ACTIVE LEARNING IN ELECTRONICS ENGINEERING AT PONTIFICIA UNIVERSIDAD JAVERIANA

Alejandra María González Correal, Jairo Alberto Hurtado Londoño, Kristell Fadul Renneberg, Flor Ángela Bravo Sánchez, Francisco Fernando Viveros Moreno

Electronics Engineering Department, Pontificia Universidad Javeriana. Bogotá, Colombia

ABSTRACT

The present article shows a selection of different courses' activities designed to develop the disciplinary and CDIO competences. These activities utilize the active learning methodology in the classroom and promote the students' centered learning. There are presented two categories of activities, their development in introductory courses, and the ones done in advanced courses. For the introductory ones, the evolution of the Introduction to Engineering course is shown, as well as some activities that develop the criteria related to group formation and evolution, ethics, social responsibility, and problem solving among others. For the Introduction to Engineering specific case, the activities are developed in a design and implement project context. This article presents the evolution of the course during several semesters additionally to the thematic chosen for the projects. The activities complement the project and give elements for the disciplinary, interpersonal and problem solving competences development.

For the advanced courses, four examples are shown: Logic Circuits, Design of Digital Systems, Processor Architecture, and Signal and Systems. In these courses, activities are centered in the disciplinary competences development and in the association of engineering concepts with reality. In all cases, it is presented the courses evolution, the characteristics and advantages of the new approaches, the way on which students receive these activities, and an evaluation of the obtained results. Finally, the general conclusions, and the improvement proposals for the activities and for the courses orientation are presented.

KEYWORDS

Active learning, Engineering Education, CDIO approach, Standards: 1, 4, 8.

INTRODUCTION

During the last four years, and in favor of the improvement of the Electronic Engineering program in the Javeriana University, a curriculum review was done based on the CDIO (Crawley, et al. 2014) initiative. This review affected directly several courses changing their methodology from a theoretical structure to one based on product design projects. Several pilots have been made to prove the impact and results of the methodology implementation, all which provided positive outcomes.

Different perspectives from students and professors were obtained in order to evaluate the courses and the reactions generated by the change. The learning results were also valued, as well as the progress made in the level of competence of the abilities expected to be learned on those courses. Based on these perspectives and evaluations, changes to the courses were proposed and implemented. At the present time, improvement actions are continuously applied in order to identify benefits and disadvantages of the new methodology. This process also has provided very important evidences and tools that are used to in the program improvement model.

In the present article, it is presented, in the first place, a brief description of the active learning methodology. Then, it is shown the utilization of the methodology in the Introduction to Engineering freshman course, its evolution and results. In the next section, it is found the approach given to the senior courses of Logic Circuits, Design of Digital Systems, Processor Architecture, and Signal and Systems. Finally, conclusions and future work are presented.

ACTIVE LEARNING IN ELECTRONICS ENGINEERING

Many of Electronics Engineering courses are highly theoretical and abstract. Students often have difficulty understanding complex abstract concepts and transferring their knowledge to real life, especially in the engineering practice. A good way to help students in their learning process is to include active learning strategies in engineering courses.

Active learning is one of the key concepts in the CDIO approach. ***CDIO Standard 8*** addresses the importance of using active and experiential learning strategies. These strategies involve engineering students, as active participants, in their own learning and reflection of their learning process (metacognition). When students take on roles that simulate the practice of a professional engineer (i.e. designing projects, case studies or simulations), active learning becomes experimental learning (Crawley et al., 2014).

This student-centered learning engages students in thinking about concepts and helps them make better connections between old and new concepts. By using active learning strategies, such as role-plays, case studies, problem based and project organized learning, students usually showed improved learning over strategies in which students take a passive role in the learning (Bruff, 2009).

ACTIVE LEARNING IN FRESHMAN COURSES: ENGINEERING INTRODUCTION

This section describes our experiences using Active Learning in freshman courses. These courses have been designed to follow ***CDIO standard 1- context***, which promotes the learning of fundamental concepts under the context of Conceiving, Designing, Implementing, and Operating systems, products, and services in the real world (Crawley et al., 2014). ***CDIO standard 4 - Introduction to Engineering*** is a framework for engineering practice and introduces essential personal and interpersonal skills. Freshman courses also have been formulated to include Active Learning approaches ***(CDIO Standard 8)***.

These first-year courses aim to show the student the nature of the discipline, the professional role of an engineer, and his social responsibility. Introduction to Engineering helps to develop some basic skills such as teamwork, oral and written communication, planning, time and resources management, model construction and strategies to solve problems. The Introduction to Engineering course demands 216 hours of student work during an academic period of 18 weeks. It has a weekly session with supervision of teacher of 4 hours and it requires from every student a weekly dedication of independent work of 8 additional hours on average.

The Evolution

Introduction to Engineering began as a theoretical and practical course based on engineering challenges. Students had to solve those challenges using tools learned independently through investigation or given to them in class. In spite of the efforts to create challenges that motivated the students to actively participate and helped them develop important and basic skills, the theoretical component of the course was too wide. This caused a lack of time to develop the challenges, which resulted in nonfunctional final products that frustrated and discouraged the students.

The perceptions of the students were consulted in order to collect indicators for the evaluation of the course. As a general finding, two main failings were taken into account. The first one showed the necessity of more time to develop the projects, which implied less theoretical classes. The second one established the need of a higher accompaniment of the professors and instructors in order to support and guide the students' progresses.

Based on these difficulties, it was made a transformation to the course based on the CDIO approach. The course was divided in two parts. The first part presents to the student the nature of the discipline, the role of a professional engineer and his main abilities as well as his social responsibility. The second part is based in a design and implementation project that brings the student closer to the product construction process and to the development of those basic skills.

Freshman courses under the CDIO approach have been taught since the first semester of 2014 with positive results. The topic of the first pilot course was energy efficiency. Students participated in designing and building an electric car (Figure 1). The objective was to improve the car's energy efficiency through its features, such as weight, shape and size. At the end of the course, it was made a competition to select the faster and more efficient car. As a general perspective, students and professors highlighted the motivating learning process that included the correct understanding of the concepts.

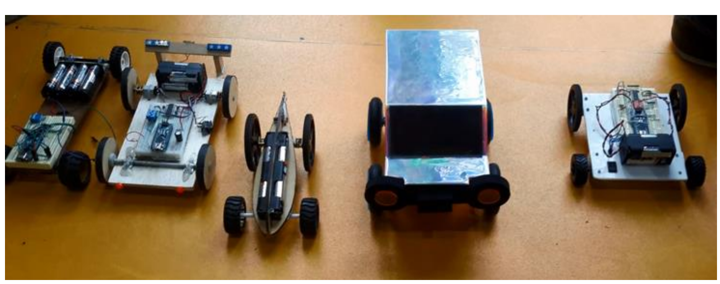

Figure 1. Electric car project. – Pilot 2014-1

In the second period of 2014, the course's project was the automation of the process of transportation of goods in a port to a railway. Students had to face a collaborative design challenge in a consortium model. Each group had to develop a part of the transportation process that had to be integrated at the end and work as a unity. Figure 2 shows the general idea of the proposed project. The experience in the course was based on collaborative learning and communication between groups, points that were satisfactorily achieved.

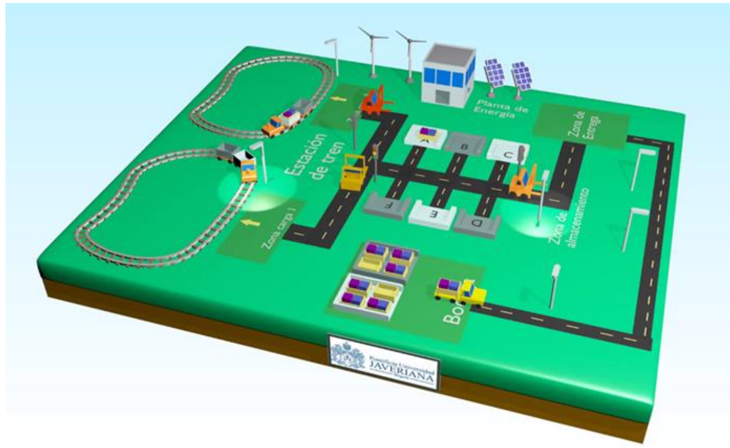

Figure 2. Automation of the Process of Transportation of Merchandise in a Port. –
Pilot 2014-2

The project developed during the first period of 2015 was based on disability. Each group interviewed a person with disability in order to find a problem of their daily life. After finding it, students presented and developed a solution, utilizing the CDIO design phases. Abilities such as the understanding of ethical and social responsibility, oral communication and context knowledge were specially improved. In Figure 3 are shown two of the projects developed by the students.

Figure 3. Disability Projects: Robotic Hand and Color Sound. – Pilot 2015-1

IoT and domotics were the topics chosen for the second period of 2015. Again, student selected their work teams and chose a specific topic belonging to the proposed ones. In Figure 4 can be seen two projects developed by the students. The methodology showed again its advantages to develop important abilities such as teamwork. Teams collaborated, participated and organized to design and implement the different projects. In addition, disciplinary abilities, such as the correct utilization of several engineering tools, was correctly applied, showing the growth and learning achieved with the methodology.

Figure 4. IoT and Domotics Projects. – Pilot 2015-2

During the academic cycle, different workshops are offered. These seek to show the student basic tools and knowledges that can be used in the development of their projects (Giraldo et al., 2014). Some examples are: soldering workshop, robotics approach through LEGO mindstorms kit, introduction to electronics through Arduino, and assembly of circuits in protoboard. Other workshops are used to introduce abilities like oral and written communication, the engineering tasks, ethics and social capital among others. Figure 5 shows the icebreaker workshop “Caricature Drawing” where each student learns how to look at himself and others in a different and fun way. Conferences with experts on the topic are also used, and it is proposed to include the support of the industry by visiting companies or having meetings with their leaders.

Figure 5. Icebreaker Workshop “Caricature Drawing”.

ACTIVE LEARNING IN SENIOR COURSES

Digital Area

The courses of the digital area, Logic Circuits, Design of Digital Systems, and Processor Architecture, can be easily used to apply active learning processes. In these, students learn by developing projects under the guidance of the professors. The mistakes and problems found are used to feedback the teamwork and the course in general.

Logic Circuits

The Logic Circuits course does not develop the contents in a traditional way. Many techniques, where the learning of the contents is a mechanic process, were eliminated. Some examples of these techniques are Karnaugh maps, algebraic minimizations and the teaching of all the different flip flop types.

During the first half of the course, the student focuses on understanding the requirements of the client, the restrictions of the problem, and determining the inputs and outputs of the circuit to be designed. These steps allow him to develop a block diagram that clearly describes the architecture of the system. This process is made for three different designs, each one with a higher complexity than the last one.

The course has a maximum of twenty-four students divided in groups of three. The groups propose solutions for the requirement and share their ideas with the other ones in order to find solutions for the problem. The professor acts as a guide whose main role is to orientate the proposals into viable solutions inside the logic circuits domain as well as shortening the extension of them so they can be developed in the available time. Students have different roles inside the group and are divided in Architects, Designers and Reviewer, roles that alternate on the three designs. Each student has to make their own written part according to their role. It is normally seen that at the beginning, while they learn to understand the function of each role, the architecture writings are clearer than the other ones.

After this task is completed, a playful activity is done to help the students understand the concepts of synchronous and asynchronous systems. This ends in selecting the synchronous one after recognizing its advantages and how it is more appropriate for the designs developed.

In the second part of the course, the first two requirements are retaken and the design of each block is made. After it, the VHDL description is also made as well as the configuration of a FPGA device in order to test and verify the functioning of the system and that it actually solves the necessity of the client. Classes are used as a meeting point in the same way they were used while developing the architectures. There are spaces where students share their designs and solutions to the problems they found.

Digital Systems Courses

The Digital Systems course is a continuation of the Logic Circuits course, therefore the methodology is maintained. Students conform groups of three students that during the first part of the course work in the third requirement of the last course. Because that requirement is quite complex, the architecture was not completely defined. They have to complete the architecture as well as the block diagram, and finish in the implementation and verification with the FPGA device.

Generally, in this case, there are more than two courses with twenty-four students, and this is used to implement a role-play in the second half of the semester. On it, each one of the courses receives a requirement and each team makes a proposal of the architecture to solve the problem. When the architecture is finished, the team gives their solution to a team of another course, which now has to design and implement it. In the same way, the first team also receives the proposal of another course's team. Students use an online forum to ask questions between them, give corrections or modifications of the architectures. It is established that the only valid changes are those that appear in the forum. While this task is done, professors of the courses guide their students and periodically revise the forum in order to follow up the development of the projects.

Processor Architecture Courses

The Processor Architecture is the last course of the line and its methodology is very similar to the mentioned before. In the course, the students have only one project to be done during the entire semester. They have to develop the architecture, design and implementation of their own processor. During the proposal of the architecture, a playful activity is made (a play) in order to help the students understand the difference between hardware and software and do not end up designing both of them as hardware. A processor's simulator is also used so the student can practice the writing of programs using machine language. Each one of the blocks is analyzed in detail, and especially in the ALU there are proposed different implementation models. At the end of the course, teams must hand in their processors working and running a program chosen since the beginning of the course.

Signals And Systems

Signals and Systems is a third year course of Electronics and Electrical Engineering programs. This course is highly theoretical with high mathematical content, so the students have to deal with several concepts previously seen on the math courses. This combination makes even harder the student's learning process and gives an extra difficulty to recognize the possible applications of the new concepts presented in class (Cruz et al., 2015).

Several activities of Active Learning have taken place and have been implemented gradually (Cruz et al., 2013), many of which are inspired in teaching models used by Professor Eric Mazur (Fagen et al., 2002) of Harvard University. A model we have used is Peer Instruction (Fagen et al., 2002) (see Figure 6), but also we have used other tools and models that have been applied in accordance with cultural differences, technology available, budget and program needs (Cruz et al., 2013) (Cruz et al., 2015).

Figure 6. Active Learning in Class Using Peer Instruction Model.

Although at the beginning the students presented some reluctance and resistance to methodological changes, since they did not want to get out of their comfort zone, they wanted a change. The results of it have been highly satisfactory, with very good reviews and acceptance by students. It was also obtain significant improvements in their interest and motivation for the class and its activities, increasing attendance rates and even getting higher grades.

CONCLUSIONS AND FUTURE WORK

This paper provides examples of the application of active learning strategies in courses of Electronics Engineering at Pontificia Javeriana University under the CDIO approach. Active learning involve engineering students as active participants in their own learning. By using new strategies, such as, role-plays, case studies, oral presentations, problem based and project organized learning, students can easily transfer their knowledge to real life, especially in the engineering practice. The results have been highly satisfactory. Active learning activities improved teaching methods, including engaging students in the learning process. Students showed interest and motivation for the classes and their activities.

As future works, new pilots on different courses are being designed. Elements of Technology, Instrumentation and Electronic Measurements, Fundamental of Design, and Capstone Project are some of the selected courses to implement active learning methodologies. A new challenge is presented since some of these courses are already based on project learning, but are not used to develop non disciplinary abilities and therefore are separated from the CDIO approach. Another course that will keep experiencing changes is Introduction to Engineering since it is constantly evaluated to include new strategies that can provide even better results. A future change to the course is an annual implementation in which in the first semester students develop the theoretical design, and on the second semester they implement it.

REFERENCES

Bruff, D (2009). Teaching with classroom response systems: Creating active learning environments. John Wiley & Sons, 2009.

Crawley, E.F., Malmqvist, J., Östlund, S., Brodeur, D.R. & Edström, K. (2014). Rethinking Engineering Education. The CDIO Approach. Springer.

Cruz, J. Giraldo, J. Hurtado, J. (2013) Metodología alternativa para la enseñanza en ingeniería. Teledu 2013. Medellín. Colombia.

Cruz, J. Giraldo, J. Hurtado, J. (2015) Peer Instruction: Signals and Systems Class, A Case Of Study Proceedings of the 11th International CDIO Conference, Chengdu University of Information Technology. Chengdu, Sichuan, P.R. China, June 8-11, 2015.

Fagen, A. P., Crouch, C. H., & Mazur, E. (2002). Peer instruction: Results from a range of classrooms. *The Physics Teacher*, *40*(4), 206-209.

Giraldo, J., Cruz, J. Hurtado, J. (2014) Learning Through Challenges: Introducing Soft Skills To Freshman Engineering Students. Proceedings of the 10th International CDIO Conference, Universitat Politècnica de Catalunya, Barcelona, Spain.

BIOGRAPHICAL INFORMATION

Alejandra María González Correal, Ph.D. is an Assistant Professor in the Electronics Engineering Department at Pontificia Universidad Javeriana. Bogotá, Colombia.

Jairo Alberto Hurtado Londoño, Ph. D. is an Associate Professor at Pontificia Universidad Javeriana at Bogota, Colombia, at Electronics Department. He was Chair of Electronics Engineering Program and he has working in different projects to get a better process learning in his students.

Kristell Fadul Renneberg is a lecturer in the Electronics Engineering Department at Pontificia Universidad Javeriana. She also is an assistant to the Center for Learning and Teaching at the Faculty of Engineering.

Flor Ángela Bravo Sánchez is a PhD student in Engineering at Pontificia Universidad Javeriana. Bogotá, Colombia. Her current research focuses on Educational Robotics and Human-Robot Interaction.

Francisco Fernando Viveros Moreno is a Titular Professor in the Electronics Engineering Department at Pontificia Universidad Javeriana. Bogotá, Colombia.

Corresponding author

Dra. Alejandra González Correal
Calle 40 No. 5-50 Edificio No. 11.
Pontificia Universidad Javeriana
Bogotá, Colombia
agonzalez@javeriana.edu.co
Tel: +571 3208320 Ext. 5318