EMBRACING CDIO
DEVELOPING A MECHATRONICS LEARNING STUDIO

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ABSTRACT

The objective of this paper is to present the evolution of a learning studio that facilitates collaborative problem/project-based learning (PBL) for engineering students using a mechatronics platform. The paper presents a list of major activities that are included in the platform such as lab experiments, student projects, competitions, and outreach programs. The students were encouraged to consider the complete process structure of CDIO-based projects. Few examples of these projects are available as learning modules in the project websites: www.g9toengineering.com and www.greenengineers.ca. These modules can be used by future engineering students as a guideline for their projects. In addition, the modules are essential to strengthen the pipeline to high school education where they help link math and science to engineering. Also, the paper discusses the implementation of an interdisciplinary green mechatronics application as a platform for student competitions.

KEYWORDS

CDIO concept, mechatronics studio, student activities, play and learn.

INTRODUCTION

Mechatronics represents a system design approach in which mechanical, electronics and software components are tightly integrated and are seen to influence each other, and therefore have a design impact on each other and the system as a whole [1]. Mechatronics as an interdisciplinary field of engineering has been evolving over the last few decades. The development of mechatronics may be attributed to the rising number of applications and product development at the interfaces of traditional disciplinary boundaries within the broad areas of engineering [2, 3]. Specifically, it caters to the needs of a growing number of commercial products and industrial processes that involve the integrated use of mechanical and electronic components as well as control software in their design and development [4].

In education, mechatronics has emerged as an interdisciplinary engineering branch that spans mechanical engineering, electronics, microcontrollers/digital signal processing, controls, and information technology [5]. Another subject that mechatronics naturally serves as a vehicle for course material is mechanical design. Students can be taught traditional mechanical design techniques, such as planning tools, evaluation matrices, and functional decomposition through the use of mechatronics examples and projects [6].

In a multidisciplinary education context, project-based learning (PBL) appears as one of the most interesting instructional strategies. PBL differs from the typical lecture teaching where the instructor teaches fixed problems using common techniques. With PBL, the students' understanding of the material deepens by requiring them to apply the learned techniques to an open-ended task. The students get information on various aspects of a design as they progress in the project, such that it becomes easier to realize the connection between various subject areas [2].

It has also been observed that students using the teaching studio approach acquire a deeper understanding of the subject and obtain better grades than those students who use the more traditional approaches [7]. A typical studio session consists of a mixture of lectures, discussions, demonstrations, computer simulations, problem-solving activities, and projects supported by laboratory exercises. Studio pedagogy aims to develop professional skills for careers in industry and to explore technical challenges with an emphasis on PBL.

This paper describes one of the many activities going on in the area of mechatronics in Canada. There are many other Canadian institutions that offer mechatronics learning activities such as University of Waterloo, Waterloo, ON, Canada [8]; University of British Columbia, Vancouver, BC, Canada [9]; and McMaster University, Hamilton, ON, Canada [10]. At the heart of this initiative, mechatronics has been chosen as an effective platform of learning that helps engineering students from various disciplines interact with each other and with high school students to better understand fundamental math and science concepts and grasp the hidden connection between topics in engineering and as a result gain a better understanding of real life applications. We aim to establish a multi-faceted mechatronics learning studio that reflects the content of the curriculum and assists in developing projects that facilitate professor-student, and student-student interaction. The Mechatronics Learning Studio-initiative at the Faculty of Engineering, University of Ottawa provides a structure for learning, in which students are trained to think in a complete process structure instead of just being trained to solve certain specific problems. The studio-initiative proposes that teaching and learning can be based on a CDIO (Conceive-Design-Implement-and Operate) structure. Connected to this goal, a multi-faceted program of activities has been initiated that includes creation of design-simulate-and-build projects by engineering students as well as online learning platform (www.g9toengineering.com and www.greenengineers.ca) whereby engineering students connect with the community and especially high school students through the sharing of information about projects that they create in their engineering courses.

MECHATRONICS LEARNING PLATFORM

A model "Mechatronics Learning Studio" is in the development process to support teaching a number of mechanical and electrical engineering courses. The initial stage of the "Studio" targets teaching electronics to third-year mechanical engineering students. The main objectives of this initiative are: (1) to provide the students with a platform of knowledge to conceive, design, implement, and operate products that involve electronics, mechanical and software components; (2) to improve student competencies in teamwork, communication skills, and project management; and (3) to address the need of industry to have engineers educated in the important area of mechatronics. The following is a description of major activities that are included in the Studio:

Laboratory

This work-in-progress is focused on the integration of hands-on laboratory experiences with undergraduate electronics courses and electromechanical applications. A group of students is assigned to develop a few modules for the mechatronics engineering laboratory. These modules are based on: 1) a mix of high-level industrial controls with low-level, embedded systems, 2) a variety of modular sensors, usable and interchangeable, upon a pre-designed analysis system (such as evaluation boards, ready do be plugged in a serial interface), 3) supporting hardware and devices to evaluate, calibrate and measure the performance and preciseness of all systems, and 4) communication monitoring and evaluation, in order to compare and understand present and future trends.

Our plan for mechanical students taking the electronics course is to work on the analog control of simple electromechanical systems. By the end of the semester, students will progress to a more complex microprocessor-based mechatronics system. The exercises introduce the students to controlling components like lights and servomotors and to reading input from various sensors. Therefore, the experiments range from basic electronic circuits to a microprocessor controlled systems with multiple inputs and outputs. These experiments help students conceiving ideas and envisioning new systems for their proposed projects.

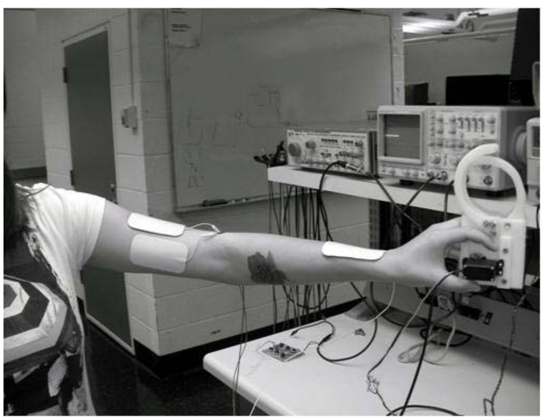
Course Projects

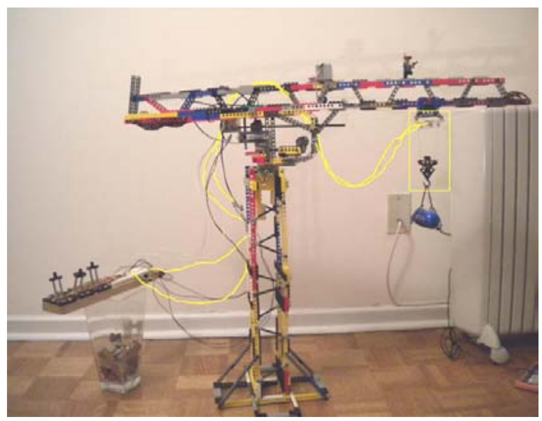
The inclusion of mechatronic projects benefits students, who are able to practice the design concepts that they have been taught, while forming a strong foundation in mechatronics principles. The projects are also rewarding, as they often afford the students their first opportunity to design and build a computer-controlled machine. However, the integration of mechatronics projects into the course poses significant challenges for the faculty [5].

At the Faculty of Engineering, projects are introduced into engineering courses in order to increase students' motivation, to provide a context for practical engineering skills, to encourage student teamwork and to integrate hand-on mechatronics in the educational program. Each student project requires the development of building blocks for the design of a mechatronics system. These projects involve teams of three students and require the purchase of components such as breadboards, sensors, motors, gears, controllers, and other accessories. The students define their project topics according to their own interests. The first author teaches electronics to third-year mechanical engineering students. Students taking this course are encouraged to form groups and pick a mechatronics project that can be successfully completed. It is unrealistic to expect students to immediately undertake a complex team-oriented design project. Therefore, the course contains laboratory experiments to expose the students to the design process and encourage teamwork and technical writing. Forming a solid understanding of technical communication at this point in the course will allow the students to better work and document the relatively complex machines that they will develop later.

Project guidelines, constraints, presentation format, research resources, and deadlines are clearly specified at the beginning of the semester. Students are encouraged to apply what they learned in lectures and labs. They are given access to many tools for use in the construction of their mechatronics devices. This process is supervised and judged by the instructor and teaching assistants. Often, impressive prototypes are realized (Figure 1). Documentation of several team projects is provided at: http://www.g9toengineering.com/MechatronicsStudio/main.htm.

CoinBot: Play and learn | Refreshment replenishing robot





Myoelectric controlled prosthetic hand | Mechatronics crane

Figure 1 Examples of student projects.

Competitions on Green Mechatronics

The competition is obviously extremely challenging for the students and as a result they spend much more time on the course than before. This is the key to deep learning as was stated already by R.W. Tyler in 1949 [11]: Learning takes place through the active behaviour of the student; it is what he does that he learns, not what the teacher does. A project with a challenging competition at the end makes students work. Teaching is about inspiring students to work actively with the course curriculum. Only by this kind of effort do they really learn [12].

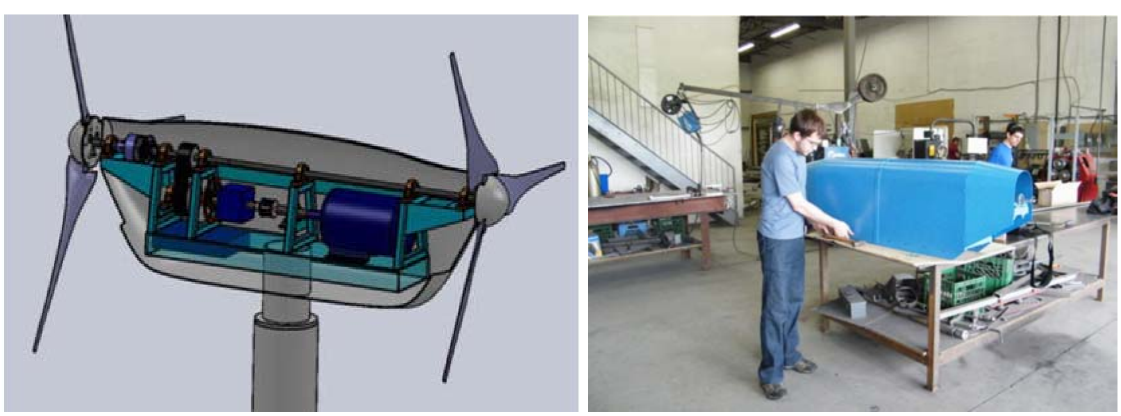
An exciting area of future mechatronics system development is the area of renewable energy production. There is an urgent need to accelerate the development of advanced energy technologies in order to address the global challenges of clean energy, climate change and sustainable development. This work-in-progress presents activities designed to create a synergy between mechatronics and renewable energy in order to disseminate knowledge related to the impact of renewable energy as part of the solution to achieve a sustainable future and economy for the society.

By embracing CDIO, a group of mechanical and electrical engineering students have formed a student activity called Green Engineers (www.greenenginees.ca). Currently, the group is engaged in an interdisciplinary green mechatronics multi-task project on wind energy with a future plan to expand their involvement in other types of renewable energy such as solar and biomass. An introductory video is available at YouTube: http://www.youtube.com/watch?v=wlf92In-kfk&feature=player_embedded. The group participated in a series of competitions. Usually, the students present their projects in a design review to a group of judges, the bulk of which are representatives from the industry. The student groups are judged on the originality and aesthetics of their design and the presentation of the system.

A major competition was partially funded by the Ontario Centres of Excellence (OCE) Connections Undergraduate Program aimed to design and develop an efficient dual-rotor wind turbine system (Figure 2). By itself, this project is a platform theme for many other student projects in diverse areas of engineering including mechanical, electrical, fluid, aerodynamics, control, and information technology. The students presented their comprehensive final project in May, 2010, first in Ottawa, and then in Toronto. Originally, 300 projects entered the competition, 71 of which were funded out of a special Ontario Power Authority (OPA) Energy Conservation Fund. Thirteen Universities and nine colleges from all over Ontario participated in the program, involving nearly 1500 students! The project topics ranged from engineering design, to mathematical modeling, to business planning, etc. 15 projects made it to the final phase of the Competition, and our group was the winner! In Ottawa, two judges from OCE and 50 students from various high school students in Ottawa region attended the first presentation on May 3, 2010.

A second team won the Elevator Pitch Competition which was organized by the Entrepreneurs Club at the Telfer School of Management, University of Ottawa: http://www.g9toengineering.com/GreenEngineering/Main.htm.

Another team won the People's Choice Award participated in Technology Venture Challenge (www.techvc.org). This three-phase competition is run by volunteers from the educational and business communities and is fully funded through sponsorship from leading businesses.



(a) (b)

Figure 2 Wind turbine generator (a) Computer model. (b) Prototype in machine shop.

OBSERVATION AND PEDAGOGICAL OUTCOMES

The Value to Engineering Students

As part of the studio initiative, the second author of this paper has been conducting research on the impact PBL on engineering students. At this point in the research, students in one of the engineering courses were invited to participate in an on-line survey about their experiences with PBL and a focus group interview with six engineering students was conducted. One of the survey questions asked students to identify what they learned through the project in their course. The question was an open-response item rather than selecting from a list and the data was coded according to themes. The two most frequent themes were that students were able to connect theory to practice and that the projects reinforced specific engineering knowledge. For instance, one student mentioned that:

> I learned that real life isn't entirely like the theory. As a group we had a lot of problems about integrating actual electronic components, I learned to deal with problems and solve them. So I can say the project, taught me problem solving skills, which I will encounter in my future career. Also, this project let me use my imagination and build a working project while keeping engineering matters in mind.

This quote also highlights other themes that emerged from the data such as building teamwork and problem solving skills. Similar themes were seen in the focus group interview. The students in the interview also emphasized that PBL gave them a strong sense of what working in engineering might be like so that they know what areas of engineering they might want to work in. Also, the project provided connections to the ideas that they learned in class, giving them a reason for the theory. They appreciated the project being given at the beginning of a course so that they had time to work on the project and connect the new theoretical learning to the practical and technical aspects of their project design. As one student claimed:

> [When given the project at the beginning] you have the time to think, and by thinking, you hit the wall, but then the course gives you the answer, instead of, after all the answers have been given to you, you have to find how they connect to your project.

The students in the interviews also talked about the value of the competitions as they find that it gives them the opportunity to learn new skills, such as listening and responding to clients and creating a project for a specific user.

High School Involvement

During the first week of May 2010, an enrichment 5-day course was provided to pre-high school students by our engineering students under the supervision of the first author. The course was based on the activities of the mechatronics studio including lectures, hands-on practical exercises, and visit to a micro hydro power station in Ottawa. This annual activity has been offered since 2002 [2]. For Grade 11 Biology class at All Saints Catholic High School, four engineering students were invited as guest speakers to talk about the discipline of biomedical engineering with emphasis on a mechatronics project "myoelectric controlled prosthetic hand". Details of the project are available at: http://www.g9toengineering.com/MechatronicsStudio/MyoelectricProsthesis.htm

Continuing Education

It is the duty of universities and other educational institutions to blend research knowledge with practical experience and spread the results through providing continuing engineering education. The authors and students with the assistance of the Centre of Continuing Education, University of Ottawa, have established a training program on green energy. The training program for 2010 includes one course for the public and a 5-day course for high school students (Grade 9 and 12) to be offered during the period August 9-13, 2010. Details of the training program are available at: http://win03.magma.ca/uoccevws/secure/english/coursedetails.cfm?cid=1177&pid=23.

Industry Involvement

Providing the resources necessary for a learning studio such as this one may be an expensive venture. Financial support for the project is coming from the University; however, significant support has come from industry sponsors in the form of technical support and donated materials. Projects mak it an opportunity for the students to become familiar with the sponsoring companies. In addition, representatives from the sponsoring companies attended many design review sessions. This provides a unique opportunity for both students and sponsors to establish relationships that may lead to summer internships, co-ops, and even permanent positions in the future. Another benefit is that the students see that industry is interested in their work, providing further motivation for the students to perform their best. It also allows the students to understand the propagation of mechatronics in industry, as reflected by industry interest in the projects.

Challenges

A major challenge of the learning studio is the lack of experience of most students in both design processes and the use of electronics and machine shop. To combat this, a series of lectures is dedicated to the basic use of the tools in the lab and machine shop. The material taught in lecture is then repeatedly reinforced during laboratory sessions.

A stated goal of the studio is to develop teamwork skills, and, as such, project work during the semester is completed in a group environment. This, however, leads to several challenges. First, the students tend to settle into comfortable positions within the groups, especially during the final project. Another challenge that the group work poses is in the grading of the students. The amount of group work often forces grade distributions to be fairly tight, making assignment of grades difficult. However, the final mark given to students depends on several tasks including design concept, completion of the task, group presentation, actual prototype and on-line visual demonstration.

CONCLUSION AND LESSONS LEARNED

The Faculty of Engineering of the University of Ottawa has embarked upon a mechatronics studio project to enhance mechatronics education. This project is funded by the University with cost-share from the Faculty of Engineering. By participating in mechatronics lab sessions, projects, and competitions, students gained experience in conceiving new research ideas and describing them in writing, in carrying out experimental work, in conducting data collection and analysis, in discussing and communicating with students and professors, and in preparing and presenting their findings to others. In addition, with online learning platform (www.g9toengineering.com and www.greenengineers.ca) engineering students can connect with the community and especially high school students through projects that they create in their classes. As engineering educators, we believe that if students carry out a research project of their own idea and design, they will better understand the practice of engineering. They will learn how to think critically, how to acquire strategies for problem solving, and master laboratory techniques. They would also realize the value importance of patience and determination in dealing with the unpredictable context of research and development. The mentorship opportunity that is provided to each student team with an approved project is really the essence of this educational program. In offering mentorship support to students, the mentor plays a vital role in the integration of a research experience into the students' education.

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