OUTCOMES-BASED ASSESSMENT FOR COMPREHENSIVE CURRICULUM DEVELOPMENT IN MECHATRONICS

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Abstract ¾ *This paper describes a comprehensive assessment plan that was carried out as part of an NSF-funded effort to integrate principles of Mechatronics throughout the Mechanical and Electrical Engineering curricula at the University of Detroit Mercy. The Project team consists of faculty members from three departments: Electrical and Computer Engineering, Mechanical Engineering, and Education. Our focus here is a description of how the assessment results have been used to refine one curricular component of the Project, the senior-level course in Mechatronics. We present an overview of the Project, a summary of the assessment framework, initial results of the formative assessment of the Mechatronics course, and an evolving model of outcomes-based curriculum development.*

Index Terms — *Assessment, curriculum development mechatronics, multidisciplinary teams.*

MECHATRONICS CURRICULUM DEVELOPMENT INITIATIVE-OVERVIEW

The purpose of *Mechatronics: A Comprehensive Interdisciplinary Curriculum Development Initiative*, an NSF-funded CCLI grant is to create an across the curriculum, industrially relevant approach to mechatronics in the mechanical and electrical engineering curricula at the University of Detroit Mercy. The Project addresses this purpose through activities designed to meet four goals:

1. Address industry need for mechatronics-trained engineers.
2. Improve student competence in communication, teamwork, and project management.
3. Increase participation of women and underrepresented minorities in engineering.
4. Cultivate interest in lifelong learning in practicing engineers.

A number of Project components address these goals at various curricular levels. The major component of the Project is the development of a new, senior-level Mechatronics course, which features a capstone design project that integrates course content with practice. The modifications made to this course based on the initial assessment results are addressed in this paper. In addition, a four-week mechatronics project (robot design) was included in two of the four sections of the freshman-level introductory course. In the Principles of Electrical Engineering course for non-EE majors, students completed laboratory activities centered on sensors, actuators, and microcontrollers. At the pre-college level, we have implemented an 18-hour course based on mechatronics components for Detroit area high school juniors and seniors. We have also conducted mechatronics design activities as part of a Summer Design Institute for high school girls. In the design of the curriculum for all the components noted, a deliberate emphasis was placed on the development of explicit student learning outcomes. The eight ABET Engineering 2000 criteria guided the formulation of the outcomes for students in each of the Project's curriculum initiatives. Details concerning the content of various Project components and activities can be found elsewhere [1-4].

ASSESSMENT PLAN

The paper focus on the results of the formative assessment efforts of Project activities related to curriculum improvement, specifically in the senior-level Mechatronics course. That the curriculum revision efforts are situated within the larger framework of the Project’s assessment plan is important to understanding the comprehensive approach that was used to guide assessment efforts. The assessment plan for *Mechatronics: A Comprehensive Interdisciplinary Curriculum Development Initiative* was designed to provide a means for assessing the impact of Project activities related to each of four goals targeted by the Project, as noted above. Multiple assessment strategies were used within an evaluation framework having both formative and summative components.

The formative evaluation facilitates continuous improvement in each of the activities by providing a vehicle for immediate and ongoing feedback about the success of Project strategies, so that these strategies can be modified for the next implementation cycle. This component of the evaluation determines the degree to which the “across the

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Table 1. Linkage of implementation strategies to assessment strategies and sources of data.

Implementation Strategy	Assessment Strategy	Data Sources/Assessment Instruments
Goal 1: Address industry need for mechatronics-trained engineers. Design and implement a course in mechatronics in the sequence of courses in undergraduate engineering programs. Design and implement mechatronics-related activities/projects into service courses.	Generate curriculum assessment criteria from mechatronics literature and expertise of partners from industry as well as instructors. Reviewers examine curricular components (courses, design projects, and activities) and evaluate the components for relevance to industry against selected criteria. Review fit of instructional strategies to course outcomes. Monitor interest, achievement, and motivation of students throughout course.	List of criteria used as checklist Observation checklist Grade reports Interview schedule End of course evaluations by students Observation records of use of specified skills Quiz, project, & final exams grades Exit skills checklist
Goal 2: Improve student competence in communication, teamwork, and project management. With industry partners, specify student learning outcomes in the areas of communication, teamwork, and project management. Develop industrially relevant activities/projects with industry partners. Incorporate learning experiences into the newly designed courses/projects that lead to the development of stated outcomes.	Observe students using new materials and participating in redesigned activities. Monitor student grades as measures of attainment of outcomes. Interview students who use new materials or participate in new activities and projects. Determine students' perceptions of value of new learning experiences. Monitor development of students' skills during courses. Assess exit skill levels of students who participate in new learning experiences.	Observation checklist Grade reports Interview schedule Survey Observation records of use of specified skills Quiz grades Final exams, projects Exit skills checklist
Goal 3: Increase participation of women and underrepresented minorities in engineering. Design and implement a mechatronics component into the existing curriculum of the pre-college experience (Detroit Area Pre-College Engineering Program—DAPCEP). Design and implement a mechatronics design activity in a Summer Design Institute for Women, aimed at high school girls.	Compare interest levels to previous years when precollege course was offered without the mechatronics component.	Surveys of students' intentions to pursue engineering-related careers, and their assessment of activities. Records of previous student interest Retention rates

curriculum, industrially relevant" approach to mechatronics is implemented, and the impact of each Project activity on specified student learning outcomes. At the end of the project period, summative evaluation will answer the question, "How effective were Project initiatives in addressing the goals?" This component of the evaluation will be based on cumulative findings in all areas, and will determine the overall impact, including intended and unintended outcomes, of the Project.

Although this paper focuses on the senior-level course related to the Project's first goal, all activities in the Project are interrelated. These connections are displayed in Table 1, which displays three of the four Project goals along with the strategies used to implement the goals, and the strategies and instruments used to assess the effectiveness of Project activities. (Activities related to the fourth goal have not yet been implemented.)

USE OF ASSESSMENT RESULTS

The discussion that follows focuses on those aspects of the assessment plan addressing the newly designed Mechatronics course. Formative evaluation of the Mechatronics course began during the design of the course components and activities for field testing, and is ongoing. The design of the Mechatronics course had at its foundation the information that was collected concerning the mechatronics-related knowledge and skills needed by practicing engineers. To gather this information, the instructors compiled an initial listing based on their own experiences in industry, as well as trends in the literature. This list was reviewed by a panel of practicing engineers for relevance to contemporary industrial settings. Using this revised document, the instructors formulated course outcomes and course content for the Mechatronics course, as well as proposed strategies for teaching the content and achieving the course outcomes. The course was field tested in the Winter 1999 semester, during which time the formative assessment began. Revision of content and instructional strategies continued in the following semester so that the redesigned course could be implemented in the Winter 2000 semester.

During the pilot testing of the course, Project team members met periodically to review the findings from the various assessments. The following sources of data were used:

- Student work, including quizzes, exams, projects
- End of course evaluations by students
- In-class observations of students conducted by instructors

Changes in Course Design

Results from the assessment were used to modify both course content, and the development of that content within the course. Thus, both curricular and instructional aspects were addressed.

In general, the results from the assessment process indicated that students would benefit from explicitly stated outcomes in all coursework, including projects, and class activities such as group work. Therefore, changes were made in course content, the syllabus, and assignments to reflect the need for greater specificity. The instructors themselves had clear expectations of the content to be addressed in the course. By adding a clear delineation of what *students* should know and be able to do at the end of the course, the instructors created a means for assessing the degree to which each course outcome was achieved by each student.

The pilot version of the Mechatronics course was designed with the third ABET criterion, concerning program outcomes and assessment, as a guideline. This criterion describes desired abilities for students in the areas of technical knowledge and skill, teamwork, and communication, and therefore, provided a foundation for the specification of outcomes for the Mechatronics course.

Analysis of data concerning student performance in the pilot course revealed that, although students had generally mastered the course content, much time was spent during the course clarifying, re-explaining, and providing more detail concerning instructors' expectations for student work. Consequently, the instructors revised outcomes for each assignment and project. The purpose of this revision process was to create outcomes that would provide useful guidelines and benchmarks for students as they progressed through the course. Examples of revisions of the outcomes of each component of the course follow.

Content

- Provide clear guidelines for all work. The instructors found that students were often uncertain about what precisely was expected of them in assignments and projects. For example, in writing the final project report, it was evident that the students needed clearer guidelines as to the nature and structure of the information required. For oral presentations, students were given more detailed criteria for evaluation. For example, the number of points assigned to various aspects of the presentation, e.g., clarity, effective use of visual aids, eye contact, etc., were given to students in advance, so that they knew what was expected.
- Refocus outcomes to include those that challenge students to use higher order thinking skills. For example, in a laboratory that focused on distance measurement using an ultrasound sensor, students were

expected to explain the effect of a 1 ms time resolution limitation on the accuracy of a measurement.

- Reformulate outcomes related to team skills. In the first offering of the course, the instructors encountered some problematic team dynamics. They found it helpful to provide student teams with guidelines to help them achieve a fair distribution of responsibilities among team members. For example, all reports for team projects required a section that explained the individual contributions to the project. Major disparities in assumed responsibilities was reflected in individual grades for that project.
- Re-order presentation of some theoretical and practical aspects of course content. The instructors received student feedback from the initial offering of the course that it would be helpful to better integrate theoretical concepts with the end-of-term project. For example, in the Winter 2000 offering of the course, a general theoretical discussion of sensors was supplemented by a practical discussion of the actual sensor to be used in the final project.

Activities

- Monitor student group work more closely. Because of the problematic team dynamics mentioned above, the instructors wanted to better ensure individual accountability for all students. To achieve this, they added more detailed expectations for the final project's action plan. The action plan required a team presentation, and instructors provided feedback to help the teams take corrective action early in the project.
- Make laboratory activities relate more closely to the mini-capstone project. Student feedback from the first offering of the course indicated an interest in having the laboratory activities linked to the final project requirements. The second offering of the course included two new activities. The LabVIEW exercise of the previous year involved measurements using a strain gage. This was replaced by a distance measurement laboratory using the actual ultrasound sensor to be used in the final project, still using LabVIEW. A laboratory addressing microcontrollers, sensors, and actuators, using the Stamp II microcontroller, the servo motors and the ultrasound sensor, all actual components in the final project, was developed. To make room for this activity, the instructors had to drop a simulation laboratory exercise.

While the above discussion specifically addresses the improvements made to the new Mechatronics course, some of the changes also pertain to other Project components. For example, monitoring group work to ensure accountability is something that carries over to all courses, since they all involve team-oriented activities. One important change in the pre-college mechatronics course was to limit enrollment so that the maximum team size is three students. Reformulating assignments to clearly communicate faculty expectations of learning outcomes is also integral to all of the Project components.

A MODEL FOR OUTCOMES-BASED ASSESSMENT

Given the curricular focus of the Project, these assessment efforts can provide a means for examining the use of ABET criteria as guidelines for outcome-based programs. The Mechatronics Curriculum Development Initiative was designed to address specific areas within the eight ABET Engineering Criteria 2000 [5], namely:

- *Criterion 1. Students*. Monitoring of students
- *Criterion 2. Program Educational Objectives*. Periodic determination and evaluation of objectives; curriculum that ensures the achievement of stated program objectives; ongoing evaluation that use results to improve the effectiveness of the program
- *Criterion 3. Program Outcomes and Assessment*. Students demonstrate the ability to: apply knowledge; design and conduct experiments; design systems, components and processes to meets desired needs; function on multidisciplinary teams; identify, formulate, and solve engineering problems; communicate effectively, use techniques, skills, and modern engineering tools necessary for engineering practice.

Instructors, as well as students, benefit from explicit outcomes for courses, assignments, and projects. When clear and specific outcomes are used, not only are instructors able to focus their instruction on specific knowledge, but they also able to link their assessment of this knowledge directly to these outcomes. Given clear descriptions of what they will accomplish in a course, students can have a more complete picture of the knowledge for which they will be responsible, and how their skills in specific areas of knowledge will be assessed.

Ensuring that program objectives are met through a series of courses demands continuous review of the fit between program objectives and course outcomes. The ABET criteria provide a useful source of benchmarks and a starting point for both program assessment and course assessment designed to maintain the effectiveness of a program.

The assessment strategies used in the Project focused attention on the acquisition and use of mechatronics-related awareness, knowledge and skills as practitioners in an industrial setting might apply them. We are confident that the next few cycles of assessment will result in further improvements in the effectiveness of the Project components in preparing engineers to work in mechatronics-related areas.

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