A Writing Program for Industrial Engineering Capstone

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Writing is integral to the two-semester capstone sequence in the Mechanical and Industrial Engineering Department at Northeastern University. The writing content needs to satisfy university and ABET requirements. Students perceived the existing writing requirements as distraction from their technical work. An update to the Industrial Engineering capstone program is described. An integrated set of assignments using templates efficiently uses student time without unnecessarily restricting creativity or the needs of specific projects. A simplified set of lectures and resources gives students a framework for good storytelling and style. A transparent and explicit grading rubric emphasizes both the course requirements and ABET skills. Skill gaps, observed to be primarily dependent on secondary education and first language, are addressed through the iterative structure of the assignments, teamwork and peer learning, and mentoring.

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Introduction and Background

The undergraduate program in the Mechanical and Industrial Engineering (MIE) Department at Northeastern University requires a 2-semester capstone sequence. A capstone experience is a required part of the Northeastern degree program. It contributes to all categories of the new ABET assessment standards.[1] It also satisfies the university requirement for Writing-Intensive Courses in the Disciplines, as part of the broader Writing Across Audiences and Genres requirement.

Until recently, the capstone courses were run as a unified course across both the Mechanical Engineering (ME) and Industrial Engineering (IE) divisions of the department. This arrangement had a number of disadvantages, both organizationally, and in terms of student satisfaction. The IE students expressed dissatisfaction at the targeting of much of the lecture material towards the more numerous ME students. Worse, there was a measured gap between the performance of the IE and ME students, in particular in their writing performance.[2]

In response to these findings, much of the instructional materials for the IE students has been separated from the ME track. The groups still share a course number and large-scale course goals, but meetings, instructional materials, grading, and (most relevant here) writing programs have become independent. This paper describes the writing program crafted for the IE division.

The program is based on recognized best practices, and observations during its creation have aligned with the literature. The basic motivation for a separate writing program for capstone is that available writing programs focused on writing mechanics do not address the problems of capstone students. Multiple authors have observed that capstone students have more trouble with coherence, organization, and clarity than with spelling and grammar.[3,4] Students are not highly motivated by writing content; when presented with writing assignments not closely aligned with their capstone projects, students tend to be disengaged and dissatisfied. Peretti[5] urges "creating an environment that connects [writing] assignments to meaningful project needs and helping students understand the functions reports and presentations serve in supporting engineering design." Some best practices for achieving this include templates, transparent grading rubrics, timely assignments aligned with project milestones, and chances for iteration and improvement.[3-6] Ideally, integration of writing and other communication content into capstone will help students with the content of their projects. Creating clear, well organized communications can help students clarify their technical goals, and better understand their underlying problems.[3]

The program presented here is the result of three years of evolutionary development. It addresses the weaknesses noted in the performance of the IE students under the old system, and is responsive to student inputs. It is still under continuous improvement, but is a complete "1.0" version of a capstone writing program.

Program Structure

During the first semester (Capstone 1), 4 or 5 person teams are formed to tackle projects proposed by faculty or industry partners (sponsors), and supervised by individual faculty members (advisors). Two faculty
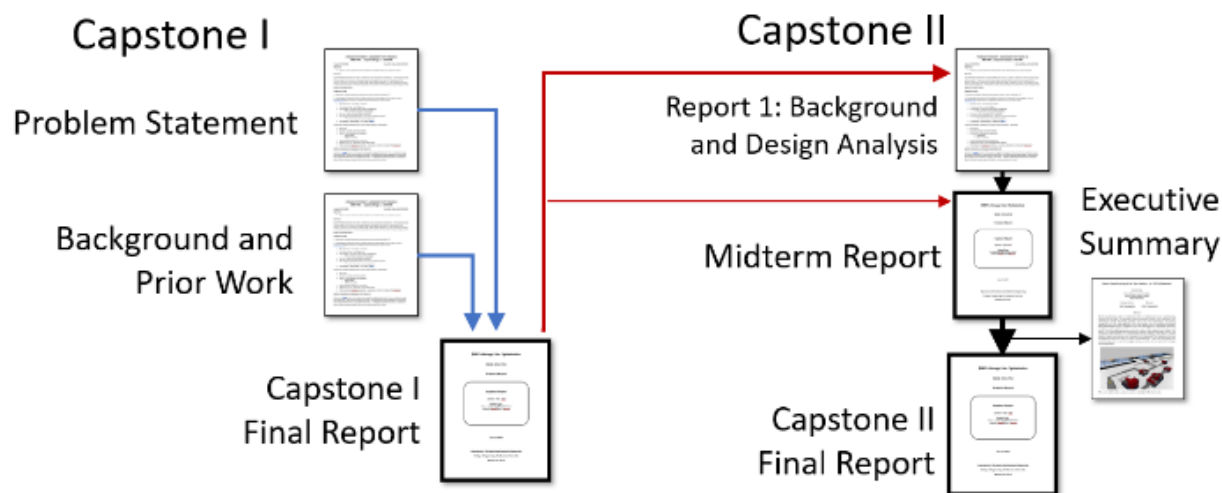
Figure 1. Capstone writing program structure

members (coordinators) coordinate the course requirements and grade most of the work; advisors have significant impact on the final grade through their assessment of project success.

The structure is shown in Figure 1. During Capstone 1, students create a Problem Statement and research and write a Background and Prior Work section. These efforts are graded and edited, and updated versions of them are used as major sections in the Capstone 1 Final report. Other assignments (such as a Gantt Chart and program management plan) also fold into the final report. The intent in all these cases is that the students get constructive feedback and a chance to iterate, and are motivated to improve their work as it will be used in the next graded artifact.

In Capstone 2, where the majority of the technical work takes place, the writing follows a pattern of interactive improvements to existing material while new materials (e.g. experimental procedures, data, results) accumulate. The interim Report 1 allows a final iteration on the capstone work as well as the integration of a design review and analysis; the Midterm Report is a fully formatted draft of the report, with experimental procedures, preliminary results, etc. included. The Final Report, written for an academic audience, is the equivalent of the students' undergraduate thesis. The Executive Summary on the other hand is written for public consumption, and in particular is used as a reference by the alumni judges who evaluate (and award prizes to) the students' final presentations. The intention is that both of these documents be highly polished, without piling a great deal of work into the final weeks.

An important aspect of the new structure was pruning of assignments that did not fit into the workflow. The number of writing assignments was reduced by around 40%, mostly by eliminating weekly or bi-weekly progress report memos. All remaining written assignments were designed to flow into the final report.

Assignments from the early part of Capstone 2 such as Design and Program Management memos are also integrated into the final products, assuring efficient use of student time, and high quality work due to iterative improvement.

Templates and guides

As part of the structure, students were provided with templates and guides, rather like the template that this paper is written on. The templates were designed to enforce a uniformity of style for the final products, and make the organization and inclusion of material created in the earlier assignments easier. The templates included short lessons in formatting, referencing, and correct practices for figures and tables. MS Word styles were provided to make importation of work into the templates as painless as possible.

The templates were explicitly not designed to either restrict the organization of the material or let the students just plug in content into a pre-organized document. The great diversity of types of projects seen in IE capstone would have precluded that in any case. Suggestions for organization were provided, but not hard-wired into the document.

Instructional Approach

The IE students have a very diverse set of backgrounds, particularly when it comes to technical writing in English. They all take a technical writing course as part of the degree program, but this seems to have less impact on them than their previous experiences. Many of our students do not have English as a first language, although that does not necessarily lead to poor writing. On the other hand, an informal study into the backgrounds of

particularly good writers revealed the somewhat dismaying fact that they universally cited having excellent instruction *in high school* as the source of their skill.

This precluded a one-size-fits-all approach to instruction in writing. No attempt was made to provide formal instruction in the details of technical writing. Instead, the students were given an overall approach that gave context to the iterative feedback and individual mentoring that were used to improve their documents; the hope was that they would then learn by doing—which is, after all, the point of capstone.

The instruction centered on a simple triplet: Tell your story, simply and concisely, and obey the rules. The framework included a discussion of storytelling, including a tongue-in-cheek reference to the Hero's Journey (Figure 2), in order to motivate organization of thoughts and flow of ideas. The intent was not to teach epic storytelling (indeed, students were warned against that) but to help students think about the structure and coherence of their writing, and indeed their work.[3,4] The classic style guide Strunk and White[7] was invoked to encourage brevity and conciseness. The templates included not just instruction on formatting, but also proper practices for citations, figures and tables, and academic integrity.

The framework was supplemented by tailorable resources. The university writing program resources, some excellent online resources for grammar and usage, and individual mentoring were used to address the needs of individual students and teams.

Rubric and Grading

To clarify the expectations on the students and provide structured and useable feedback, an existing was improved and aligned with ABET requirements. This allowed the grades on the rubric to do double duty as ABET competency assessments.
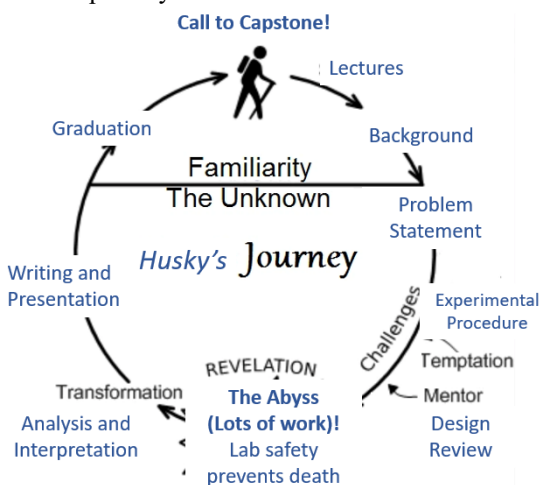

Figure 2. The Husky's Journey

Table 1: Rubric

Story Elements — 50% of total weight

- Abstract. Reviews document. Has key elements of Problem, Approach, and Results (or Progress).
- Problem Statement. Describes the problem that the team addressed. Element of scoring for ABET SO 2.
- Background. Concise summary of knowledge collected beyond the team's existing course-based skills. Element of scoring for ABET SO 7.
- Use of IE Tools. IE and other mathematical and engineering tools used to formulate and solve the problem. Element of scoring for ABET SO 1.
- Organization / Story Arc. The overall report clearly tells the story of a problem that is solved using engineering and scientific methods, and that ends with believable conclusions. The entire report factors in the scoring for ABET SO 3; this element receives extra weighting.
- Validated Conclusion. The work concludes with experiments or other forms of quantitative evidence used to support clearly stated and reasonable conclusions. Element of scoring for ABET SO 6.
- References and Appendices. Supporting material collected and presented in a way that ensures the credibility of the work. Element of scoring for ABET SO 7.

Style Elements — 25% of total weight

- Formatting. Compliance to both the letter and intent of the templates and guidelines.
- Grammar and Clarity. Clear technical writing in the spirit of the material presented in class.
- Figures and Tables. Clear, simple graphics, laid out according to the directions and/or in a way that maximizes understanding.

Required Components — 25% of total weight

- Ethics and Societal and Global Impact. Evidence that the team maintained a high standard of professional ethics, and gave serious consideration to broader societal and global impacts and issues of diversity, equity and inclusion. Element of scoring for ABET SO 4.
- Program Management (PM). Includes program planning and Gantt chart, use of PM tools and techniques, readiness and design reviews.
- Intellectual Property (IP). Consideration of IP used in project; correct attributions given and permissions gained. Clear statement of IP created by the project and its intended disposition.

The rubric was made available to the students. It was used to grade the Capstone 1 Report and the Capstone 2 Midterm and Final Reports. Students received both a numerical score and written comments on all elements of the rubric.

After the students receive the feedback on the rubric, they receive individual mentoring. The writing mentor goes over the components of the rubric one-by-one, with suggestions for improvement given in the spirit of the instructional approach. All student teams get at least one such session, and the teams with lower scores are encouraged to seek additional sessions.

A work in progress

The new program has only reached its final form in this academic year. Some aspects of the program were implemented in the previous two years and progress is very encouraging. The most gratifying single result has been a marked decrease in the "writing gap" observed between student teams with different initial skill sets. Figure 3 shows the rubric scores of every IE team over the course of the 2019-2020 academic year. Despite the disruptions of the pandemic, the writing scores of almost all teams improved, and the best improvement was seen in the teams needing the most help.

Significant quantitative student feedback has not yet been collected, but the qualitative feedback has been very positive. Students particularly appreciate one-on-one mentoring done after they receive the rubric. The mentoring seems to be particularly useful for students with good attitudes and work ethics but poor starting English technical writing skills. Overall, the simple,
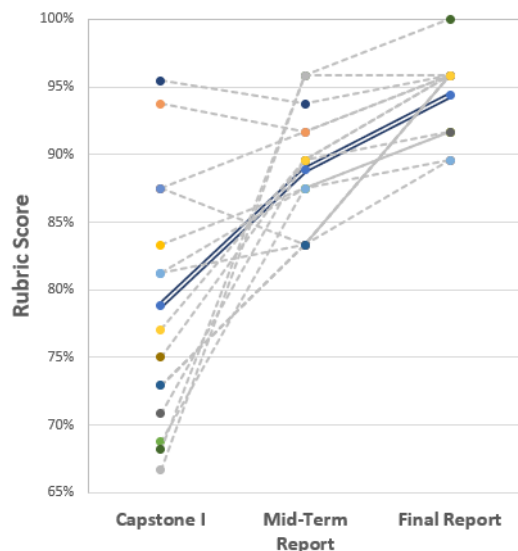
efficient and iterative structure, simple instructional approach, and transparent feedback seems to work. We look forward to reporting more quantitatively on its successes (and improvements) in the future.

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Figure 3. Writing scores of all teams, 2019-2020, showing improvement and gap narrowing.