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Real-World Industry Collaboration within a Mechatronics Class

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Abstract – **This paper describes the implementation and assessment of an innovative senior/graduate level mechatronics (robotics) module that integrated structured and unstructured learning experiences, in collaboration with an industry partner. With real-world constraints and expectations, students designed and delivered a product as the final project. In fall 2007, the corporate partner provided state-of-the-art, programmable robotic kits with a user-friendly programming environment. The assigned project was to design a biomedical robot to work in a hospital intensive care unit (ICU) to perform tasks such as transporting supplies or delivering paperwork. Students with diverse skills and majors were grouped in ten teams, two to three students each. Student learning activities included designing a robot from a box of FisherTechnik materials, without the aid of instruction manuals; writing program code using the PCS environment; and integrating hardware and software. After four weeks of building, training, and testing, each team's robot was unique. In the final competition, each robot was assigned to a particular room in the ICU to perform a specific task. Overall, the results indicated that the students gained hands-on experience with the state-of-art technology and effectively applied the conceptual course content to a real application.**

Index Terms – Design and analysis of mechatronics systems, real-time problem solving skills, diverse teamwork impact, collaborative project-based learning.

INTRODUCTION

Effectively connecting classroom theory to workplace experiences can be challenging for both students and faculty. Due to constraints of covering extensive course content, there is often little time for engineering curricula to provide open-ended problem-solving experiences – where there's no "right answer," where students get frustrated and must reach beyond the textbook and ultimately partner with diverse colleagues to achieve a successful design. This article discusses a learning module developed in collaboration with an industry partner to enhance the students' research creativity and enable them to function as self-directed and collaborative learners. The project challenged students to use engineering communication, creativity, multi-disciplinary thinking, team dynamics and strong interpersonal skills, instead of solely concentrating on analytical and problem-solving methods [1]. Many research papers [2]-[3] discuss that creativity in engineering education is an essential component to create technological advances. Hence it is critical that we identify the factors associated with educational creativity in academic experiences [2].

The term "creativity" is increasingly recognized as an important engineering design element for industry. To foster creativity in engineering education, there is a trend among educators responsible for designing educational programs to strengthen the "design component" of engineering curricula [3]. A typical engineering curriculum teaches design process via faculty assigned projects that require the students to follow classical, well-proven methodologies covered in the textbooks or lectures. Infusion of authentic design activities in projects for senior/graduate level engineering students widens their knowledge and equips them for real world engineering work [2]. Also driving both curricular content and delivery methods are the Accreditation Board for Engineering and Technology (ABET) criteria. Now completely implemented across the country, ABET EC 2000 [4] mandates educational outcomes that include many so-called 'professional skills' such as communication, teamwork and awareness of the importance of societal issues in addition to the traditional analytical and design skills. Many engineering educators have seized on the many design opportunities throughout the curriculum as opportunities for students to learn and demonstrate the professionals' skills that support good design skills. The approach described in this paper is such an attempt.

In fall 2007, a module on robotics was developed for a senior/graduate level engineering course titled "ME 478/578 Design and Analysis of Mechatronics Systems" at Boise State University. This course combined emphases on creativity and design as a part of our design course and assessed how well students integrated design fundamentals into real product development. In effect, this module simulated a real-time internship environment within the classroom among students of diverse backgrounds.

Overall, the design project in collaboration with the industry was a joint venture. Not all universities have the resources to purchase the kind of equipment students used in this project. Creating an industry partnership enabled our students to be involved in this kind of open-ended project using state-of-the art equipment. At the same time, the industry partner gained real-time product evaluation,

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resulting in a win-win situation for both the university and the industry partner.

METHODOLOGY

I. Course Description

A mechatronics system is defined as an integration of mechanics with electronics (hardware) and information processing (software). This integration involves finding an optimal balance between the basic electromechanical structure, digital information processing and control, in which embedded computer systems play the "brain" role. The complex structure of a mechatronics system, with interactions among multiple engineering disciplines is described in Figure 1 [5]. The rapid pace of the development of components presents challenges for research in both industry and academia because design approaches must be constantly reevaluated.

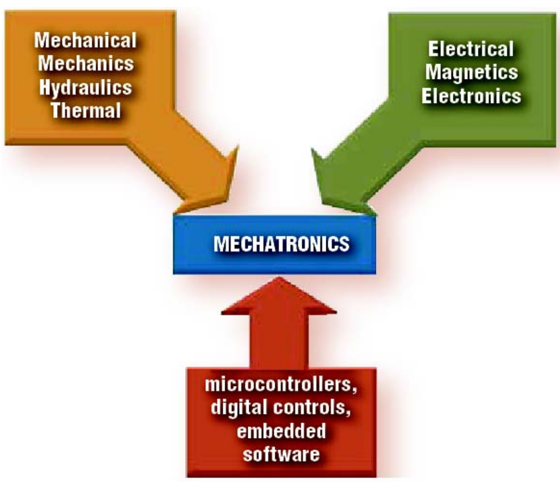

FIGURE 1
MECHATRONIC SYSTEM MODEL [5]

II. Design Project

Designing a complex mechatronics system leads to challenges in modeling and controlling the behavior of the system using digital communication. In the ME 478/578 class, lectures covered both the theory and application of mechatronics. During the first few weeks of class, students learned about various topics involved in a design process. Then, students engaged in five simple experiments designed to help them learn how to work with the electromechanical systems and communicate using embedded systems. Finally students engaged in a robotics project, "Biomedical Robot," for which the design required that students draw upon multiple engineering disciplines. This project simulated an internship environment within the class, as students had to design a robot to meet the needs specified by the industry partner, PCS Edventures Inc., an educational products company. The class (N=23) was divided into ten groups with two to three- member teams. Diverse teams were constructed; students were mixed by their majors (e.g. mechanical and electrical engineering students) and based on their level of industry experience. Some students were familiar with robotics while others were first timers.

Modeling the system involved strategies for electromechanical interactions and software validation. The client provided the students with a box of hundreds of Fishertechnik manipulatives, a PCSRC2 controller, and different sensors along with the company's software interface, which was a new work environment for the students. The company provided simple examples but no preconceived designs. The task for the groups was to design a unique robot with the materials in the box and connect the hardware and software so as to train the robot to perform the tasks of an ICU attendant. The robots were unique for each group, were trained to achieve different tasks, and were assigned to different patient rooms. The project was an open-ended and creative learning experience for students during which they were required to connect theory with industry-realistic, state-of-the-art technique. As their final deliverable, the students demonstrated their robotics design to the company representatives, who were involved in evaluating their work in terms of creativity of engineering design. This final demonstration was a student robotics competition at the end of the semester, during which each group trained their biomedical robot to do a particular pre-assigned task. Some robots were assigned to cheer up the patient with Christmas songs, and some were assigned to do simple tasks such as picking up or dropping off reports; all the robots were required to return to their docking station in a prescribed amount of time. Each robot was trained so that it would make no mistakes, such as entering the wrong room or bumping into walls or performing the wrong tasks. Students trained their robots such that there was ongoing checking and error correction. All of the final products designed by the students were successful. After the performance demonstrations, students conducted a drag race among the robots to demonstrate and compare the optimal weight ratio in design. Overall, the design project was relatively unusual because groups worked on different sets of assigned tasks for their robotics projects.

III. Assessment/Measuring Techniques

A survey at the end of the course measured the success of the module. The survey was designed and developed to measure student perception of learning outcomes based on their work on the final design project. The university's Institutional Review Board (IRB) approved the Human Subjects survey used to collect anonymous student responses. The students filled out the survey after their final product development. The survey was based on the learning objectives for the course, which were the development of skills in each of the following areas:

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- Problem solving
- Team interaction
- Hands-on experience with state-of-the-art technology
- Applying course content to real applications
- Real-world experience
- Improved academic performance

The questions of the survey are described below:

1. To what extent did this project improve your ability to tackle a new problem in a work place environment?
2. To what extent did this project improve your ability to interact productively with a set of diverse team members?
3. To what extent did this project increase your knowledge of skills of state-of-the-art technology?
4. To what extent did this project help understand basic course concepts?
5. To what extent did this project help you to understand basic concepts to real problem?
6. To what extent did this project help you to understand the complexity of the real-world problem?
7. To what extent did this project increase your ability to solve an open-ended problem in which many parameters are not well defined?

The survey utilized a four-point scale where 1–No Change, 2–Useful, 3–Gained Experience and 4–Greatly Improved. The survey also asked several open-ended questions, such as:

8. What was the "most valuable" part of the project with respect to how much you learned? Explain.
9. What was the "most valuable" part of the project with respect to how much you learned? Explain.

SURVEY RESULTS

Overall, the survey showed that this approach increased students' conceptual knowledge as well as their ability to address interdisciplinary challenges as if this were a real job. The responses of the students for all the survey questions (1-7) are summarized in Table I. According to the results, the project was effective with respective to all goals. Students recognized value on a variety of measures based on their positive responses to all questions. This suggests that simulating an internship experience by collaborating with an industry partner in a real-word design is perceived by students to effectively foster their learning. For each objective, about 5-10% of students noted that the project did not impact the skill. While we cannot be certain, this may be due to the fact that approximately 10% of the students had extensive industry experience and may have already had strong skills in each of these areas.

For purposes of analysis, student responses to each question were compiled to reflect the percentage of students who responded "3" and "4" on the survey, indicating the project was effective in increasing their skills. Figure 2 summarizes these results and clearly indicates the areas of greatest strength and areas in which improvements can be made to the project to better foster student-learning development.

TABLE I
INDUSTRY COLLOBORATION SURVEY RESULTS

N=23	No Change (%)	Useful (%)	Gained Experience (%)	Greatly Improved (%)
Q1	10	38	47	5
Q2	14	19	62	5
Q3	19	19	52	10
Q4	10	29	37	24
Q5	10	33	52	5
Q6	5	33	57	5
Q7	9	32	54	5

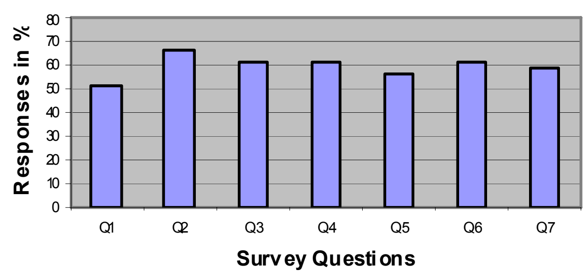

Figure 2
SURVEY RESULTS FOR SCALES 3 AND 4 COMBINED FOR Q1-Q7.

Just over 50% of the students rated the project as effective in increasing their ability to tackle a new problem in a work place environment (Q1). This is the lowest value for all the questions (see Figure 2). Similarly, student responses to Q5 (To what extent did this project help understand basic concepts to real problem?) were somewhat lower (57% found it effective) than for the other questions. While it is useful to know that many students saw the project as providing them valuable skills that will transfer to the workplace or to real problems, the results also suggest that more could be done to help students understand that even if their future work does not involve robot design specifically, the skills used in open-ended problem solving are

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transferrable to any workplace and that this project has all the features of a "real" problem.

Students had the strongest response to Q2 (To what extent did this project improve your ability to interact productively with a set of diverse team members?), where 67% of the students indicated the project was effective at increasing their skills. This implies that engineering students gained experience from interdisciplinary group work, which is relevant to real world work environments. Teams with diverse backgrounds worked together to accomplish a common goal, in which they share their knowledge and best talents and function synergistically [6].

Student had similar responses to Q3 and Q4 (To what extent did this project increase your knowledge of skills of state-of-the-art technology? and To what extent did this project help understand basic course concepts?), with 62% and 61% of students responding that the project was effective at increasing their skills, respectively. These results imply that engineering students gained experience with real-time, hands-on projects in which they applied their engineering knowledge to product development. To improve student perception of their learning even further, in future offerings, assignments will be modified slightly to help students explicitly reflect on the connection between the course content and the project.

The results for Q6 (To what extent did this project help understand the complexity of the real world problem?) indicate that 62% of the students found the project effective. As indicated earlier, some students in the course brought significant work experience. Anecdotally, it appeared that groups with experienced students contributed to their team's troubleshooting more effectively compared to other groups. This kind of dynamic may be useful in future offerings of the course, if the experience of these students can be used to help other group members see how this assignment is indicative of the kind of problem complexity they will encounter in the work place.

Figure 2 shows the results of Q7 (To what extent did this project increase your ability to solve an open-ended problem in which many parameters are not well defined?), with 59% of students responding positively (gained experience and greatly improved). This illustrates that engineering students at this level of program benefit from open-ended problems to prepare them for industry work. However, for those students who were less likely to recognize the project as effective with respect to their learning of this outcome, it may be that raising the level of the challenge will be helpful. Alternatively, it may be that students need to be supported to reflect upon how their individual problem solving skills have advanced as a result of the project.

In this module many parameters were open-ended, allowing students to design the robots using their individual creativity, which was unique for each person and team. This gave experience to students in which they tackled the handshaking barriers between the software and hardware system. Controlling the real time motion was a challenge in which students were exposed to various constraints of the project, leading them to develop valuable brainstorming techniques and problem solving methodologies. Eventually, after a few struggles, students completed the activity with a unique solution for their algorithm for controlling the robot actions. This was a good exercise for the students to understand the theories and procedures learned in class and transfer them to the design of the project.

Keeping the objectives in mind, the survey helps us understand the degree of changes required to improve curriculum for levels of development, delivery and assessment. While successful overall, the survey results highlight that there is still room in the project design to enrich and broaden engineering education to improve the quality and make the learning experience more meaningful and challenging for students [7]-[8].

CONCLUSIONS

For more than a decade, engineering education leaders have been strongly urged to transform methods of teaching and make changes to the curriculum to address more complex, open-ended problems. Our curriculum development approach needs to explicitly link student awareness of their own learning and pedagogy, faculty goals for the course and industry demands. The assessment of learning outcomes for the robotics module was based on the end-of-semester survey, designed to assess the quality of the educational experience. Examination of student perceptions shows that it is advantageous to include open-ended, unstructured problems in engineering education. The authors recommend that the assessment methods utilized in this class can be formally or informally adopted to facilitate teaching aimed at enhancing student development. Periodically assessing student learning can then lead to ongoing improvement of student independence and creativity.

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