AC 2011-1200: A WRITING PROGRAM FOR MECHANICAL ENGINEERING

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A Writing Program for Mechanical Engineering

Abstract

A writing program was initiated for mechanical engineering undergraduate students. The program is part of a larger, university-wide effort called the Writing Enriched Curriculum (WEC) program. The purpose of WEC is for faculty, in a bottom-up process, to infuse discipline-specific writing instruction into their curricula. The three-phase WEC process is (1) to develop a writing plan based on discipline-specific writing outcomes desired for graduating majors, (2) implement the plan and (2) assess the plan and revise based on the assessment. The plan for mechanical engineering defined nine attributes of mechanical engineering writing and 14 desired writing ability outcomes for graduating majors. Stakeholders agreed that problem sets were the number one form of writing for engineering students and that attention paid to writing a problem set would help students to learn the material. The plan was implemented by targeting three core courses for explicit writing instruction and raising the awareness of writing in other required courses in the program. Assessment is on-going and is tied to the ABET accreditation process.

1. Introduction

Despite widespread acknowledgment that effective written communication is as essential for learning as for disseminating ideas and discoveries, teaching writing and improving the quality of student writing remain challenges for educators in engineering. National studies, such as those conducted by the Commission on Writing[1] and the Boyer Commission on Educating Undergraduates in the Research University[2], argue that writing is a central means for developing students' critical thinking, communication, and metacognitive skills. These studies urge reforms, suggesting that educators pay greater attention to writing instruction in all disciplines and urging science, technology, engineering, and mathematics (STEM) educators in particular to engage their students in higher order modes of learning. The uneven rate at which writing and STEM reforms are implemented[3,4] reinforces the need for a new approach to reform, one that is discipline specific and faculty-driven.

The Writing-Enriched Curriculum (WEC) model is informed by shifts in the perception of writing itself. Since the mid-20th century, the traditional view of writing as a mode of communication, has evolved. Guided by psycholinguistic research, the current, expanded view is that writing is a mode of communication *and* learning. Writing is now recognized as an ability that students continue to develop throughout their academic education and later careers as they engage with increasingly complex content[5,6,7]. Further, research on the variations of written discourse within different disciplines explains why writing that students are expected to do in, for example, mechanical engineering looks so different from the writing they are expected to do in political science. Each discipline's written discourse is shaped by the evolution of the discipline to filter specific rhetorical purposes, formats, and styles over others[8,9,10,11].

Although basic courses in composition can help strengthen students' generalized writing and research abilities, these courses cannot assign or evaluate the kinds of writing students will be doing later on their majors. In STEM disciplines, where experimentation and problem-solving are central, and where written properties such as precision, accuracy, and transparency are highly valued, faculty members and other instructors from inside these disciplines are best qualified to

coach student writers. Throughout the 1980s and into the 1990s, therefore, many post-secondary institutions across the country created Writing Across the Curriculum (WAC) programs and implemented writing intensive course requirements to ensure that writing would be taught in all undergraduate majors[12]. A national survey of colleges and universities conducted between 2006 and 2008 identified more than 500 WAC programs. Of these, 330 have instituted writing intensive course requirements[13].

Despite three decades of emphasis on writing in all fields, faculty members in many disciplines—particularly in the engineering, life, and social sciences—are not comfortable with the idea of including writing instruction in their courses. Although all recognize writing as an essential academic ability, many are unsure about how best to incorporate writing instruction in the courses they teach, and question their own qualifications as content experts to teach this basic skill[14,15,12]. As a result, the centrally mandated integration of writing into courses in all disciplines—a central objective of Writing Across the Curriculum (WAC) reform—has been unevenly successful inside and outside STEM units. Moreover, professional development resources designed to support faculty members and graduate students who teach with writing are eroding[13].

Lack of departmental faculty involvement is another factor contributing to unsatisfactory adoption of STEM education reforms. Meaningful change cannot take place without the deep involvement of those who are doing the teaching. Authors of a recent study conducted by the U.S. Office of Education and the Rand Corporation concur, noting that change in education occurs on the local level, that is, in the classroom, and depends on "the teachers themselves"[16]. In essence, faculty members within departments must become involved in identifying desired learning outcomes. Although it may seem inefficient to ask departmental faculty to identify learning outcomes when national experts provide vetted lists, involving them in identifying relevant outcomes increases the likelihood that they will integrate these outcomes into their own teaching[17].

Recognizing that competency in writing is essential for engineers and recognizing that the responsibility for writing instruction rests within the major, the Department of Mechanical Engineering at the Twin Cities campus of the University of Minnesota has undergone a process of transforming the ways its undergraduate majors learn to write. The department is part of the innovative Writing-Enriched Curriculum (WEC) program at the University of Minnesota that aims to transform writing instruction at the university by enabling faculty members in all disciplines to infuse meaningful writing and writing instruction into their undergraduate curricula (*http://www.wec.umn.edu*). In the four-year pilot period (2007-2011) the WEC program will engage 22 academic units (colleges, majors, or departments). The program grew out of a writing task force convened as part of the university's strategic positioning process and is supported by a $1M grant from the Bush Foundation.

Mechanical engineering faculty at our university have long been dissatisfied with the quality of writing by students in the major, a reason for participating in the WEC program. In 2007, in a round table discussion of the department Industrial Advisory Board, the statement was made that, "your students do not write as well as the students from Georgia Tech and Purdue," a further call to action.

The WEC program entails a three-phase, recursive process in which academic departments develop, implement, and assess discipline-specific undergraduate writing plans. These plans articulate discipline-specific writing expectations, and plans for curricular integration of writing instruction, writing assessment, and instructional support. At the center of this process are collaborative dialogues between department faculty and specialists in writing pedagogy and assessment about the effective integration of writing into the undergraduate curricula. Unlike other writing across the curriculum initiatives that are centrally driven or initiated by writing departments, a merit of the WEC program is that it is discipline-faculty owned and directed. Further, writing instruction is infused throughout the curriculum rather than being concentrated in one or two writing-intensive courses.

2. Methods

In Spring 2007, on-line surveys were conducted of students, faculty and professional affiliates to determine, from multiple viewpoints, the importance of writing in the mechanical engineering discipline, attitudes towards writing and opinions about the quality of student writing. Responses were received from 70 of 398 students (15% response rate), 15 of 40 faculty (38%) and 11 of 22 professional affiliates (50%). A follow up survey was administered in Fall 2008.

With the survey as reference material, a smaller group of faculty met several times to develop the three parts of the mechanical engineering writing plan: (1) a list of characteristics that define writing in the discipline of mechanical engineering, (2) a set of desired abilities that undergraduate students should have by graduation and (3) a plan to integrate writing and writing instruction into the core undergraduate curriculum.

The writing plan was completed in Fall 2007 and approved by the Campus Writing Board, which is charged with review and approval of plans. After two years of pilot implementation, in Fall 2009 the plan was revised and again approved by the Campus Writing Board. The results describe the revised plan, which is not significantly different from the original.

2.1. Assessment of the Program

The purpose of writing program assessment is to see if there is meaningful integration of writing instruction into the curriculum and to determine if students are attaining the desired writing abilities, the major goal of the program. Several forms of assessment are used, some of which are tied to the ABET assessment process. The data from program assessment is interpreted by the department undergraduate curriculum committee that in turn can make recommendations to the department faculty for writing program changes. The committee also writes a brief evaluation of the writing program for the ABET self-study report. The archived ABET reports allow evaluation of the program over a longer time window.

A random set of writing samples are drawn from student work and evaluated by a group of three or four faculty members. The evaluation uses a rubric with metrics based on the desired writing abilities. Writing samples may include a portfolio, a lab report, a design report and one or more

problem sets. The sampling takes place on the biennial cycle that matches assessment of course material for ABET purposes.

At periodic intervals, the curriculum committee reviews the department writing program resources such as the style guides, grading rubrics and instructor resources, and recommends changes. A small sample of students in the major, department faculty and practicing engineers are interviewed through survey or in-person for comments on student writing and the department writing program.

3. Results and Discussion

3.1. Survey Results

As indicated in Figure 1 from the follow-up survey, all stakeholders who responded recognize that writing is important in mechanical engineering, with faculty having the strongest opinions.

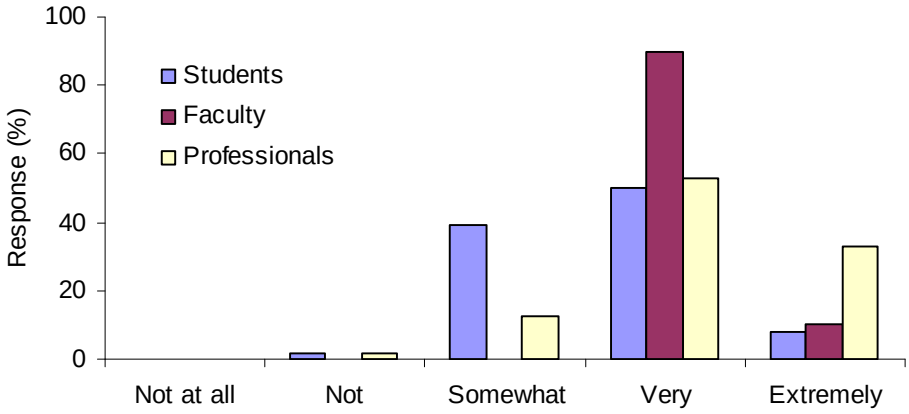

Figure 1. Survey responses to the importance of writing in mechanical engineering.

There was general agreement that effective writing in mechanical engineering must be clear, concise and accurate. Figure 2 shows the top 11 characteristics noted by students, in order. Faculty generally followed the same order, with a higher weight on concrete description, word choice and integrating sources. Professionals also agreed but with more weight on focused ideas and word choice and less on specific formats.

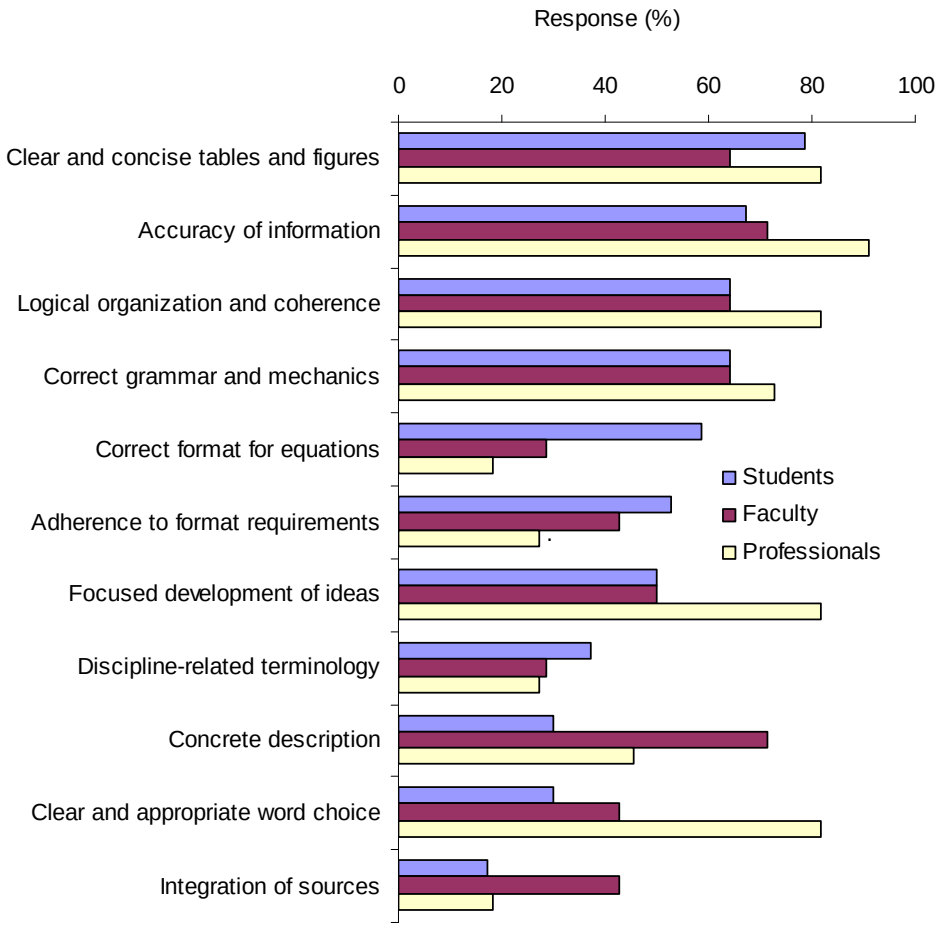

Figure 2. Survey responses on what characterizes effective writing in mechanical engineering. The chart shows the top 11 characteristics cited by students.

Views varied on the types of writing that is most commonly assigned (students and faculty) or encountered (professionals). For example, Figure 3 shows 90% of students had notebooks as an assignment while 43% of faculty responded as having notebooks as an assignment. Professionals correspond frequently while students rarely see correspondence as an assignment.

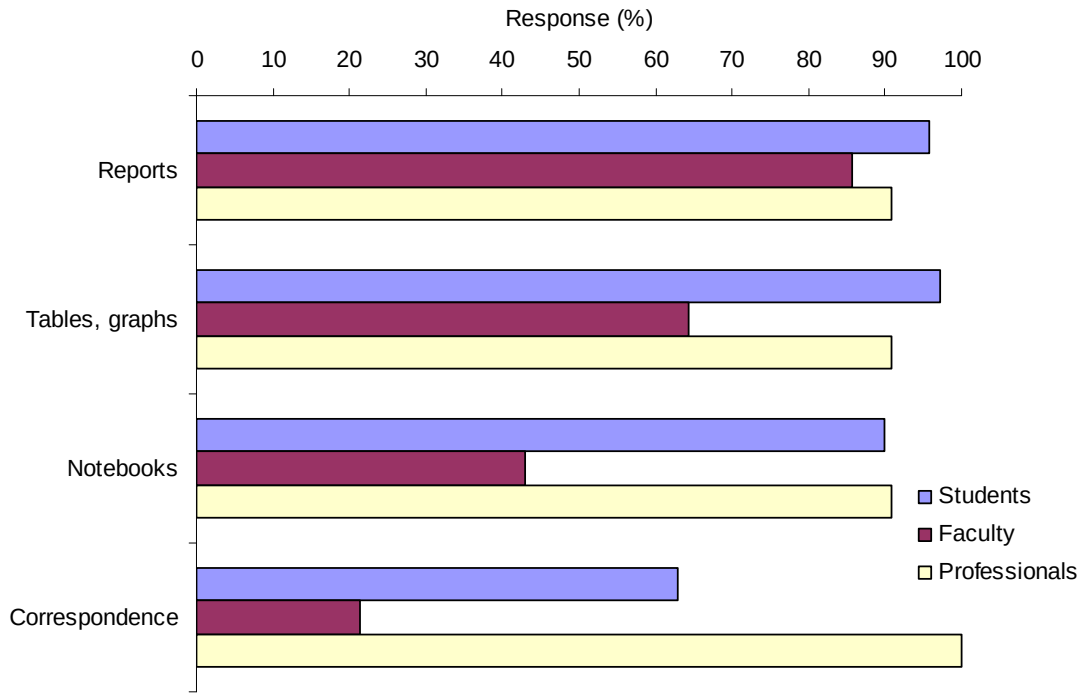

Figure 3. Survey results on the types of writing commonly assigned (students and faculty) and commonly seen in the workplace (professionals).

An expected, but perhaps unrecognized, result from the surveys and follow up discussions was that the most common form of writing for mechanical engineering students is the problem set. Recognizing that problem sets are a form of writing helped in getting faculty to understand that writing is more than grammar and that faculty could play a role in helping students to become better writers by providing instruction in how to write a problem set. This result highlighted that writing is discipline specific because writing problem sets plays no role in majors other than science, engineering and mathematics.

The survey indicated that 57% of the faculty were unsatisfied with the quality of writing from the students, reinforcing the need for action. However, it was clear from survey comments that faculty do not have time to teach writing and felt unqualified to be writing instructors.

3.2. Characteristics and Outcomes

From the surveys and subsequent discussion, the faculty refined the list of characteristics that define writing in the discipline of mechanical engineering (Figure 4). While the characteristics are not unexpected, comparing it to the equivalent list from a humanities department reinforces how writing is discipline specific.

Effective writing in mechanical engineering is:

- Pointed, concise and factual, avoiding redundancy, abstraction, and extraneous information
- Data-driven for credibility
- Systematic, logical and efficient in describing and solving problems
- Seamless in its integration of textual, numeric, and graphic information
- Explanatory, often involving depiction of spatial objects and description of complex technical concepts and data
- Predictable in its frequent use of prescribed formatting and structure
- Collaboratively authored as work is often conducted with a geographically distributed team
- Presented using multi-media applications of text and graphics, including oral presentations, posters and web sites
- Written and formatted in ways that are appropriate to technical and/or non-technical audiences

Figure 4: Characteristics of writing in mechanical engineering.

The set of desired writing abilities that undergraduate students should have by graduation was developed and refined (Figure 5). Once the desired abilities were defined, it was possible to create a writing instruction program within the major with the purpose of enabling students to attain the abilities. This is the same process used by ABET-accredited programs to define program objectives and outcomes, for example that by graduation students must know and can apply basic principles of thermodynamics.

At graduation, undergraduate students in mechanical engineering should be able to:

1. Apply knowledge of physics, mathematics, and engineering in their writing
2. Record and analyze activity related to laboratories and design projects
3. Visually represent designs and explain salient features of a part or concept
4. Synthesize and summarize key points
5. Strategize and demonstrate engineering project metrics such as productivity, costs and time to completion
6. Analyze the audience and create a document that meets the needs of the audience
7. Represent themselves professionally
8. Explain, discuss, and demonstrate physical apparatus
9. Integrate visual, textual and oral explanations
10. Communicate among a distributed design team using web-based collaboration tools
11. Create team-written documents
12. Create reports in the style of academic journal articles
13. Create reports in the style of professional engineering reports
14. Write according to faculty approved style guidelines

Figure 5: Desired writing abilities for mechanical engineering students.

3.3. Mechanical Engineering Writing Program

Integrating writing into the undergraduate mechanical engineering program was based on these assumptions:

1. Students do not enter the undergraduate program as competent technical writers.
2. It is the responsibility of the department to participate in writing instruction for its students.

3. Department faculty generally will not spend extra time teaching or evaluating writing mechanics.
4. Problem sets, lab reports and design reports are the three main forms of writing done by undergraduate students in mechanical engineering.

The writing program has two components: core courses targeted for writing instruction and courses where writing is valued but where there is little or no explicit writing instruction. Core courses targeted for writing instruction are ME2011 Introduction to Engineering, ME4031 Measurements Laboratory and ME4054 Design projects (Figure 6). Each course contains substantial writing assignments and students receive explicit, discipline specific writing instruction as shown in Table 1.

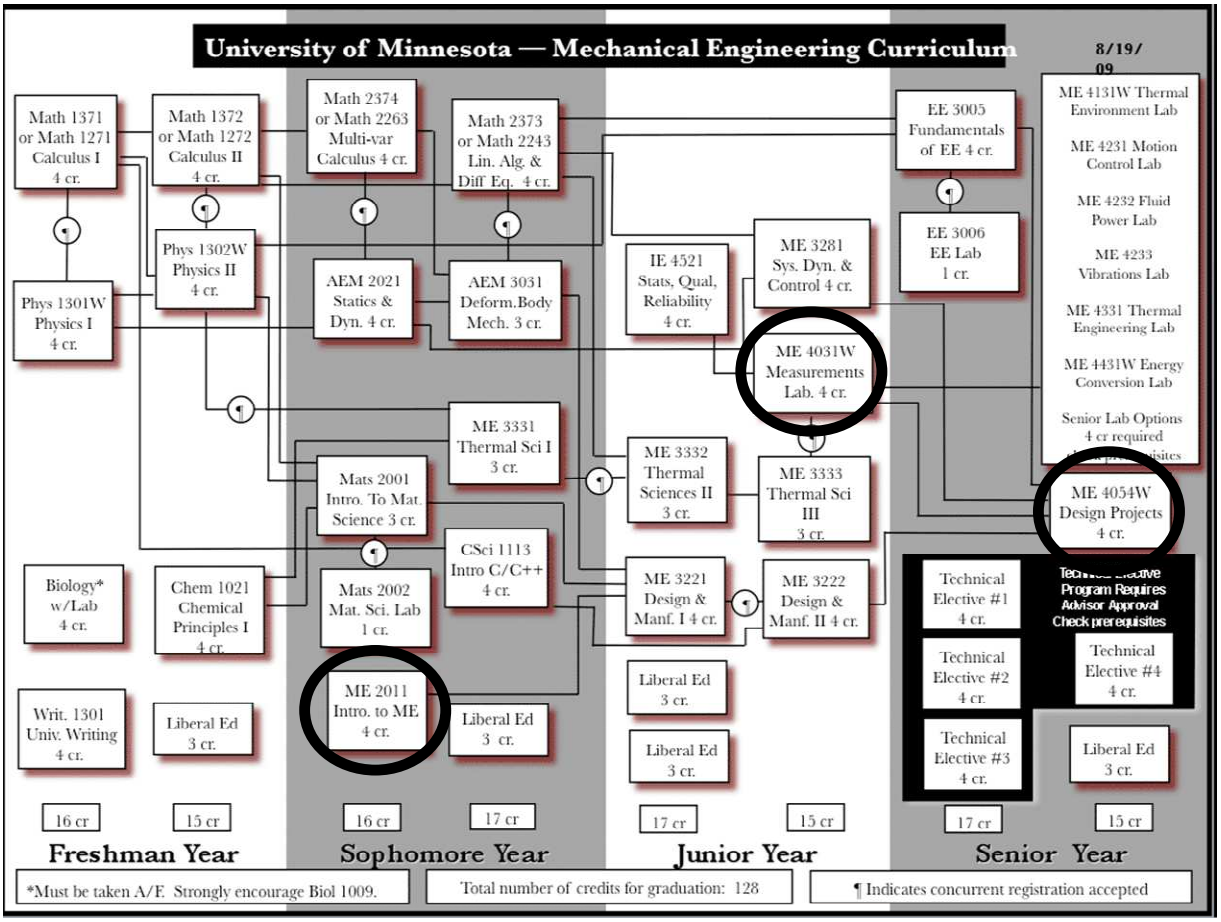

Figure 6. Mechanical engineering curriculum. Circled courses are those targeted for explicit writing instruction.

Course	*Writing Instruction*
ME 2011	Instruction on maintaining a design notebook, writing a lab report, delivering a technical presentation, writing a resume, informal professional writing and other technical writing forms. Evaluation and critical review of student writing. Introduction to department writing standards and style guides.
ME 4031W	Instruction on maintaining lab notebooks and writing lab reports. Formal and informal evaluation of writing.
ME 4054W	Instruction on maintaining a design notebook, writing technical memos, writing group-authored design reports, communicating among a distributed team. Formal and informal evaluation of writing including review of drafts.

Table 1. Writing instruction targeted for three core courses.

Courses where writing is valued without commitment to explicit writing instruction include the required and elective engineering science courses that are problem set based. Students in these courses are provided with instruction in how to write a problem set and expected to deliver problem sets that meet department expectations for communication. The other set of courses in this category are the senior lab courses. Here students are provided with resources on keeping lab notebooks and writing lab reports, which they learned in the pre-requisite core writing course ME4031W. Instructors in the lab courses make it clear that excellent communication in reports is essential for success.

A set of discipline-specific style guides was developed to assist students and instructors in assignments that involve writing (Figure 7). The guides include writing problem sets, writing lab reports and writing design reports. The guides are non-course specific and can be used in any course that requires the genre covered by the guide. While much of the material in the guides can be found in numerous technical writing books, the value of creating our own guides is that they can focus on what is most important to mechanical engineers and they send the message that writing is important in mechanical engineering.

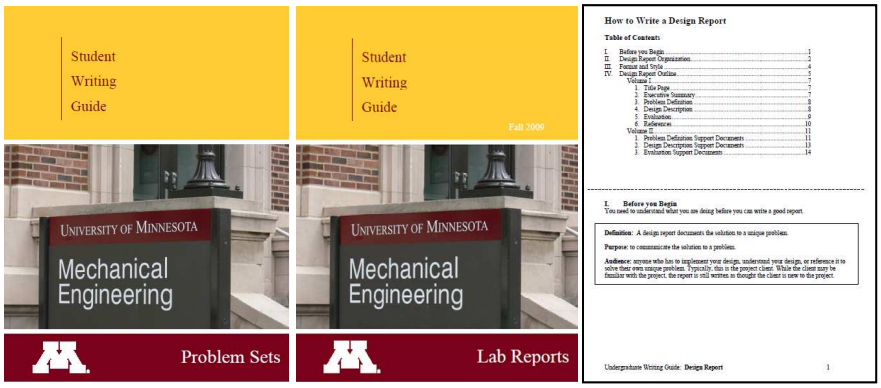

Figure 7. Three mechanical engineering style guides.

The writing program recognizes that while the expectation for high quality writing in a course is set by the faculty member in charge, the majority of the assessment of student work is done by teaching assistants (TAs) who for the most part are evaluating student work for technical content. Therefore, training in the goals of the department writing program and in how to assess problem

sets, lab reports and design reports for communication, and an introduction to the department style guides is provided to all department TAs during the required TA orientation session that occurs at the start of every semester. A department Writing Standards web site was established and contains a statement on writing, the department writing program, style guides and instructor resources. (*http://me.umn.edu/education/undergraduate/writing.shtml*).

3.4. Assessment

Assessment of the project's success related to its impact on the improvement of student writing is still in the early stages of data collection and analysis. For example, in Spring 2010, a baseline measure was taken of capstone design project reports. The evaluation team consisted of one mechanical engineering faculty (a disciplinary "insider") and two experts in college-level writing (disciplinary "outsiders"). Design reports were rated on a two point scale (“sufficient” or “insufficient”) using criteria derived from the list of desired writing abilities. Included in the results were that students were most successful in applying knowledge of physics, mathematics and engineering to their writing (rated sufficient in more than 80% of the samples) and least successful in summarizing key points (rated sufficient in less than 40% of the samples).

Every six years the mechanical engineering undergraduate program goes through a comprehensive ABET accreditation process, which involves self-study, a site visit and implementing a process of continuous assessment and improvement. ABET accreditation requires that the program have a set of published educational objectives and outcomes for the program, and a documented assessment process that demonstrates that the objectives meet the needs of stakeholders and that the objectives are being attained. Several of the ABET-required program outcomes are directly or indirectly connected to the department writing program, including objective (g), an ability to communicate effectively. For example, in a previous self-study, faculty in the department felt that objective (a), an ability to apply knowledge of mathematics, science and engineering, was not adequately achieved in the capstone design course as evidenced by sampling design reports. This led to an increased emphasis on analysis-driven design projects and an explicit requirement to document the design in the report. Writing ability 1, “apply knowledge of physics, mathematics, and engineering in their writing”, comes directly from ABET objective (a), and is assessed in the same way, by sampling design reports from the capstone course. Evaluating the ability of students in the major to communicate is a natural part of the ABET evaluation process.

4. Conclusion

While the results from formal program assessment are emerging, several conclusions were drawn from experience with the writing program and process. First, all stakeholders recognize that writing is important in mechanical engineering and all stakeholders are motivated to improve the writing skills of mechanical engineering students.

Second, it is possible for a faculty to come together for informed discussions about writing and to develop a writing program, despite the normal resistance of engineering faculty to teaching writing. The reason is that the WEC program process is discipline specific and faculty centric. Faculty determine the writing abilities and faculty determine the means used to ensure students

attain those abilities. Because faculty are sensitive to their own work load the list of desired writing abilities resulting from the process are limited, important and realistic.

Third, while mechanical engineering will never devote overwhelming resources to writing instruction, effective teaching and learning can be achieved with incremental, low-cost, low-effort steps such as style guides, TA training and sending a consistent message to students that writing is important.

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