Towards a Multi-disciplinary, Project-Based Mechatronics Curriculum

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Abstract
In the past year, a joint effort between the mechanical and electrical engineering departments at TTU has focused on creating and implementing a curriculum designed to strengthen the mechatronics experience for engineering students at Tennessee Technological University (TTU). This effort, along with the support of NSF, has led to the implementation of the a true collaborative, project-oriented course combining students in both the mechanical and electrical engineering departments as well as faculty from the two departments. This collaborative effort was implemented with an eye on providing the students with an appropriate experience in design, development, and realization of mechatronics systems for practical applications. This paper will describe the project in detail, discussing the goals of the project in the context of appropriate background and motivations. The approach employed to implement the course will also be discussed. Outcomes and assessments of the initial implementation are presented, with a report on the results. Finally, the implications of these assessments and future directions for the course and curriculum will be presented.

1. Introduction:
In the past year, a joint effort between the mechanical and electrical engineering departments at TTU has focused on creating and implementing a curriculum designed to strengthen the mechatronics experience for engineering students at TTU. The goal of this effort was to create the instructional curriculum and laboratory resources to support a truly multidisciplinary, project-based experience for engineering students in the area of
mechatronics. The merits of the mechatronics experience have been demonstrated by many sources [1-3].

Mechatronics is a contemporary approach that is based on integrating the many technologies and various engineering skills available in realizing smart products [11]. This is why many engineering schools have organized curricula to offer instruction in this area or even grant a degree in Mechatronics (e.g., University of Utah). TTU has followed suit initiating a mechatronics program in the mechanical engineering department in 1997. This program provided the opportunity for mechanical engineering students to obtain skills mechatronic system design and basic application of micro-controllers. This program was fashioned after the general approaches used at many other schools. While successful in providing the mechanical engineering (ME) students with knowledge about mechatronic system design, this curriculum did not provide students with the proper interdisciplinary platform to integrate this knowledge in a systematic, interdisciplinary and team-oriented, engineering experience. A natural platform to promote such integration is afforded through the joint effort at TTU between the mechanical and electrical and computer engineering (ECE) departments. This initially began with an area of concentration in mechatronics offered to engineering students in both departments, and taught collaboratively. While the constitutive elements of mechatronics are not new, methods and ideas for integrating those elements with a multi-disciplinary environment are appealing and timely. There are many issues that arise in bringing students together at a senior level course, such as their diverse backgrounds and course objectives. These issues are challenging to the course but prove to be assets when combined in the laboratory and associated project-based experiences. The laboratory experience provides a central point of common interests between the ME and ECE departments, and provides a platform through which a curriculum can be created to provide mechatronics-based learning in a true multidisciplinary environment. The goals and objectives, and resulting approach to this multidisciplinary effort are discussed in the following sections.

2. Goals and Objectives

The overall goal of this effort is to bring students from the ME and ECE disciplines to a project-oriented, hands-on training experience in a research and development lab environment. This opportunity offers them a chance to integrate electrical, digital and mechanical systems into mechatronic systems [4]. Therefore, the long-term goal of this project is to enhance the ME and ECE curricula to produce graduates who are able to,

1. integrate diverse areas of knowledge in engineering in solving technical problems,
2. participate successfully in multidisciplinary teams,
3. understand the product design and development cycle,
4. learn the basic skills of leadership.

These goals will be addressed in creating an interdisciplinary class and laboratory experience at the senior level. The defined objectives for this class are to,

1. provide a learning environment that promotes hands-on, interdisciplinary, team-work experience among students
2. create an environment in which contemporary process learning concepts are practiced in delivery of information and in allowing students to take more responsibility in their learning;

3. enhance team-work and interpersonal skills among students by requiring group participation in various roles.

These objectives were implemented using the strategies defined in the next section.

3. Approach

This section will describe development of the combined mechatronics course curriculum and detail the role of the laboratory in this curriculum. The course is designed as a first course in mechatronics, for both mechanical and electrical engineering students; introducing the students to the design of integrated mechatronic systems with embedded microprocessor control. This course is taught at the senior level and is offered as a technical elective in both ME and ECE departments. The course was structured to contain four basic parts, lecture-based course instruction with laboratory units [5], student-directed course study, student/teacher driven application learning, and project-oriented learning. This four-phase approach was used to encompass the multiple goals of the course curriculum and to target the various learning styles needed to achieve each of these goals. These components are described in the following sections:

a. Lecture-based course instruction:

A traditional lecture-based instruction approach was used during the first quarter of the class. This approach was selected to cover a large amount of basic material in a general review fashion. The content began with an introduction to mechatronics and mechatronic system design, and then proceeded with review of the engineering components that go into mechatronic systems. Here, the class was then divided with the ME students reviewing the basics of electrical circuits, electronic systems interfacing, and the ECE students covering basic mechanical system synthesis, modeling and design. During this first phase, 4 lab instructional units were included for both the ME and ECE students. For example one of the labs for the ECE students involved gear system modeling and analysis, motor power testing, and efficiency determination of a geared DC servomotor. An example lab for the ME students involved utilization of simple transistor circuits in driving DC motors.

b. Student-directed study:

The second phase of the course provided the students with a brief period of student-directed course study. In this phase, the ME and ECE students were brought together (and remained together for the remainder of the course) to complete a simple mid-term project. The project required the student’s to incorporate sensors and actuators in a system combined with digital logic. Along with the project, basic proficiency of digital logic design was tested for the students. The students worked in teams to study and prepare the project, but were tested individually. Students were responsible for their rate
of learning, with a deadline given to finish this phase. This phase was completed at the midterm.

Faculty-led instruction:
The third phase of the course covered basic instruction in the use of the Motorola 68HC12, the micro-controller unit (MCU) implemented in this course. This phase of the course consisted of an overview of the MCU followed by a series of small modules covering each of the functionalities of the HC12. Each module contained a brief overview, an example program, and a specific assignment to be completed before moving to the next module. The faculty gave a brief introduction to the topic during lecture time leaving the students to work on the assignments of these modules in small groups. The instructors were available to answer questions and offer support to the students. This phase covered the third quarter of the course.

Project-driven learning:
The final phase of the course was the term project. This project was introduced at the beginning of the course and was designed to require the students to draw together the various areas of the course in a single application. Students worked on the project in teams of four, with each team having at least one mechanical and one electrical engineering student. During this last phase, the class time involved student-led discussion of issues in their design projects, laboratory testing and design, and review of various sensors and actuators. In addition, class time was given to the students to meet in their teams and work on the projects. The projects culminated at the end of the course in a demonstration. The significance of the projects attracted many engineering students outside of the class. The demonstration gave the students the chance to present their designs to the instructors and interested viewers, as well as the opportunity to have their projects evaluated against the design specifications and other projects in the class [6-9].

These four sections provided a significant diversity in the course, appealing to the various backgrounds of the students in the course while providing a means to cover a large variety of material. It provided multiple opportunities for the students to work together as teams, completing labs, performing the intermediate and final project, and in teaming to learn implementation of the MCU. Due to the nature of the laboratory, with fixed lab stations, lab kits and lockable storage areas, the groups that were formed at the beginning of the class continued to work together throughout the course. In addition, this four-part course structure required care to be taken in creating a new grading structure, and to keep the students up to pace in each the four phases, particularly the student directed phases (2 and 4).

4. Project Assessment
The mechatronics course has been taught at the ME department for three years before the start of this collaborative effort with the ECE department. The class was offered in its
new format, as described in the previous section, starting in the spring of 2000. The new format and objectives of the course were advertised to the students, of both ME and ECE departments, via various mechanisms including flyers and direct contact with the students via email and faculty advisors. Enrollment in the class substantially exceeded the expectations of the instructors, indicating a strong interest on the part of the students. The number of students attending the course from both departments was 35 for the first offering and 40 for the second offering. The makeup of the students in the course was approximately at a ratio of 3:1 with majority of students from ME department. Several factors affect this makeup including the fact that the class was listed in the ECE department as a special class and it was a relatively new offering in the ECE department.

Assessment of the current state of project effectiveness was performed by three diverse parties, with the results combined to yield an overall evaluation model [10]. These parties were students, responding to evaluations and course survey, the course organizers providing an internal review, and an industrial advisory panel performing an external review. The assessment focused on the course four-phase course structure, the multidisciplinary experience, and the integral role of the laboratory in the curriculum.

**Student Assessment:**

A survey was conducted at the end of the class to assess student perceptions in success of the overall course as well as the effectiveness of each individual phase. Table I below gives a summary of some of the important survey questions and their results.

<table>
<thead>
<tr>
<th>Question</th>
<th>Student Response</th>
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<tbody>
<tr>
<td>1 Have your expectations from the Mechatronics course been satisfied?</td>
<td>Satisfied: 70%</td>
</tr>
<tr>
<td></td>
<td>Not Satisfied: 15%</td>
</tr>
<tr>
<td></td>
<td>No response: 15%</td>
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<td>2 In your opinion, which of the learning methods utilized in this class</td>
<td>Traditional: 3%</td>
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<td></td>
<td>Teacher guided: 50%</td>
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<td></td>
<td>Student guided in projects: 35%</td>
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<td></td>
<td>Combination of all: 12%</td>
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<tr>
<td>3 How would you rate your interdisciplinary group experience in the</td>
<td>Favor: 88%</td>
</tr>
<tr>
<td>course?</td>
<td>Don’t favor: 9%</td>
</tr>
<tr>
<td></td>
<td>No response: 3%</td>
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<tr>
<td>4 As a result of you taking this course, have your team skills improved?</td>
<td>Yes: 81%</td>
</tr>
<tr>
<td></td>
<td>No: 13%</td>
</tr>
<tr>
<td></td>
<td>Don’t know: 6%</td>
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<tr>
<td>5 Do you think the project was an essential component to your learning</td>
<td>Yes: 94%</td>
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<td>experience in the course?</td>
<td>No: 6%</td>
</tr>
<tr>
<td>6 How would you judge the overall learning experience in the course?</td>
<td>Favorable: 88%</td>
</tr>
<tr>
<td></td>
<td>Not favorable: 12%</td>
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Course Organizers Assessment:

The assessment of the course organizers who were involved in basic development of the course considers the actual outcomes of the course with respect to expected outcomes. These observations can be summarized in the following points:

1. Teaching the mechatronics course collaboratively between ME and ECE students presents significant issues. In particular, the ECE students tend to initially be much more comfortable with the information, and generally take the lead roles in any group activity. In many cases, the ECE students play a teaching role in the group. This teaching from ECE to ME student is not clearly represented in the course layout, but may account for a significant portion of the learning by the ME students. Conversely, this effect does not seem to be reciprocal. It was noted that by the end of the course, ME and ECE students were equally sharing group leadership roles. However, the ME students never had the opportunity to act as teachers to the ECE students. The outcome of this observation is of concern, it probably affects ECE enrollment in the course and affects the ECE faculty acceptance and support of the course. If a long term, truly multidisciplinary class is to be taught in mechatronics, this issue must be addressed. Currently, one consideration is to move the multidisciplinary class from a
first time to second course in mechatronics. An alternative approach is to emphasize teaming only at the lab and project level and increase the mechanical design component in the project.

2. The interdisciplinary group experience was highly favored by both students and the industrial review panel. Group interaction between various disciplines resulted in a more definitive role selection by the group members, and a much higher level of knowledge transfer than was expected.

3. The design project provided a significant amount of motivation and a realistic environment for the design and development process. Difficulties arise in assessing and grading the diverse results of the design project. These can be addressed in part by regular design reviews by the instructors and by clearly stating the design evaluation process.

4. A significant level of failed design projects occurred because just one of the several subsystems that went into the design failed. This course may provide students the first opportunity to work on a system in which they truly depend on contributions from each individual, and collaboration of the overall group.

5. Another positive outcome of the mechatronics course was students moving into industrial positions based on experience from this course, with both students and employers showing interest in the class experience. An additional outcome is partnering with middle school students to get a comprehensive view of engineering through a design project in a single course.

Assessment of Industrial Review Panel:

The intention of the instructors is to form an external industrial review committee formed from local industry performed a review of this project. This committee would review the curriculum, laboratory, and student outcomes (through exams and projects) and respond to a survey. A summary of the survey questions is presented in Table II. Due to some logistical problems, the attendance of the advisory board to project presentation was lower than expected. Thus, although the assessment was generally positive, it will not be reported at this time.

Table II: Summary of Industrial Panel Survey and Response

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5. Results and Conclusions

The initial implementation of a jointly-taught mechatronics course at TTU has proven successful in student interest and response, as well as industrial support. The combination of joint-discipline teaching with a varied teaching approach has proven challenging, but also provided the mechanism to achieve the objectives of teaching a new, large subject while emphasizing interdisciplinary teaming, integrating diverse areas of knowledge, and learning the design and development cycle through example. The course had many positive outcomes, some expected and some unexpected. Expected outcomes include the desire of students to direct their own learning, the interest of industry in practical, teaming projects, and the difficulty in assessing open-ended design projects. Unexpected outcomes involve both the degree of unplanned student learning from ECE to ME students, and the difficulties in ensuring the course value to EE faculty and students.

A summary of the survey results for the students is presented in Table 1 and Figures 1-2. Examining these results, several conclusions can be drawn:

1- In its current format the course has achieved to a great extent the objectives of improving the interdisciplinary teamwork skills of the students.

2- Among the various learning strategies used in the course, the teacher guided learning was the highest rated by students. The big surprise came from the low rating the students have given to the traditional lecture method. The traditional lecture is the method mostly used in both ME and ECE departments to teach other courses including courses with major design objectives. Further investigation of this discovery is warranted as it may help reshape the teaching philosophy in both departments.

3- Although the project came in second as the preferred learning method, the students, in another survey question, emphasized the importance of the project as part of their learning experience in the course.

4- The main issues to address in the future are how to create a reciprocal and equal transfer of knowledge between ME and ECE students and how to increase the level of acceptance of the mechatronics curriculum among the more traditional ECE faculty and students?

References


