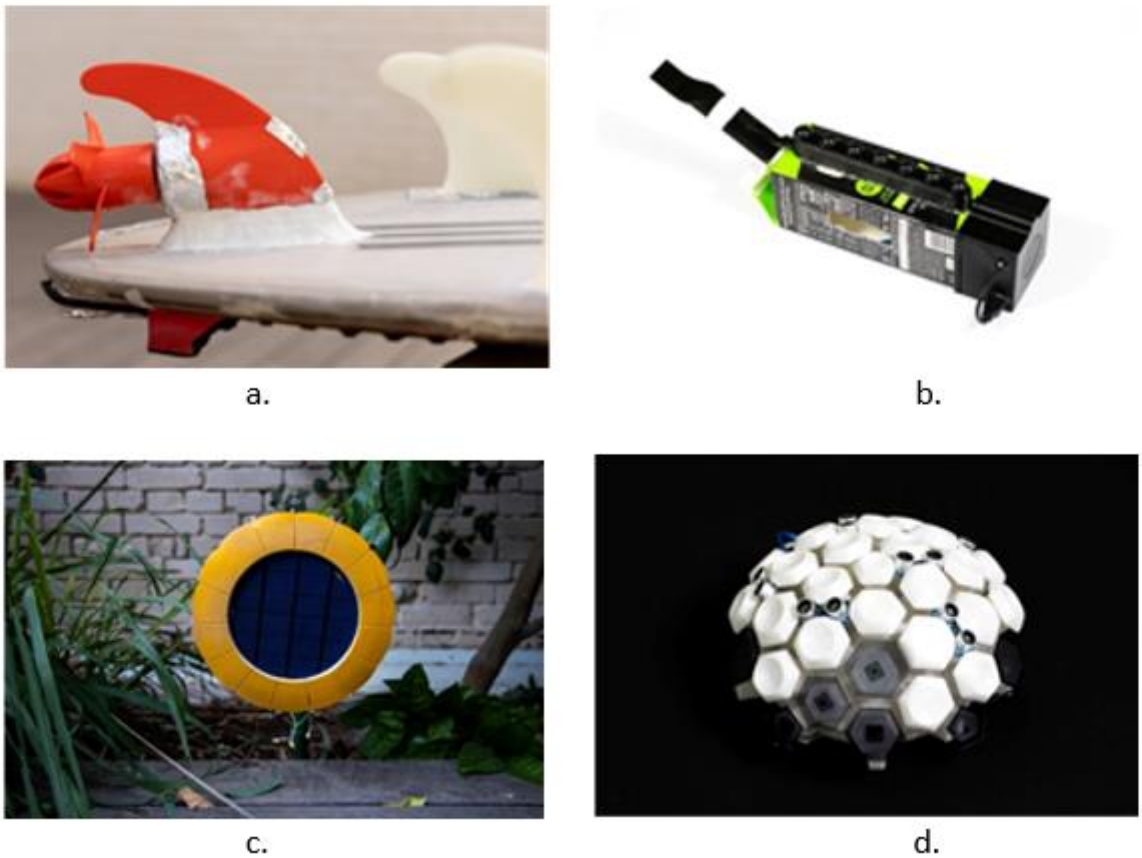

Figure 2. Examples of products developed in the TPD course over the past few years. a. Electric fin, b. Milk saxophone. c. Solar sunflower, d. Electronic Hang

DISCUSSION

In this section we consider some of the relevant issues with respect to the TPD course.

The first issue is the interaction of the course with the preceding core EE courses, that “feed” this course with relevant engineering concepts and methods. Namely, we ask: to what extent does this course provide a framework for students to implement previously acquired engineering knowledge? And, conversely, may the course provide useful feedback with respect the content of some of these preceding courses? We first note that in most cases, for the types of products implemented in this course, there are mainly two relevant elements of such knowledge: hardware coding, and basics of electronic components and circuitry. Preceding the TPD course, among many other core courses, there are: a. courses in C & Python languages, b. labs that focus on Arduino and Raspberry pi, and c. basic courses in electronics, that deal with amplification, sensing, actuating, etc.

The elements of knowledge acquired in these preceding core courses are typically the most useful ones for the TPD course. Among them, perhaps most useful is the knowhow of using the Arduino microcontroller and (to a lesser extent) the Raspberry pi miniature computer platforms. These are the backbones of most products designed in the course, and the respective knowhow, both hardware-wise and software-wise, provides a needed flexibility for realizing reasonably functional (though, arguably, not too complex) products. Notably, theoretical knowledge acquired in other core courses is considerably less implemented in the TPD course. Further, the TPD course also benefited from changes made in some of these core courses. Specifically, some five years ago, when the microcontroller lab course switched from teaching the concepts on an older TI micro-controller card, to using the more ubiquitous and user-friendly Arduino platform, the projects in the following TPD courses stepped up their levels of functionality.

A second aspect that deserves attention is the effect of the TPD course on the subsequent, final year, capstone projects. Meaning: to what extent the course facilitates more challenging capstone projects? This has not been studied methodically, yet it is reasonable to say this course serves as a useful introduction to the capstone project in more than one way. Most important, the course provides some basic skills for a project, by guiding the students through the main phases of the process of product development, and by training them in using some newly acquired soft skills. Although the scope of the TPD products is more limited than that of the end-products of the capstone project, these newly acquired skills make the progress at the capstone phase somewhat smoother.

A third aspect to discuss relates to the complexity of the TPD products, attainable in a framework of a one-semester course. Notably, throughout the decade that the course exists, it has constantly evolved along two axes: the engineering (EE) axis and the design (ID) axis. The two main changes took place in recent years were: 1. Four years ago, in two of the core courses that precede the TPD course, we started to teach (and extensively experiment) the Arduino platform, and later on, the Raspberry pi platform. These changes provided the students with considerably more updated and flexible platforms for building more complex, functional products. 2. Three years ago, an ID co-teacher was joined to the course (previously, he was a freelance counselor, on demand). As a result, students became familiar with some of the ID-related methods of product design (I.e., elements of design thinking). In addition, an ID student was added as an assistant, mostly for helping in tasks that required 3D printing. These changes resulted in stepping up the appearance, and the ergonomics of the prototypes. In recent years, the prototypes tended to look more like real products, rather than a bare breadboard attached to some wires and LEDs (as was case in the earlier years of the course). Altogether, these two changes have upgraded the level of the typical TPD course product.

The fourth aspect is the way students view the TPD course. Over the years, student's feedback was monitored, qualitatively and quantitatively, by conducting teaching surveys. The results normally show a high satisfaction rate, e.g., course grade above 6 out of 7. In the qualitative part, students acknowledge the high effort that the course requires, considerably higher than the accredited academic points “justify”. However, the final goal of a fully working, presentable prototype seems to keep most students highly committed, despite the time-consuming effort required. Also, students are quite satisfied with the "widening horizons" attitude of the course, touching various industry aspects that are not taught in any other curricular course. Notably, the course includes guest lecturers, given by external experts, that deal with various hi-tech industries subjects, such as entrepreneurship, R&D, and accounting.

CONCLUSION

We described, and discussed, a CDIO-oriented course that was developed, and is being taught at Shenkar college (Israel), for about a decade, in the third year of study. The course provides a platform for students to implement core EE knowledge that was accumulated during their first two years, in developing a product. It is taught in collaboration, by EE & ID teachers, and as such incorporates elements of product design into the traditional core engineering knowledge base. It also prepares the students for their 4th year capstone projects, encouraging them to carry out challenging projects. Bottom line is that students are, in general, highly satisfied by this experience, judging by their feedbacks, and the many long hours that they dedicate to the design of the course products.

The following topics for study are: The contribution of this course to the quality of the capstone projects and the impact of the skills acquired during the course on the success of the graduate in achieving key positions in the high-tech industry.

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