

Lessons Learned in Implementing a Multi-disciplinary Senior Design Sequence

John-David Yoder and Juliet Hurtig
T.J. Smull College of Engineering
Ohio Northern University

Abstract:

During the 2003-4 academic year, the authors advised four student senior capstone teams. Unlike traditional capstone teams at Ohio Northern University, these teams were intentionally chosen to be multi-disciplinary, including students from two departments and a variety of majors, and faculty with varying specialties. Two teams worked on a national robotics competition, one team for an industry-sponsored project, and one team on a research project in the area of robotic controls. The challenges and rewards of these projects will be discussed in the paper, including coordination between departments, suitability of projects, and student feedback. Lessons learned and requirements for future multidisciplinary projects, as well as student preparation, will also be discussed.

Introduction:

Ohio Northern University (ONU) has an enrollment of almost 3300 students across five colleges. The engineering college is divided into three departments: the Department of Civil Engineering (CE), the Department of Electrical & Computer Engineering and Computer Science (ECCS) and the Department of Mechanical Engineering (ME). Senior engineering students at Ohio Northern University in the ECCS and ME departments enroll in year-long capstone courses. These courses focus on a team-based design and implementation project. Each department offers their own courses, with faculty acting as advisors for each team. Both departments have multiple projects from which student teams can pick and choose.

In the 2003-2004 academic year, it was decided that several of these projects would be multi-disciplinary, and require students from various majors to work together to complete the project. There are several reasons that this was attempted. Industry projects are increasingly requiring multi-disciplinary skills, and ABET requires that students must attain “an ability to function on multi-disciplinary teams.” [1] Also, emerging fields such as robotics and automation are inherently multi-disciplinary, requiring the integration of computers, electronics, and mechanical systems. In addition to these requirements, the ONU Mechanical Engineering Working Group (a group of representatives from employers and graduate schools) has commented on the increasing need for engineers to work across disciplines.

There is a significant body of work describing multi-disciplinary capstone courses, only a brief overview of which is presented here. In 1994, Miller and Olds [2] describe the development of a multi-disciplinary design capstone course at the Colorado School of Mines. Todd *et al* showed

that twenty-one percent of capstone projects involved inter-departmental teams in their 1995 survey [3]. Carnegie Mellon University currently offers a course titled “Engineering Product Design” [4] which brings in students from a variety of disciplines to work on industry-sponsored projects. Oakland University offered multi-disciplinary teams the chance to design and build a working prototype of a game or toy [5]. Universities have also used national competitions as models for multi-disciplinary projects, *e.g.* [6][7]. A more recent trend has been to focus on entrepreneurial projects which require multidisciplinary teams in order to be successful. Many such programs have been initiated, including those discussed in [8][9].

This effort described here differs from some of the above work in two major ways. First, the projects varied considerably, including an industry-sponsored project, a national competition, and an internally-funded research project. Secondly, this was not done through the development of a new course. Rather, the multidisciplinary projects were simply some of the projects from which students could choose as part of the standard capstone course. It is hoped that the lessons learned from these initial teams will allow smooth integration of further multidisciplinary projects in the future.

Design Teams:

Four student teams chose multi-disciplinary projects in the 2003-04 academic year. Dr. Yoder (ME department) and Dr. Srinivasa Vemuru (ECCS department) served as advisors for two groups entering the Trinity College Fire Fighting Robot Contest [10]. Each of these teams consisted of one ME student and 3 ECCS students. The contest has clear instructions and design constraints, and requires students to build an autonomous robot capable of searching a maze, finding a flame, and extinguishing it.

Dr. Yoder and Dr. Hurtig (ECCS department) served as advisors for two teams as well. One of the teams worked on a research-oriented project, using computer vision to control an industrial robot. This team consisted of two ME students and three ECCS students. The final team (also consisting of two ME students and three ECCS students) designed the instrumentation, software, and test specifications for an automated test stand for an industrial client.

In total, 12 students from the ECCS department participated in these multi-disciplinary projects, compared to 34 students working on projects made up of only ECCS students. Six ME students took part in multi-disciplinary projects, while 29 students worked on ME-only teams.

The electromechanical nature of robots and the fact that the test stand was being built to test mechanical products made these projects clear choices as ones that would be well-suited for multidisciplinary teams. This “mix” of projects is typical of ONU capstone projects, combining design competitions, industry-sponsored projects, and undergraduate research.

Among the challenges to be faced in order to make these projects possible were departmental differences. The two departments have somewhat different requirements for their capstone course sequences, and the students have been introduced to the design process in different ways. All engineering students are introduced to the design process as freshmen, and participate in

multiple design projects through their time at ONU. While it is not necessary to describe all of the courses in detail, a brief overview of the major differences is worthwhile.

In the ME department, Dr. Yoder teaches a course (ME 311, Process of Mechanical Design) at the junior level which requires students to work in teams to design, build, test, and redesign a mechanical component. Students then follow this same process during the senior year, presenting their work in written reports and oral presentations at the end of each quarter, as well as preparing a poster presentation when they are complete.

In the ECCS department, Dr. Hurtig teaches the fall-quarter senior design course, which covers teamwork and the design process. Student design teams work in the fall quarter to prepare a formal proposal. The design and building of the system starts in the winter quarter, and groups complete their formal report and poster presentation in the spring.

It was decided that the four multidisciplinary groups would follow the ECCS schedule. They would present their formal proposal to the ECCS faculty at the end of the fall, present a progress report to the ME faculty at the end of the winter quarter, and submit their formal reports to the ECCS department in the spring. This schedule allowed faculty from both departments to be sure that the work of these teams was worthy of a capstone project, without requiring much additional work on the part of the students. This was felt to be important, since ONU wants to encourage more students to choose multi-disciplinary projects in the future.

Assessment:

Assessment of these projects was completed in a variety of ways. Students began the course by creating team charters. At the end of the project, students are then asked to rate themselves and the other team members on how well they completed the items in the charter. The faculty advisors meet weekly with the student teams to evaluate current progress and team dynamics. Other ECCS and ME faculty helped to evaluate student presentations, and members of the College of Engineering Advisory Board were involved in assessing the student poster presentations, as well as the oral presentations of some of the best groups. Finally, students involved in the multi-disciplinary projects were asked to complete an additional questionnaire to assist the authors in assessing this program. Two-thirds (12/18) of the students completed the questionnaire. The questionnaire is shown on the following page, with the mean and median values of the student responses shown in the blank for each question. For example, for question number 2, the average of the responses was 2.8, while the median response was “agree,” or 3.

Several disclaimers should be made here. There was no control group for this study, and the values are based on self-assessment. A total of 12 students responded, but there were so few students in each project that differences between them are not statistically significant. ME and ECCS student responses were not tracked separately. However, it was found that the numerical results and student comments were generally in agreement with faculty observations. Since ONU has a small engineering school and these project teams are small, faculty advisors were able to track student accomplishments quite closely.

2003-04

Capstone

Project: _____

Use the following scale

4 – Strongly Agree 3 – Agree 2 – Disagree 1 – Strongly Disagree

- 3.0-3 1) The project I worked on required a multi-disciplinary team.
- 2.8-3 2) I learned more by being on a multi-disciplinary team.
- 1.9-2 3) I had to do more work because I was on a multi-disciplinary team.
- 2.1-2 4) My role was not clearly defined because I was on a multi-disciplinary team.
- 3.2-3 5) I had a clear understanding of project requirements.
- 2.0-2 6) I felt the workload was balanced among team members with different backgrounds.
- 2.8-3 7) Our group generated more ideas because we were a multi-disciplinary team.
- 2.3-2 8) Our group communicated poorly because we were a multi-disciplinary team.
- 3.0-3 9) Our group had a clear leader.
- 3.2-3 10) I would recommend working on a multi-disciplinary team to another student.

Please include any comments regarding your capstone experience, especially as they relate to being on a multi-disciplinary team.

Lessons learned:

The College of Engineering at ONU expects to continue to offer students the choice of working on multi-disciplinary projects for their capstone experience. In accordance with our continuous improvement policy, the various assessment tools described above are used to improve future offerings. Here are some of the lessons learned during this process.

- Students are very uneasy with the idea of having multiple advisors from multiple departments. Several students commented on this, and on the feeling that they did not know who would be assigning their grades. A distinct effort will be made to be clearer in terms of grading policies, due dates, and course structure for the multi-disciplinary projects. Simply creating a separate syllabus for this course (rather than combining the syllabi from the ME and ECCS courses) will likely benefit the students.
- Clear project definition is especially critical for multi-disciplinary projects. While project definition is important to any project, it seemed to be of even more importance on these projects. All of the assessment tools described above indicated that the students in the Trinity College contest groups did better than their peers in the other groups. While some of this could be due to the students involved in the groups, having clear 'rules' in place was a benefit to the students. Students in these groups were above the average on the questionnaire on question 1 (3.3 compared to 3.0) and question 10 (3.4 compared to 3.2) indicating that they felt the team needed to be multi-disciplinary, and that they would recommend this type of project to another student. They were much lower than the average on question 8 (1.8 compared to 2.3), indicating that their communication was good between members of different disciplines.
- By contrast, the open-ended research problem of using computer vision to control an industrial robot fared worse than the other groups on nearly all assessment measures. Again, some of this is likely due to the individuals involved in the project, but several lessons were clearly learned. First, the students in this group were not adequately prepared to do a literature search and find the current state-of-the-art information in order to define their task under the time requirements for the proposal. Secondly, students quickly became bogged down in the details of making equipment work (communicating to the robot, frame-grabber, etc.) rather than focusing on the 'big picture' of solving the research problem. On the questionnaire, this group fared worse in terms of feeling their role was not well defined (2.7 compared to 2.1 on question 4), that the workload was unbalanced (1.3 compared to 2.0 on question 6), and that their project did not require a multi-disciplinary team (2.0 compared to 3.0 on question 1). Future projects involving multi-disciplinary research will clearly require more direction and management from the faculty advisor in order for the students to fully gain the benefit of exposure to undergraduate research.
- Perhaps one of the biggest difficulties encountered was that students did not truly function as a team. Multi-disciplinary teams always face an inherent conflict – do they truly function as a team with collaborative work products, or do they each individually solve subproblems in their area of expertise and then combine these. As an illustration, consider the fire-fighting robot. All of the students could have worked together to brainstorm ideas on the shape of the robot, the configuration of components, and the process to be used to search for the flame. Then each person could work on their area of expertise – the mechanical engineer could select the proper gearing, an electrical engineer could size the batteries, and the computer

engineer could select the processor. Unfortunately, it seemed that in most of the teams, people did not want to contribute at all to areas outside of their ‘niche,’ so that students did not get the full benefit of working in a team. In particular, the mechanical engineers seemed very reluctant to contribute to discussions about algorithms and processes, even though the ability to take a problem and provide a process to solve that problem is a basic skill in all of engineering. This was most clear in the vision-guided robotics project, where a student commented that the mechanical engineers did not do any work since the project was “99% software.” ECCS students ended up doing all of the process and kinematics development work which could have clearly benefited from the inclusion of the ME students.

- In all teams, it is to be expected that some people will do more than others. This problem can lead to even greater problems in multi-disciplinary teams. In groups where students from one discipline are significantly stronger than those from another discipline, the project can flounder since problems which require the expertise of the weaker student may not be completed as well or as quickly. It is noteworthy, though not surprising, that the project which faculty rated lowest of these four also had internal team ratings which were the lowest. That is, the stronger students knew their team had not performed well, and felt that the weaker students from another discipline were largely to blame.

Despite the obvious room for improvement indicated above, it is clear that multi-disciplinary teams can provide excellent results, and projects that capture people’s imagination. One of the fire fighting robot groups was selected by the ECCS faculty as the best final report, and was selected by the College of Engineering Advisory Board as the best project in the college. All of the poster presentations were evaluated favorably by the Board, as well. The industrial sponsor of the test stand development project has also indicated to the authors that he was very pleased with the work the students have produced.

It is also clear that, overall, the students who responded to the questionnaire felt there was a benefit to being on a multi-disciplinary team. Looking at the median values of responses, one can see that most students agreed that they learned more by being on one of these teams (question 2), that their team generated more ideas (question 7), and that they would recommend working within such a team to other students (question 10). Most students disagreed with all of the “negative” questions (3, 4, 6, and 8), indicating that they did not feel that begin on a multi-disciplinary team “hurt” them in any way. In addition, several students commented in the ‘free-form’ response area that they felt this exposure was helpful, even if they did not always enjoy it, such as “multi-disciplinary projects are helpful because they are more ‘real life.’” “I would definitely recommend it to other students.” “Overall, [the] experience was positive. I would recommend continuing multi-disciplinary teams in the future.”

It is hoped that the number of interdisciplinary capstone projects at ONU will continue to grow and become a consistent option for the students. By building on the lessons learned from this first experience with such projects at ONU, student learning during participation in such projects can continue to improve.

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Biography

DR. JOHN-DAVID YODER is an Assistant Professor of Mechanical Engineering and currently holds the LeRoy H. Lytle Chair at ONU. His Doctorate is from the University of Notre Dame. Research interests include education, controls, robotics, and information processing. Prior to teaching, he ran a small consulting and R&D company and served as proposal engineering supervisor for GROB Systems, Inc.

DR. JULIET HURTIG is an Associate Professor of Electrical Engineering and Assistant Dean of the T.J. Smull College of Engineering. Her doctorate is from The Ohio State University. Research interests include control systems, nonlinear system identification, and undergraduate pedagogical methods.