A Communication-Focused Four-Semester Design Requirement

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This paper overviews the communication-focused four-semester design clinic requirement included in New Mexico Tech's Mechanical Engineering program. Beginning in the junior year, majors begin a sequence of four consecutive semesters of design. Paired with the design courses is a required technical writing course taught from within the Mechanical Engineering department whose course design includes course deliverables linked to students' design projects in order to promote knowledge transfer of communication skills. This four-semester model involves juniors and seniors working together on teams for a range of projects including those supported by industry and government organizations, faculty research, and driven by national student competitions. This unique model involves mentoring of junior students by seniors and includes opportunities for students to work on projects of greater complexity than a one or two-semester design course. Feedback from alumni surveys from 2011-2016 consistently ranked the design clinic as the "best aspect" of the department and attribute "amount of time spent on design" as one of the most valuable components of alumni's degree. ABET's Fall 2016 evaluation cited the four-semester design clinic sequence as a program strength.

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Introduction

The results of the 2015 capstone design survey indicated that the majority of design courses do not extend beyond two semesters[1]. While a trend towards the length of capstone courses increasing was observed, out of 464 distinct departments participating in the survey, only 6% of programs used a model extending beyond three semesters[1]. This paper provides insight towards an established program that uses a curricular model exceeding three consecutive semesters of capstone design. A prominent feature of New Mexico Tech's Mechanical Engineering B.S. degree program is a four-semester design clinic requirement which has been in place since 2008. In the junior year, students enroll in Junior Design, a course spanning two semesters, and then progress to a two-semester Senior Design course. Since Fall 2013, this four-semester progression has included a linked technical writing course taken in the junior year. In this model, communication is emphasized throughout each design clinic course, and students are taught to integrate writing and presentations throughout their design process.

Overview of Mechanical Engineering at New Mexico Tech

New Mexico Tech is a publicly-funded science and engineering-focused institution offering degrees at the undergraduate and graduate levels. Undergraduate enrollment is approximately 1700. ABET-accredited since 2005, the Mechanical Engineering degree at New Mexico Tech is the university's largest undergraduate major, including approximately 23% of all undergraduate students. The rigorous 135-credit hour curriculum includes general degree courses in mathematics, chemistry, physics, and humanities and social sciences, as well as general engineering science courses in computer programming, statics, dynamics, and heat and mass. Courses required for the major include hands-on laboratory experiences in fluid and thermal sciences, mechanics of materials, vibrations, mechatronics, dynamic systems and controls, instrumentation, and measurement.

Junior and senior design clinic courses

Students enrolled in Junior and Senior Design Clinic work on a project team whose end goal is to satisfy their sponsor's requirement by designing, building, testing, refining and delivering a fully functioning prototype. Projects range from those sponsored by industry (examples include Honeywell, GE, regional solar companies, and petroleum companies), to projects sponsored by national laboratories such as Los Alamos National Laboratories, Sandia National Laboratory, Lawrence Livermore National Laboratory, to military or government-sponsored projects from Holloman Air Force Base, Kirtland Air Force Base, Naval Air Weapons Station China Lake, and NASA. All potential

sponsors submit a project proposal by early summer identifying project goals, committed resources (such as materials and equipment and financial support for items such as parts and components, and tasks such as machining and travel), and designated individuals to serve as POCs**.** Design clinic faculty review proposals and select those that best fit the program's educational objectives and complement student interests. Several repeat customers propose projects; new clients typically hear about the program through the department's faculty, advisory board, or alumni. Additionally, some projects included in the design clinic further faculty research, and a handful of teams work towards competitions such as SAE's Baja off-road vehicle competition and AIAA's model airplane competition. The design clinic includes some interdisciplinary projects involving senior students from Computer Science, Materials Engineering, Civil Engineering, and Management disciplines.

To guide student work within their projects, the 2 credit hour Junior Design class, taught by an adjunct who works as an engineer in industry, meets once a week, as does the 3 credit Senior Design class (also taught by an adjunct with extensive industry experience). While these courses have separate meeting times, they share common objectives focused on teaching students to rely on design principles to make decisions that can best help them solve design problems.

Also required in the design clinic curriculum is a technical writing course linked directly to design clinic courses. This course was implemented in Fall 2013 (prior to its implementation, design clinic students took a general technical writing course open to all majors offered through the Humanities department). Students take the linked technical writing course as first or second semester Junior Design students. The majority of course assignments relate to the written reports and oral presentations students work on within their design teams. The technical writing course requires early drafting of team deliverables and rehearsals of team presentations, providing the opportunity for feedback before teams finalize communication deliverables.

The course instructor, a communication professor, is a tenured member of the Mechanical Engineering department. The technical writing course instructor also serves as the Design Clinic Coordinator. She works closely with the Junior and Senior Design course instructors to select, coordinate, and facilitate projects, create course syllabi and schedules, communicate with team sponsors and advisors, and evaluate team progress and deliverables.

Communication emphasis and knowledge transfer

The department's increased communication emphasis began six years ago in response to both faculty and industrial sponsors' observations that students demonstrated a need to improve both writing and presentation skills. Further information about the evolution of communication emphasis is presented in a prior publication[2]. Throughout the design clinic curriculum communication is emphasized. Each semester teams are required to submit several written documents, beginning with a proposal and a detailed Gantt chart. Throughout the semester teams submit written status reports, and at the close of projects teams submit a final written report along with any required documentation (ie: user manuals, device descriptions, operating procedures). In addition, some teams may write conference proposals, journal articles, or participate in patent applications with their advisor.

In addition to written communication deliverables, teams also present multiple times throughout the course of their project. These oral presentations include proposal presentations, quad chart presentations, formal design reviews, poster presentations, and brief teaser presentations. Some teams may also deliver presentations at competitions related to their project, at a campus-wide research symposium, or at professional conferences.

The junior-level technical writing course was designed to promote knowledge transfer of communication. In this case, knowledge transfer is defined as the impact and adaptation of prior communication instruction on similar or novel rhetorical situations[3]. This course includes connected assignments, a dialogic environment, and assignments that foster knowledge building, conditions presented as ones that help ground theories of genre and situated learning in a way to promote transfer of rhetorical strategies within engineering disciplines[4]. Since the course instructor also serves as the Design Clinic Coordinator, she also reads all team documents and helps evaluate all team presentations. In this role, the communication faculty member has a unique opportunity to witness and provide feedback on student communication work not just for an isolated semester course of technical writing, but throughout the four semesters of Design Clinic.

Senior students mentoring junior students

The four-semester model, which resembles a vertically-integrated model, allows opportunities for senior students to mentor juniors[5]. Each Design Clinic team's membership includes a mix of juniors and seniors. With two semesters' experience of design instruction, seniors are expected to both take the lead in technical activities and informally mentor junior members. Such informal mentorship may include helping expose juniors to software packages (such as Comsol—a program not formally introduced in the curriculum until a senior-level FEA course), hosting welding workshops, and

rehearsing presentations outside of class. Especially for teams whose projects span beyond two semesters, this model of juniors learning from seniors also helps ensure continuity of the design process.

Additionally, the department hires a Junior Design Clinic Assistant and a Senior Design Clinic Assistant, each of whom work up to 10 hours per week to help support Design Clinic activities and serve as a liaison between students and faculty. The Senior Design Clinic Assistant helps train and mentor the Junior Design Clinic Assistant so that there is continuity each year (Junior Design Clinic Assistants go on to become Senior Design Clinic Assistants). These student assistants help manage and coordinate the department's 3d printer used by design teams, maintain laboratory space and other equipment, help plan a large design conference event at the end of each semester, and help coordinate poster format review and printing for that conference.

Program evaluation

Anecdotally, the department has heard from multiple employers of past students that the program's multi-year emphasis on design sets students apart from graduates from programs without extensive design experience. To more formally evaluate the program the department relies on multiple methods.

Design Clinic faculty conduct informal assessments throughout the semester at multiple points. Included in these informal assessments are a debriefing session with all design clinic students at the end of each semester. Regarding formal assessment, industrial sponsors, the department's advisory board members, and faculty are requested to rate posters and presentations of design projects on a 1-10 scale at the end-of-semester design conference each spring. The projects are evaluated using a rubric with categories to determine student competence in the following areas:

- Definition of the problem
- Planning the project
- Alternative approaches considered
- Evaluation and selection of preferred approach
- Results and conclusions
- Effectiveness of presentation
- Overall evaluation of project

Data from the last five years indicates 100% of teams each year were evaluated as competent or above for overall evaluation of project. Additionally, the department's assessment of junior and senior design courses each semester using ABET outcomes and a continuous improvement model (which was implemented in 2014), found no deficiencies for any of the outcomes and no students who failed to meet minimum competencies for any of the outcomes. The lowest average competency found for any of the ABET outcomes assessed since 2014 was 4.10.

The department also relies on surveying exiting seniors. Results from exiting senior surveys from 2011-2016 consistently ranked the design clinic as the "best aspect" of the department and attribute "amount of time spent on design" as one of the most valuable components of alumni's degree. Formal external evaluation also highlights the benefits of the program; ABET's Fall 2016 evaluation of the B.S. program cited the four-semester sequence as a program strength and praised the fact that the department has a dedicated faculty member in the area of communication.

Inherent challenges of a four-semester Design Clinic requirement

The department believes strongly in the program and considers the benefits of four semesters of design instruction to outweigh the challenges inherent in this curriculum. However, it is worth noting the particular issues faced.

- While the majority of students begin the first semester of Junior Design in the Fall, there are a handful of students who begin midyear at the beginning of Spring. By joining midyear, these students hear Junior Design course lectures in reverse. Design clinic faculty provide an overview of essential design process steps for these students, and they are expected to review the first half of the textbook on their own.
- Requiring four semesters of consecutive design instruction results in students having very little leeway in their schedule. Other than one 3-credit technical elective requirement, the rest of the undergraduate curriculum is very scripted. While there are other curricular factors beyond the design clinic requirement responsible, the majority of NMT Mechanical Engineering majors take more than 8 semesters to complete their degree. The department and the larger university are currently considering this issue and seek to improve the current average graduation rate for Mechanical Engineering majors (4.5 years) without sacrificing the quality of education.
- Projects vary in scope and complexity; as a result, some projects span four semesters or longer while others may span two or three semesters. While there is an advantage to the flexibility of having students work on a project for up to four semesters, for students who join a project midyear or who finish a project after three semesters, there can be a somewhat awkward fourth semester where students are reassigned to a different project. Those students

are assigned to projects within the same topic area where they can connect specific lessons learned from their former projects to the new project starting.

- Scheduling junior and senior design courses so that they do not conflict with other engineering labs is difficult. Especially when design teams are required to deliver formal presentations, it is difficult to schedule a joint junior and senior class session that avoids course conflicts. The department has solved this problem by pushing back the start of design clinic courses until the early evening when there are fewer lab and course conflicts. The benefit of an evening timeslot is that industrial sponsors have more flexibility to attend presentations.

Conclusion

A few years ago the department's faculty members worked on a marketing campaign to highlight strengths and help promote these strengths to prospective students, industry partners, and research collaborators. As part of this campaign, a phrase was established and is now used department-wide in email footers, the website, and hanging on banners in department hallways. This phrase: *NMT Mechanical Engineering: Engineering excellence driven by groundbreaking research and design* helps embody the department's commitment towards design. While the department has Master's and Doctoral programs and multiple faculty members bringing in substantial amounts of externally-funded research projects, the entire department is committed towards the undergraduate design clinic program. This commitment allows many department resources to be devoted towards what is considered the crown jewel of New Mexico Tech's undergraduate Mechanical Engineering department curriculum.

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