Using "System Sensing" During the Implementation of a New Mechatronics Engineering Curriculum

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ABSTRACT

"System sensing" [1], or a feedback loop, has been integrated into the implementation of a new mechatronics engineering curriculum at the University of Canterbury through a sustained, three-year collaboration between engineering lecturers and academic developers. Data were collected each year from the first cohort of students and lecturers through focus groups, course evaluations, specifically designed surveys, and observations. The data were analysed by the academic developers and results and recommendations were fed back to the engineering lecturers so that they could adjust the curriculum, the teaching and the assessments to better meet the goals they had in mind when designing the new curriculum such as: students engaged in significant design projects at every year and a strong connection with industry [2]. Positive outcomes from this approach included statements by mechatronics graduates that they had obtained core skill sets in both mechanical and electrical instead of an initial lack of identity as "neither mechanical nor electrical."

Keywords: Academic Development, Curriculum Development, Engineering Education, Mechatronics Education.

INTRODUCTION

The mechatronics engineering professional programme was started at the University of Canterbury in 2003, with a limited intake of 15 students. All students in engineering take common courses in physics, mathematics, engineering mechanics, foundations of engineering and mathematical modelling in the first (intermediate) year and specialize in the following three years (1st, 2nd, and 3rd professional years), leading to a BE (Hons) degree. Mechatronics, as a hybrid pathway between mechanical and electrical engineering, faced challenges in the development of the curriculum for these three professional years.

Originally, the mechatronics programme combined essential and existing topics from mechanical engineering, electronics, and computer engineering and was essentially a combination of relevant courses offered in the departments of Mechanical Engineering and Electrical Engineering. There was, however, a lack of coherence and a systemic approach in delivering the "synergistic integration of the three components – mechanical engineering, electronics, and computer control," which is supposed to be the cornerstone of mechatronics. As a result, several challenges soon surfaced:

- Students lacked formal prerequisites for some classes. Consequently they had limited choices for electives as their study progresses.
- A lack of laboratories and design projects led to a focus on teaching from the textbook, leaving students with insufficient exposure to practical-oriented and problem-based training.
- Students were confused about their academic identity. They felt that they were neither mechanical nor electrical engineers.

Partly as a result of these challenges, in the first graduation year of 2006, only six out of the original 15 students enrolled in the first professional (2nd) year of mechatronics completed their degrees.

These challenges called for a curricular overhaul of the programme in order to continue offering the degree pathway. This process began in late 2006. The new 2nd year curriculum was rolled out in 2007, the 3rd year curriculum in 2008, and finally the 4th year curriculum in 2009.

The curriculum development process deliberately sought collaboration from colleagues outside the College of Engineering. In particular, these included academic developers from the University Centre for Teaching and Learning. The academic developers' role was to do "system identification"; obtaining input from students, academics, and industry, and "system sensing"; acting as a feedback loop where information from the output of the (curricular) system is monitored, evaluated and fed back in order to better accomplish a goal.

This curriculum development model allowed for monitoring the learning outcomes against a set of parameters in a timely manner, continual refinement of the course components and assessments, and optimising the delivery of the degree programme. Three new courses that were developed are discussed here: 201 (Introduction to Mechatronics, 1st pro year), 301 (Mechanical design for Mechatronics, 2nd pro year), and 401 (Capstone project, 3rd pro year).

CONSIDERATIONS FROM THE LITERATURE

The following considerations from the fields of academic development and engineering education guided the collaborative efforts in the mechatronics programme.

Using Student Feedback

While collecting feedback from students has been used for several decades as a means of measuring perceptions of teaching quality, its usefulness in improving teaching and curriculum development "is dependent on the extent to which staff respond to and apply the information obtained in this way" [3]. Thus, to create a more responsive system of delivering a curriculum would suggest determining how to incorporate students' data into ongoing program design.

In Situ Academic Development

Prebble, et al. found in their synthesis of research on academic staff development that "the academic work group is generally an effective setting for developing the complex knowledge, attitudes and skills involved in teaching" [4]. Therefore, the combination of engineering content experts and academic developers, each bringing a different skill set, could be fruitful in the development of a quality mechatronics engineering curriculum.

Redesigning Engineering Education

According to an article by Basken in *The Chronicle of Higher Education* [5], a new report from the Carnegie Foundation for the Advancement of Teaching, *Educating Engineers: Designing for the Future of the Field*, is a reiteration of warnings from the National Science Foundation and the National Academy of Engineering "that American engineering education is too theoretical and not hands-on enough." While Basken indicates that colleges of engineering have known for quite some time that both students and employers desired a more relevant curriculum, both faculty members and accreditation practices are often more wedded to the traditional approach. Hence, the envisioned emphasis on practical and design work in the mechatronics curriculum was in accordance with international directions for engineering education.

These considerations regarding using student feedback, in situ academic development, and redesigning engineering education, indicate that a responsive and effective approach to curriculum design would include:

- collecting student and lecturer feedback in ways that go beyond standard teaching and course evaluations
- using that feedback in situ and in a collaboration between academic developers and discipline-based lecturers
- placing that feedback within the context of calls for redesigning engineering education in a more hands-on manner.

METHODS OF DATA COLLECTION AND ANALYSIS

Starting from an inquiry-based learning [6] approach where the engineering lecturers' questions guided the collaboration, data were collected by the academic developers in 2007, 2008, and 2009 from the first cohort of students and lecturers as they experienced the new curricula. Focus groups, course evaluations, specifically designed surveys, and observations served as the primary collection instruments.

The data were analysed by the academic developers and results and recommendations were fed back to the engineering lecturers so that they could adjust the curriculum, the teaching and the assessments to better meet the goals they had in mind when designing the new curriculum such as: students engaged in significant design projects at every year and a strong connection with industry [2]. In addition, final reports were generated and shared with the Board of Studies that oversees the Mechatronics Program – academics from the Departments of Electrical and Mechanical Engineering.

FINDINGS

The data collected from the same cohort of students at the conclusion of each new course for three years were specific to both the individual courses and the whole programme. A summary of the findings per course will be followed by the conclusions and implications for the overall mechatronics curriculum.

Mechatronics 201, 2007
This course is the first full mechatronics course that students in the program take. It is both an introduction to the discipline of mechatronics and a combination of mechanical and electrical engineering knowledge. Its content includes circuit analysis, sensors, control, and basic labs about robotics.

The data collected from students in the 201 course in 2007 suggested that students enjoyed the class, found the content appropriately challenging, and developed a sense of programme community or camaraderie through their experiences. In the qualitative data, the areas that students though could be improved were primarily logistical with: more equipment for particular labs, coordination of assessments with other courses, same location for lectures, and more explicit coherence or explanation for sequencing of topics.

These findings from the 201 course were fed back to the lecturers, programme coordinator, and the Board of Studies that oversaw the curriculum development. The curriculum for the following year was developed and implemented while considering these findings.

Mechatronics 301, 2008
This course provides students with an intensive opportunity to apply their knowledge from lectures to the creation of a robotic search and rescue vehicle in labs. The projects were undertaken by teams of 4-5 students. The data collected from students in the 301 course in 2008 indicated that they:

- appeared to immerse and to enjoy themselves in designing and building a search and rescue robot. Five different students used the word "fun" in individual surveys and 100% of the respondents believed that they had accomplished something significant in the course and 100% would recommend this course to others.
- did not find the project too daunting. There was a discrepancy as to what level of guidance students thought they needed, either the same amount as this year or an increased amount.
- saw the identity of themselves in the programme to be inherent in the nature of the course (a designated lab space, the team approach, a "cool" project).
- saw the lasting lessons of the course to be what they learned about: the design process, project management, and working in teams.

These findings from the 301 course were fed back to the lecturers, programme coordinator, and the Board of Studies that oversaw the curriculum development. The curriculum for the following year was developed and implemented while considering these findings.

401 Course, 2009

The capstone project consists of a year-long mechatronics design exercise. Students can work either in teams (typical for mechanical engineering projects) or individual (typical for electrical engineering projects). Most projects are sponsored by industry and students are responsible for all aspects, including organization, management (both time and budget), design and prototypes, and final reporting. The data collected from students in the 401 course in 2009 suggested that students:

- thought they learned considerable skills in the project, with an emphasis on non-technical, managerial, skills.
- saw areas of improvement could include increasing the timing of the lectures, clarity of project briefs, clarity about assessment, more specific mechatronics projects and, to a lesser extent, support and logistics.

These findings from the 401 course were fed back to the lecturers, programme coordinator, and the Board of Studies that oversaw the curriculum development. The curriculum for the following year was developed and implemented while considering these findings.

Programme review, 2009

The graduating class from 2009 (the first to have gone through the revised curriculum) was asked to reflect upon the programme as a whole, and to identify strengths and weaknesses. Students indicated that they:

- were very pleased with the mechatronics programme overall and that the department has succeeded in creating an "academic home" for the students.
- considered the programme to be very time-intensive and demanding and noted that several topics are covered multiple times in different mechatronics papers.
- had a desire for more, and structured exposure to industry throughout the programme.

In addition, students made several comments with regards to individual papers and curriculum structure.

Collectively, this review along with the data from the courses will be considered by the lecturers, programme coordinators, and the Board of Studies as the mechatronics curriculum continues to be developed.

CONCLUSIONS AND IMPLICATIONS

The combination of engineering and educational expertise in developing the new mechatronics curriculum has proven to be a successful endeavor. The system sensing and feedback facilitated by the academic developers brought in an objective perspective and new impetus. The non-engineering academics complemented engineering academics by bringing valuable insights in terms of setting and achieving learning goals, managing students' expectations, and advising on collecting feedback.

Arguably, students, staff, and the departments were more open to collaboration, feedback, and data collection as the academic developers were outside of the traditional line management structure, and were thus seen as neutral. This experience at the University of Canterbury has led to the implementation of several effective approaches for mechatronics education, which included integrating labs and design projects into and across courses and cooperative learning. In addition to the curricular adjustments, other positive outcomes involved the students with mechatronics graduates stating that they felt "both mechanical and electrical" in the core skill sets instead of their initial lack of identity as "neither mechanical nor electrical."

After 3 to 4 years' concerted effort, the Mechatronics Engineering Programme at the University of Canterbury has developed into a premier engineering programme that attracts top students nationwide and overseas. It has grown to an intake of 30 students per year, with room for expansion. The graduates are sought after by industry. Further work is needed to monitor the graduates' profiles and industrial acceptance, which will serve as another feedback in our work toward excellence in mechatronics engineering education.

This merger of mechatronics engineering content and expertise with the field of academic development has provided all involved with a unique opportunity to experience a best-practices model of inter-disciplinary collaboration with the subsequent students of the mechatronics program being the ultimate beneficiaries. It is anticipated that further beneficiaries of this transferable process may be other departments who develop their curricula by collaborating with academic developers.

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