Work in Progress: Harmonizing Senior Design Projects between Engineering Departments

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All three departments in the T.J. Smull College of Engineering at Ohio Northern University have the completion of a year-long capstone design project as a graduation requirement. However, the departments do not have a common framework for outcomes, deliverables, due dates, etc. This means students working on interdisciplinary capstone design projects must deal with an additional, and sizeable, challenge of conflicting specifications. Thus, it is important to harmonize the main components of the capstone design project across all programs in order to improve the students' overall experience, assess senior design projects across the college more consistently, and serve students working on interdisciplinary projects. This paper describes the current work in process to implement a single, college-wide capstone course core sequence to address this.

Keywords: capstone design project, engineering, harmonization, interdisciplinary

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Introduction

Ohio Northern University (ONU) is a private, comprehensive university located in rural, northwest Ohio. The College of Engineering currently enrolls almost 500 students who pursue one of six majors: civil engineering, computer engineering, computer science, electrical engineering, and mechanical engineering as well as its newest program in engineering education. The college only offers undergraduate degrees and its mission is to engage students through personal relationships and high-impact educational experiences to maximize their success.

Historically, the engineering departments at ONU – Mechanical Engineering (ME), Civil Engineering (CE), and Electrical & Computer Engineering and Computer Science (ECCS) – have provided their capstone design experiences through one-year-long practical and real-world, discipline-focused projects. Given the three degree programs housed therein, the ECCS department has prior experience in successfully harmonizing their senior design process[1,2]. For over a decade there has been an interest within the College of Engineering to conduct interdisciplinary capstone design projects between the ME and ECCS departments.[3,4] Interdisciplinary capstone design projects are important as, in practice, engineers and computer scientists work in an interdisciplinary manner[5-11]. Accordingly, there has been a considerable amount of research performed regarding interdisciplinary approaches to capstone design courses or projects. As an example, Sirinterlikci's work demonstrates how to make a one semester senior design course interdisciplinary[12]. The course activities included team formation, oral progress report in the 7th week, a written progress report in the 10th week, and a culminating presentation and report in the final week. In a different approach, Sheppard *et al.* implements the use of systems engineering in multi-disciplinary capstone project[13]. They realized that there is a necessity for both collaboration and communication skills in multi-disciplinary teams. In order to introduce this project, it was important to establish a plan to co-ordinate the multi-disciplinary effort. It was challenging to find common times between teams from different discipline in the capstone schedule. It was decided that this project would follow different timelines and deliverables from all regular discipline-specific capstone projects. Also, students were still expected to meet the requirements and deliverables of the individual disciplines. It is clear that the students who participated in this project put in more effort than those who were involved in a discipline-specific project.

ABET Engineering Accreditation Commission (EAC) Criterion 3(d) specifies that students should demonstrate an ability to function on multidisciplinary teams by the time of graduation. While this criterion does not require that the capstone experience involves multidisciplinary teams, programs usually include this as part of their capstone curriculum. However, as ABET does not provide its own definition, the term "multidisciplinary" is subject to a wide variety of interpretations. For

example, the University of Pittsburgh's interpretation is that multidisciplinary "includes teams of individuals with similar educational backgrounds focusing on different aspects of a project as well as teams of individuals with different educational backgrounds."[14] There are a number of additional challenges facing interdisciplinary projects, such as scheduling conflicts, inter-curricular coordination, and interdepartmental communication[15-17]. In short, harmonizing the capstone design experience across an entire college of engineering to facilitate interdisciplinary collaboration requires a great deal of planning. This paper presents ONU's plan to harmonize the capstone design project between different engineering disciplines.

Current Senior Design Course Sequences

The senior design sequence in the three departments at ONU is consisted of similar components, but they may not have same deliverables, schedule, or credit hours. The CE senior design course sequence includes CE 4101: CE Design Seminar (1 credit hour) and CE 4141: Project Management (3 credit hours) being offered in the fall semester, and CE 4151: CE Design Project (3 credit hours) being offered in the spring semester. Engineering economics is embedded within the project management course. Design teams are formed in the fall semester. The Civil Engineering students are offered a number of possible capstone design projects to select from. Each project is a real-world project and has a client from industry. The teams utilize a bidding process by preparing statements of qualifications and proposals for two or more projects. The Civil Engineering Department reviews the submissions to decide which team will be assigned to each project. During the fall semester, students work on their analysis and design, then develop and submit a final design proposal. In the spring semester, the Civil Engineering students finish the bulk of their capstone design projects. The main deliverables for CE students are the final written report, oral presentations, and engineering drawings.

The ME senior design course sequence includes ME 4011: Capstone 1 (1 credit hour) and ME 4011: Process of Design (3 credit hours) being offered in the fall semester, and ME 4121: Capstone 2 (2 credit hours) being offered in the spring semester. Similar to Civil Engineering, the engineering economics content is embedded within the Process of Design course. Design teams are formed and projects are assigned prior to entering the course sequence in the spring semester of the junior year. Each project is a real-world project and has a client, and sometimes sponsorship, from industry. During the fall semester, students develop and submit a final proposal and start to work on their analysis and design. In the spring, the Mechanical Engineering students finish the bulk of their capstone design projects and fabricate any necessary prototypes. The main deliverables for ME students are the final written report, oral presentations, and final products.

The engineering-specific ECCS senior design course sequence includes ECCS 4711: Senior Design 1 (2 credit hours) and ECCS 4391: Engineering Economy (1 credit hour) being offered in the fall semester, and ECCS 4721: Senior Design 2 (3 credit hours) being offered in the spring semester. Computer Science majors have the option of either taking the engineering-specific capstone course sequence or a computer science-oriented year-long capstone design sequence. All ECCS students are placed onto teams and projects are assigned in the spring semester of the junior year. Projects are derived from industry (some with sponsorship), faculty research, competitions, or service learning opportunities. In the fall semester, students develop and submit a final proposal and start to work on analysis and design. In the spring semester, the ECCS students finish the bulk of their capstone design projects and finish fabrication of any prototypes. The main deliverables for ECCS students are the final written report, oral presentations, project website, and final products.

As mentioned earlier, students who were involved in interdisciplinary capstone design projects have struggled since their experience was hindered by the different project schedules and deliverables between the departments. For example, one recent interdisciplinary project involved developing an alarm system to predict failure of a prefabricated metal roofing system due to loads caused by snow. It was difficult for students from different departments to work as a unified team due to different schedules and deliverables between departments; therefore, the students worked in separate teams, communicating only as necessary in order to transfer any needed information. In another recent project, students from the civil and electrical engineering programs were involved in the design of a solar array for a partner in Haiti. Because of the need to travel to the site, this team by necessity had to follow a schedule different from any established within the College, so not only did this group of students have to deal with disparate requirements between the two departments, they also had to deal with the relative lack of flexibility afforded under the two capstone formats. In order to avoid similar problems in the future, and thereby arrive at a more positive experience for all of the students in the college, various changes need to be effected into the capstone design curricular structure such that there is both commonality and flexibility for all teams, regardless of the makeup of each team.

Proposed Revisions

It was important to design a unified format for the engineering capstone design projects in order to improve the students' experience and also make conducting the assessment process easier. A number of changes are being made and are presented in this section. These changes will take effect starting in the 2016-17 academic year and are meant to address the following goals. First, align the credit hours received for projects such that they are consistent across all programs. This addresses the problem of students from different programs working on the same multidisciplinary project but receiving differing amounts of credit for equivalent workloads. Second, harmonize the deliverables associated with the capstone design projects such that there is a subset of materials, consistent from group to group, that can be used for both project evaluation and assessment purposes. Finally, synchronize the mileposts commonly associated with the various capstone design projects across the college so that the entire process can be overseen by a single capstone coordinator.

The fall capstone design experience will be 1 credit hour, and will be listed as ENGR 4011. Deliverables in this course will include weekly meetings with advisors and/or clients, weekly written progress reports, oral presentations using a critical design review format[18], a project design proposal that serves as a final written report, and peer evaluations.

The spring design experience will be 2 credit hours, and will be listed as ENGR 4021. Deliverables in this course will also include weekly meetings and written progress updates, oral presentations, a written final report, and peer evaluations. In addition, students will present to an external audience (either at a professional conference or to a real-world client), to the College of Engineering Advisory Board, and at the College's annual Design Showcase where they are expected to describe their final design and, if appropriate, demonstration their prototype. As projects are normally scored during the Design Showcase by members of the Advisory Board through use of an evaluation rubric, this data can be compared against those collected in previous years to help measure the effectiveness of this new organizational approach.

Note that this work is describing the project-based portion of the senior capstone experience. Each department will maintain their own classroom course which supplements the capstone experience.

Course descriptions are included below, and Table I shows which ABET Computing Accreditation Commission (CAC) and EAC student outcomes are covered in these courses. Note that the university also requires the capstone experience to cover two general education learning outcomes, which are also described in Table I.

ENGR 4011 – Capstone Design Experience 1
1 credit hour

Description: Experiential portion of the capstone design that is common to all majors in the college. Student teams demonstrate project management skills through use of effective communication techniques, including advisor/client meetings and written progress updates on a weekly basis, oral presentations, and written reports. Prerequisite: senior standing.

ENGR 4021 – Capstone Design Experience 2
2 credit hours

Description: Continuation of the experiential portion of the capstone design that is common to all majors in the college. Student teams demonstrate project management skills through use of effective communication techniques, including advisor/client meetings and written progress updates on a weekly basis, oral presentations, and written reports. Prerequisite: ENGR 4011.

TABLE I: MAPPING OF ENGR 4011 AND 4021 COURSES OUTCOMES TO ABET EAC AND CAC CRITERION 3 OUTCOMES AND ONU GENERAL EDUCATION LEARNING OUTCOMES

Course Outcomes – students are expected to demonstrate:	ONU Gen. Educ.	ABET CAC	ABET EAC
An ability to apply knowledge of mathematics and science, and of their respective discipline.		3a	3a
An ability to design a component, process, program, or system to meet desired needs within appropriate constraints.	2	3c	3c
An ability to effectively function on teams where individual members focus on different aspects of a project.		3d	3d
An ability to communicate effectively.	1a	3f	3g
An ability to use current techniques, skills, and discipline-specific tools necessary for practice within one's discipline.		3i	3k

Relevant ONU General Education Learning Outcomes:
1a: Effective Communication – Written
2: Critical and Creative Thinking

Conclusions

Due to an increase in interest of conducting multi-disciplinary senior design projects, it was clear that students experience is hindered by not having a formal, common senior design approach across the various disciplines to handle projects. Also, it is not easy to assess the capstone design experience college-wide since each department follows a different approach. The new proposal is expected to help to overcome all of the challenges that were observed in the past. Finally, this will lead to more interdisciplinary projects since all students are registering for the same course.

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