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Making Communication Matter: Integrating Instruction, Projects and Assignments to Teach Writing and Design

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ABSTRACT

An integrated technical writing and design course has been developed at Rowan University. This course was developed using aspects of project-based learning and recent discussions about design education, as well as pedagogical approaches from the write-to-learn and the writing in the disciplines (WID) movements. The result is a course where the writing and design instruction are highly integrated, resulting in improvements in both technical writing and engineering design.

Keywords: technical writing, design, project based learning

INTRODUCTION

Before and after the release of the ABET 2000 [1] document, the importance of both design [2,3] and communication [4–6] in undergraduate engineering curricula has increased. In many cases, instruction in these two subjects has been integrated [7]. An integrated approach makes sense, as design projects provide an obvious context for technical writing. Likewise, the so-called professional

skills that were incorporated into the accreditation criteria have led to the adoption of project based learning (PBL) into many engineering curricula prior to the capstone design experience [8–10].

An integrated, project-based design and technical writing course, Sophomore Engineering Clinic I (SEC I), has been taught at Rowan University since 1997. The faculty at Rowan University quickly found that it is relatively straightforward to develop writing assignments that are based on design or laboratory projects that mimic professional final reports. However, the faculty also found that writing assignments that were developed to merely represent completed projects or milestones send the message that communication is something that happens only after design is completed, thereby making communication secondary. Compounding this, the design component in SEC I culminates in the testing of an actual artifact. While final testing helps to motivate design instruction and to instill desirable professional attitudes, a physical test or competition can serve to further diminish the importance of writing in the minds of engineering students. Some students explicitly state feelings along the lines of "Why do I have to write about my design? There it is, and it worked—isn't that good enough?"

Given that there are indeed natural connections between design and technical writing [11], how can they be taught in an integrated manner to take advantage of these connections, and allow the students to perceive both aspects to be equally important? Engineering and Writing Arts faculty at Rowan University recently have significantly refined SEC I to address this issue. The first cohort to go through the course with its most significant changes graduated in May, 2008, allowing the effect of these changes to be assessed later in the curriculum. In its current incarnation, the instructional framework of SEC I allows the writing instruction to complement and reinforce the design instruction and the design instruction to support the writing instruction. As a result, the design and writing instruction are equal and inseparable. While many aspects of the course are rooted in well known design, writing and engineering educational practices, several aspects of the course and how it relates to the rest of the engineering curriculum make it a unique offering. This paper will present details on the instruction, projects, assignments and feedback mechanisms that will allow aspects of this approach to be adopted at other universities.

PEDAGOGICAL BASIS

Our approach is rooted in several bodies of research on engineering and writing pedagogy. Project-based learning (PBL) serves as the framework for both design and writing instruction. Models for design thinking have influenced the selection and framing of the projects, as well as guided classroom design instruction. The *Write to Learn* model [12] provides a means to link design and writing instruction beyond writing to represent final designs. The *Writing in the Disciplines* (WID)

movement [13,14] informs instruction on particular engineering conventions in the course. These topics are discussed briefly in this section, with particular emphasis on how they have influenced the development of SEC I.

Project-Based Learning

After widespread reform in the accreditation requirements introduced in 2000 [1], many engineering programs adopted project-based learning (PBL) into their curriculum prior to the capstone design experience [8–10]. In addition to addressing many of the professional skills listed in the ABET A-K objectives, PBL allows technical topics to be reinforced through active learning and may help with recruitment and retention of students [15]. PBL has become a popular format for freshman-level introduction to engineering courses [15]. Indeed, PBL has been a hallmark of the entire four-year Rowan University engineering curriculum [16].

SEC I instruction has several characteristics that are typical of PBL, namely:

- open-ended design projects;
- hands-on learning experiences;
- teamwork;
- testing of a constructed artifact as a culminating activity.

Design Instruction

Through both formal and informal assessment, the SEC I faculty have concluded that having students work on design projects is not sufficient to develop good designers. Some personal observations of this are discussed in previous articles [17–19]. Many of these observations coincide with those of Schön [20]. In summary, without explicit design instruction, most students were successful at building artifacts that sufficed, yet few showed evidence of a thoughtful design process that led to an optimal solution.

A model of design as an alternating series of convergent and divergent thinking processes presented by Dym, et al., [15] has influenced design instruction at Rowan. The instructional approach makes students explicitly aware of convergent and divergent thinking. Understanding this model, and developing the corresponding vocabulary, empowers the students to reflect on their own designing. Writing assignments in the course explicitly require students to identify and articulate their design process. The effect of incorporating the convergent-divergent thinking model into SEC I has led to:

- a systematic approach to design instruction;
- an explicit language that allows students to write about their designing as well as to describe their designs;

- a strong link between writing and designing.

Write to Learn

As many researchers and scholars have argued, effective communication is far more than the clear and correct presentation of data and conclusions; rather, communication can both reflect and facilitate the other thought processes involved in engineering work [12,21]. At Rowan University, like many other institutions, technical communication educators increasingly collaborate directly with engineering educators to develop innovative technical writing instruction that emphasizes thinking and writing as engineers throughout the design process [22,23].

A central tenet of Write to Learn (WTL) pedagogy is that students learn about content areas by writing about content areas [13]; in other words, students can learn about engineering design by writing about engineering design. However, to fully utilize the WTL approach, it is essential that students are given a conceptual model or design with which to frame their writing. In this sense, the convergent-divergent model serves two purposes: to help students design; and to help students write about, and therefore reflect on their designing. The resulting integration not only improves students' conceptual knowledge about engineering, but develops their awareness of the importance of writing at all stages of the design process.

Write to Learn principles are reflected in SEC I via:

- Informal homework in lab;
- Written homework in lecture—individual or collaborative, sometimes in a wiki;
- Record keeping in lab notebooks;

Writing in the Disciplines

Closely related to the Write to Learn movement are Writing in the Disciplines (WID) and Writing Across the Curriculum (WAC); while WTL activities are useful for increasing students' content knowledge and improving record keeping practices, WID pedagogy actually provides a framework for communicating as engineers by introducing students to the writing conventions of the engineering disciplines. As noted in the WAC Clearinghouse, "Even though students read disciplinary texts and learn course material, until they practice the language use of the discipline through writing, they are less likely to learn that language thoroughly. [24]". Writing assignments based on specific disciplinary genres and conventions—like engineering reports—provide students the opportunity to use the rhetorical practices of their chosen field while simultaneously reinforcing their knowledge of engineering content.

SEC I students learn that engineers need to write in engineering-specific genres to be true members of the profession [25]. Writing in the Disciplines is apparent in the following SEC I practices:

- Genre-based assignments typical of academic engineering writing, such as white papers, that include the multiple citation styles used in engineering research;
- Genre-based assignments common in engineering practice—specifically project progress and final reports;
- Instruction in disciplinary communication skills such as data analysis and presentation; students are given specific instruction in CAD and on using diagrams, graphs and tables (with informative captions) to convey information effectively;
- Guidance in identifying and using the rhetorical markers of engineering writing such as report format, professional ethos, and data-based persuasive strategies.

INSTRUCTIONAL FRAMEWORK AND CONTENT

This section provides details about the instruction in SEC I at Rowan University; specifically, the context of this course, course objectives, design projects, writing assignments, and classroom activities are discussed.

Rowan University is a public university located in New Jersey. The College of Engineering, founded in 1996, created a curriculum that, from the start, was informed by the same type of discussions that led to the current accreditation criteria [26]. The curriculum incorporates an eight-semester sequence of project-based learning courses, called Engineering Clinics. Rowan strives to adopt, or in some cases has pioneered, the best practices in the field of engineering education.

As a result of the innovative curriculum, engineering students at Rowan enter SEC I with a unique background compared to students beginning integrated design and writing courses at many other institutions. Students enter SEC I having had a college composition course, a freshman level introduction to engineering course (Freshman Engineering Clinic I and II), and are concurrently enrolled in core disciplinary courses such as Principles of Chemical Processes (Chemical Engineering students), Statics (Civil and Environmental, Mechanical Engineering students), or Electronics (Electrical and Computer Engineering students). As such, the sophomore students in this class begin with sound basic writing skills such as audience awareness, organizational strategies, and syntactic control, some engineering background, as well as experience working on open-ended problems in a multidisciplinary team setting. However, they do not have much experience writing in engineering-specific genres.

The four-credit SEC I is team taught by faculty representing all four programs in Rowan's College of Engineering and the Writing Arts program in the College of Communication. Two lab sections, each with approximately 60 students, meet once a week for three hours with the five engineering

faculty. Instructional formats include formal lecture, Matlab tutorials in a computer lab, hands-on project time, and informal faculty-team interaction. Six writing sections, each with approximately 20 students, meet for seventy five minutes twice a week with faculty from the College of Communication's Department of Writing Arts. The writing sections are divided between at least three writing faculty. Each Writing Arts faculty member designs his/her own class meetings and develops in-class activities. All writing faculty assign the same projects, use the same rubrics, and collaborate with the engineering faculty on course goals, assignment design, and course administration.

The next course in the engineering clinic sequence is Sophomore Engineering Clinic II, which focuses on oral communication and advanced design, i.e., problem framing. In the Junior and Senior Engineering Clinics, student teams work closely with faculty advisors on externally sponsored projects. As such, the eight-semester clinic sequence guides students through progressively less structured, and more realistic project-based-learning experiences.

Course Goals and Objectives

SEC I has four main objectives. The first three relate to developing effective technical writers in professional contexts: first, students must assess the rhetorical situation and determine the appropriate approach to communication; second, students must be familiar with various genres and conventions of engineering; third, students must be able to utilize various rhetorical skills and apply them strategically. The fourth relates to developing effective designers. These main objectives are listed below, with some detailed objectives under each main objective. The detailed objectives were identified based on specific ABET requirements, the integration of SEC I with the rest of the curriculum, and needs of industry.

Students will demonstrate rhetorical awareness.

- Present technical information to different audiences
- Analyze the audience and account for competing and/or overlapping needs of different readers
- Select the best way to address audience and context needs for a given communication task

Students will write in the various engineering genres and follow appropriate conventions.

- Write effectively in engineering genres such as progress reports and final reports
- Use conventions of academic writing in engineering (such as IEEE citations)
- Use engineering databases in library and internet resources

Students will demonstrate specific communication abilities needed for engineering communication.

- Develop skill with technical writing tasks such as description
- Understand the importance of data presentation, data usability, and ethics

- Produce effective writing in a short time period
- Collaborate with team members

Students will demonstrate effective design processes.

- Generate multiple engineering design solutions using convergent and divergent design processes
- Apply sound engineering principles to choose the best solution, and see it through to compltion
- Use parametric design to optimize an artifact or process

The objectives for all four goals are assessed by way of students' writing. The SEC I faculty team sees these goals as a means of socializing students into the engineering field. The clinic begins the socialization process by teaching students that "good writing" is different in engineering than it is in College Composition I and that content is only *one* of the key differences. On the one hand, the course employs Write to Learn strategies which require students to write to remember and synthesize material, typically in informally assessed writing assignments. Often, students write to solve problems or to analyze complex situations relating to their designs. On the other hand, Writing in the Disciplines pedagogy emphasizes the socialization processes that students undergo to become full-fledged members of a discipline—learning, for example, the disciplinary genres and standards for evidence, data display, and rhetorical effectiveness [27]. As our assignments will illustrate, students are introduced early to complex engineering genres, such as the project final report, that facilitate what Carter, *et al*, describe as disciplinary socialization [27].

As projects become more complex in subsequent Clinics, they become more difficult to write about. The expectations of student writing increase throughout the rest of their undergraduate careers and will continue to do so throughout their professional practice. In this sense, SEC I is thought of as a course where students *begin* the process of becoming better technical writers, rather than a course where students learn to do technical writing.

Because the writing instruction does not merely parallel the design instruction, all faculty must have a strong understanding of what the students are writing *about* to provide feedback regarding accurate and precise technical writing, in addition to rhetorical effectiveness and mechanics. To ensure quality feedback to students, the engineering faculty team works closely throughout the semester to ensure that writing faculty have a thorough understanding of the design concepts students are learning. Writing faculty can then incorporate examples and handouts from the lecture into the writing classroom. Similarly, engineering faculty reinforce the importance of writing in their lectures throughout the semester.

Design Projects

In its current incarnation, SEC I, students participate in two increasingly complex projects. The first is a rocket project. The second project was a crane project from 2005 through 2007. Prior to

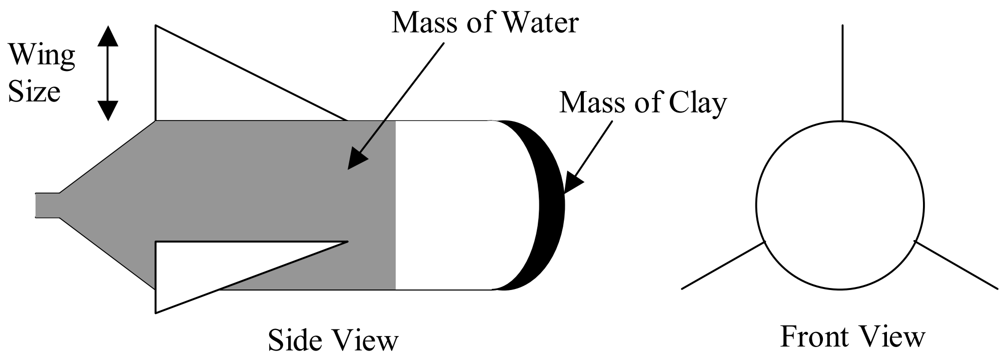

Figure 1. Schematic figure of bottle rocket with three design parameters identified. "Wing size" may be the height of the wing, its aspect ratio, or any other parameter.

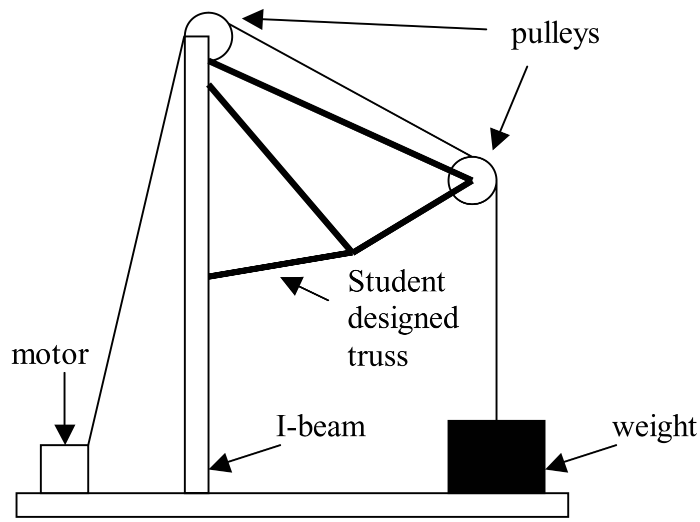

Figure 2. Schematic figure of a crane. The motor, I-beam and weights are provided; students design and build the truss structure.

fall 2005, students spent the entire semester working on the crane project. In 2008, a new project, based on a wind turbine, was introduced as the second project. These projects were described in detail by von Lockette, *et al*. [18], Dahm, *et al*. [17], and Bakrania, *et al*. [28], respectively. Brief descriptions of the projects, adopted from these references, are given below. These projects are the focus of much of the writing in SEC I, and are used to give example to explicit design instruction. As these two projects are an introduction to design, faculty provide explicit framing for both

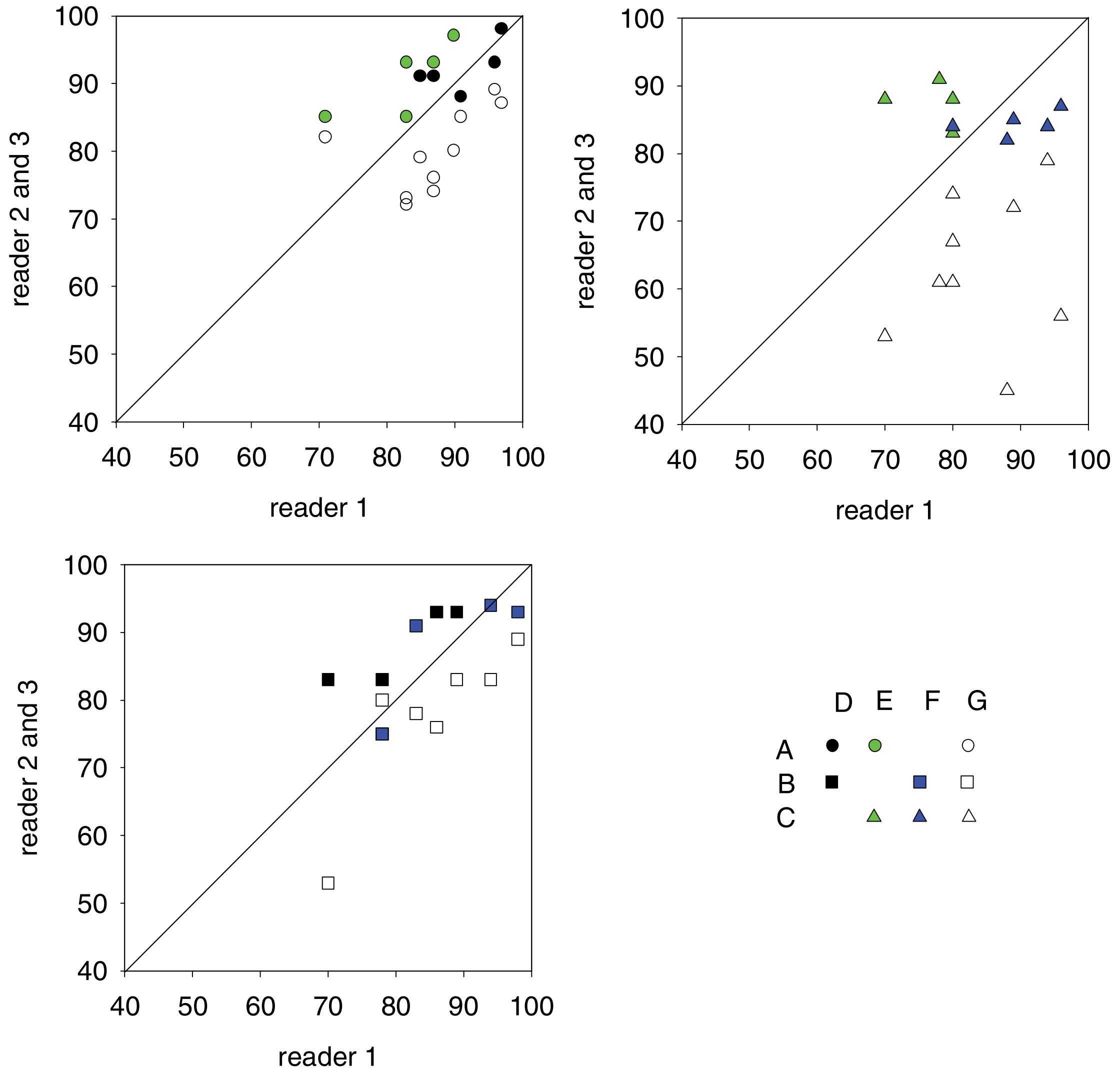

Figure 3. Correlation between evaluation of readers 1, 2 and 3 for final reports in Fall 2007. In all cases, Communication faculty (A,B,C) served as reader 1, and Engineering faculty (D,E,F) served as readers 2. A single Engineering faculty (G) served as reader 3 for all reports.

projects. For example, a single objective is clearly defined for these projects. In the rocket project, designs are evaluated based on the distance the rocket travels. In the crane project, designs are evaluated based on an equation (largely dependent on strength to cost ratio) that is provided to the teams at the start of the project. Initial framing, including developing constraints and criteria

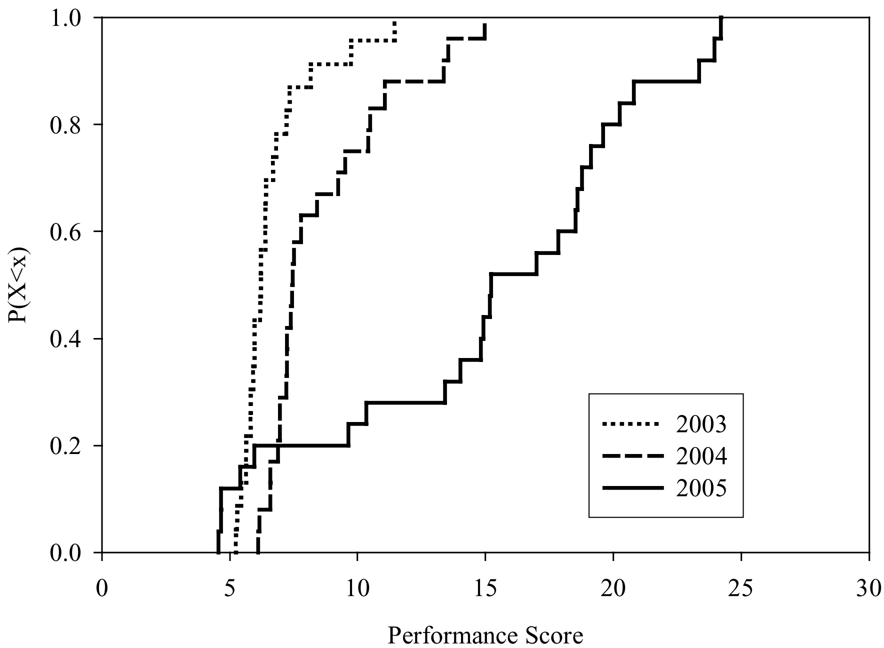

Figure 4. Performance scores for the Hoistinator (crane) project over a three year span [33, 34]. Significant changes to design instruction were made in 2005.

are addressed during a third project, which is given in Sophomore Engineering Clinic II in the spring semester. Motivation for switching the second project to the turbine, as well as some of the logistics of switching, has been discussed by Riddell, *et al*. [29].

For the first four weeks of SEC I, teams work on the bottle rocket project. In this project, students use 0.25 inch thick foam board, duct tape, a 2 liter soda bottle, modeling clay and water to design rockets that can be launched from a nozzle by using pressurized air. This concept has been used at other universities to teach core engineering principles [30], and NASA has proposed standards and lesson plans to use for grade 5–12 students [31]. The fundamental idea has been adopted to introduce parametric design in the context of the Rowan approach to design instruction.

In the first lab period, student teams design a rocket that can fly as far as possible. Initially, the teams are limited only by the materials and set air pressure for launching. In the second lab period, students are given a new, but highly constrained design challenge, and have three weeks to develop their designs. Student teams are asked to select a single family of wings (their choice) that is characterized by a single parameter—for example, triangular wings with a fixed aspect ratio, but variable height. The teams are limited to using exactly three wings belonging to the chosen family, mounted

120° apart, and placing the modeling clay in a mass at the front of the bottle. A schematic figure of a rocket is shown in Figure 1. The constraints on the design create a well-defined, three-dimensional design space that is defined by wing size, the mass of clay, and the mass of water put in the rocket. Guided by basic physical models, teams vary the three parameters and use experimental data from tests to converge on their optimized design. Since there are no requirements on the distance that a rocket must travel, and travel distance is not considered in the grading, every single design will suffice. This helps to emphasize the importance of following a process to optimize the result, rather than merely achieving a final design.

The second project was the crane or "Hoistinator" project. Student teams have ten weeks to design and construct a truss made of aluminum and plastic bars that the students attach to an existing I-beam. A schematic figure of a truss is shown in Figure 2. A three-horsepower motor, a cable, and a series of pulleys are used to lift weights. Student teams are allowed three chances to lift weights, ranging from 280 to 1400 pounds. The greatest weight that is successfully lifted is counted. The students' crane designs and lifts are graded based on an explicit performance equation that is varied slightly each year but is largely driven by strength to cost ratio.

One tradeoff that has been carefully considered is whether to re-use design projects or run a new project each year. Running a project that has run before has several advantages over running new projects. Re-using projects allows physical infrastructure, as well as writing assignments and rubrics to be re-used. A project that has been run before tends to have fewer problems and unpleasant surprises than a new project. Furthermore, the integrated approach employed in SEC I requires all of the faculty involved in teaching the course, including the writing arts faculty, to develop a reasonable background in the subject matter, and using a new project each semester would discourage this. A potential pitfall of running the same project for several years is that students would learn and copy designs from previous years. While this is a concern, it does not appear to have led to problems in SEC I for several reasons. The performance of the rocket is not considered in the students' final grade – only the design process, as documented in their written deliverables. While the performance of the second project does affect students' final grades, it is still essential that teams can discuss the design process in the corresponding deliverables. Furthermore, specifications of the project are varied each year. The performance equation for the crane project was varied each year from 2003 through 2006. The moment arm resulting from the distance from the weight to the I-beam was increased by 50% for the 2007 challenge, resulting in very different final designs. At Rowan University, projects for freshman and sophomore engineering clinics tend to be run several years, whereas projects for junior and senior engineering clinics tend to be new each year. The critical difference is that for the first two years, the scope of the clinics are carefully orchestrated for pedagogical reasons, while in the last two years, the authentic experience is more important.

Writing Assignments

In earlier offerings of the course, the goal of the writing assignments was to develop accurate and precise representations of designs at various stages in the design process. In the current offerings, writing assignments are also used to reinforce explicit design instruction. Students write to better learn course content and to gain experience communicating in engineering genres. For many students, this is extremely challenging, as they prefer to "just build the crane" or to otherwise show their understanding in a form not involving words. Over the course of the semester, students complete between three and four project-specific deliverables, some collaboratively and some individually written. Typically, in each project-based deliverable, students must demonstrate design skill, audience awareness, genre awareness, and data display facility. In addition to deliverables about the bottle rocket and crane, students also complete two to three deliverables designed to teach disciplinary research methods and discourse, such as a white paper on a sustainability-related topic. Specifics on each deliverable are provided below.

Team Wiki: Use of a wiki, a website that all team members can edit, was established in the 2007 offering of SEC I. Throughout the design projects, students maintain team accounts of design activities via their wikis. The wikis function largely as design notebooks, and provide space for students to work on collaborative reports, pool research and project notes, and communicate with one another. Because much of the course grade is based on the quality of deliverables, the wiki serves as a cache of data essential for successful report writing. Wikis are graded on the basis of the quality of the documentation and the level of collaboration exhibited.

Team Charter: Guiding principles for team work are articulated at the beginning of the crane project by the student teams. This assignment reinforces basic principles of teamwork that were introduced in the freshman year and may help to reduce conflicts throughout the semester. Writing instructors provide guidelines for the content of team charters, including team meeting schedules, ground rules, and team member skill "inventories," but generally allow teams to customize the tone and level of detail to reflect the working relationship they want to cultivate.

Progress and Final Reports: These major deliverables have multiple functions. An assignment sheet for the final report is included in Appendix A. In these reports, student teams are asked to perform several different types of writing tasks. Some tasks are typical of reports that are written in professional practice: technical descriptions, presentation of data and calculations, and project management assurances. Other writing tasks are intended to help students reflect on their designing: identification of key decision points, basis for decision making, and types of thinking required at various stages of the design process.

White Paper: students explore an issue related to engineering—in recent years, all students have looked into sustainability issues—and craft a white paper that argues for a conceptual solution.

Because many students do not yet have the technical background to solve the problems they are investigating, the success of the white paper hinges on their ability to analyze the problem, articulate its elements within a research context, and evaluate possible solutions, concluding with an argument for the most feasible or desirable. Students also learn about documentation styles and research conventions in engineering.

Resume: students typically apply for internships beginning the summer after their sophomore year; in SEC, students learn how to craft an "academic" resume that showcases the collaborative, multidisciplinary project experience they have gained through their coursework, especially SEC, as well as highlights from course work and community service.

And, as we describe below, all faculty respond to student writing, not just the Writing Arts faculty. The various levels of expertise and thoroughness of the readers forces the students to write for various types of readers simultaneously – just like in professional practice.

Classroom Activities

While each instructor is responsible for shared course content and for ensuring that students across sections have a commensurate experience, approaches to instruction can vary. In the Fall of 2007, we began allocating 10% of the students' final grades to be based on individual writing instructors' criteria for homework, in-class activities, and reading responses in the writing section. Students in one section may, for example, keep a blog or wiki dedicated to course readings on engineering innovation, whereas students in another section might have a series of stand-alone, team-based activities based on real-life communication problems.

Writing instructors work particularly closely with students on audience awareness and genre conventions. When discussing the expectations for a progress report, for example, students might be asked to role play three different report readers and to parse the readers' needs, background knowledge, and disposition. Then, students might craft a strategy for their progress report that articulates how they will satisfy each reader—with visual data, clear subheadings, or appropriate professional tone. One frequent topic of discussion—and a clear example of how disciplinary writing differs from general academic writing—is the role that narrative plays in recounting project progress. Many students describe project milestones within a larger project narrative because narratives tend to be a "default" way of structuring information; the SEC emphasizes more appropriate ways of representing progress in an engineering report that are data, rather than "story," driven.

EVALUATION OF STUDENT PERFORMANCE AND FEEDBACK

In SEC, feedback on deliverables is viewed as a form of instruction—not simply as a formality that occurs after the work is "done." Students are expected to integrate feedback on both technical and rhetorical aspects of their project in subsequent deliverables. This section discusses how feedback is given on written deliverables, how all deliverables are considered in a final grade for each student, and how the eight faculty teaching the course maintain consistent grading standards.

Feedback on Assignments

Student writing is evaluated using detailed rubrics so that students understand the expectations for genres they are likely quite unfamiliar with. Students are provided with these rubrics at the time the assignments are given. As examples, the rubrics used to evaluate the final report in 2007 are shown in Appendix B. For the assignments that are tied to the design projects, the rubrics are based on four main objectives stated earlier in this paper. The white paper and the resume are not directly tied to the design project and consequently do not include the design-related objective. Under the heading of each objective, specific indicators for that objective are given. The specific indicators vary for each assignment. The assignments that are specifically related to the design project are graded by multiple faculty members. To reinforce the notion that writers must account for different types of readers in the same document, faculty are given specific tasks, and use different rubrics, when evaluating reports. For example, in the final report, one communication faculty (reader 1) reads the report, but not the appendices. Engineering faculty serve as the second and third readers to evaluate each report. The second reader reads the entire report and double checks sample calculations and data presented in the appendices. The third reader reads only the abstract and the conclusions, and looks at figures and tables (including captions). The three perspectives are intended to represent the spectrum of readers that engineers must write for – those who will read thoroughly, those who want key data and drawings, and those who will skim around, looking for information. The weighting of various objectives of the final crane report for three different readers are summarized in Table 1. Note that, although the readers may have been evaluating the same objectives, the specific indicators for each objective may vary for each reader.

Developing a Final Grade

Students in SEC I are evaluated in multiple areas: written deliverables, design performance, and professionalism, with the bulk of the grade dependent on written deliverables. Some writing is collaborative (team-based) while some writing is individual. As examples of weighting given to the various assignments, rubrics for the final grades that were used during the 2006 and 2007 offerings

	Weighting		
Objective	Reader 1	Reader 2	Reader 3
Demonstrate rhetorical awareness	25%	25%	50%
Demonstrate specific communication abilities needed for engineering communication	15%	15%	50%
Demonstrate effective design processes	35%	35%	
Follow appropriate conventions	15%	15%	
Demonstrates effective communication and teamwork (on wiki)	10%	10%	

Table 1. Weighting for various aspects of final report for three different readers.

	% of grade	% of grade
Individual Deliverables	40	
Rocket Project Report		10
White paper		15
Crane progress Report 2		10
Resume		5
Crane Project Team Grade	50	
Crane Progress Report 1		10
Final Report		20
Crane performance		20
Professionalism	10	

Table 2. Sophomore Engineering Clinic I Grading Rubric for 2006.

are given in Tables 2 and 3, respectively. Note that the actual performance of the rocket in the first project is not considered in the student's grade in either year. These are similar to the assignments and rubrics used in the past, and are likely to be similar to rubrics that will be used in future offerings of SEC I. Each semester, the exact deliverables vary a bit, and we have recently added additional written components, such as the team wiki, which, while not calculated into the final grade individually, do impact performance on project-based deliverables, such as the crane progress report, that require significant data analysis.

Evaluation of teamwork is largely on the basis of peer evaluation. Each team member fills out a peer evaluation form, as recommended by Kaufman, Felder and Fuller [32]. These peer evaluations are used to modify the team grade to account for individual contributions. Students normally receive 100% of the grade earned by the team on team-produced deliverables, but this weighting factor may be adjusted upward or downward depending on the actual level of contribution by an individual. The final 10% of a student's grade is for professionalism. A default professionalism grade is calculated from the weighted average of the individual's performance on the rest of the course. In most cases, this default grade is used, which means that professionalism does not affect a student's grade. However, in some cases (approximately 10%), the professionalism grade is adjusted either up or down.

Maintaining Consistency

One difficulty in managing a class that is co-taught by three communication faculty and five engineering faculty is to maintain consistent standards for grading. To ensure that grading standards are consistent between faculty, grades from multiple readers are plotted against each other as shown in Figure 3. In other words, a graph is constructed for the two sections taught by each communication faculty. Each report in those two sections is a single data point (for assignments with two readers) or two data points (for assignments with three readers). The x-axis is the grade from the communication faculty. The y-axis is the grade from the engineering faculty. Perfect agreement between readers results in a straight line with a slope of one. While it was not expected that the grades of reader 1 and reader 2 would match exactly, any significant differences were discussed so that the source of the discrepancy could be identified, discussed, and in some cases rectified. Despite the different points of view that the Communication and Engineering faculty might have when evaluating student writing, scores between reader 1 and reader 2 were in general agreement about the overall quality of the reports. The evaluations of reader 3, who was focused on the abstract, figures, tables and conclusions, often did not agree with the evaluations of readers 1 and 2. In many cases, these were consistently below the evaluations of readers 1 and 2. Based on this observation, the faculty have made a commitment to place extra emphasis on these aspects of technical writing.

	% of grade	% of grade
Individual Deliverables	30	
Rocket Report		10
White paper		15
Resume		5
Crane Project Team Grade	50	
Crane Progress Report 1		10
Final Report		20
Crane performance		20
Writing Instructor Criteria	10	
Professionalism	10	

Table 3. Sophomore Engineering Clinic I Grading Rubric for 2007.

ASSESSMENT OF INTEGRATED APPROACH

The integrated approach described in this paper was largely adopted in the fall 2005, although additional changes, such as incorporating different rubrics for different readers and the wikis, have been made in subsequent years. There have been several opportunities throughout the curriculum to assess the lasting impact of the initial changes to the design and writing instruction by comparing the performances of the last cohort to pass through the previous version of SEC I to the performances of the first cohort to pass through the new version of SEC I, who graduated in May 2008. The two cohorts both worked on similar crane competitions in SEC I and II in fall 2004 and fall 2005, respectively. Approximately half of each of the two cohorts worked on similar projects in spring 2005 and spring 2006, respectively. Finally, the ChE students in the two cohorts worked on similar senior capstone design projects in spring 2007 and spring 2008, respectively. Comparing the performance of the two cohorts in otherwise similar design projects provided opportunities to assess the effect of the changes implemented in fall 2005, namely, the 4 week project to introduce parametric design, discussion of the convergent-divergent framework for design, and incorporating reflection on design theory into the writing assignments. Since then, the design projects themselves have been changed so that assessment between years is not appropriate, making it difficult to fully assess later changes such as multiple readers or incorporation of the wiki. Furthermore, it is not clear whether it was the change in design instruction, or the integration of design and writing that led to the observed improvements. However, the results do suggest that the new framework has been effective in improving students' perceptions of SEC I, their ability to design, and their ability

to write. These assessments are discussed in detail elsewhere [33, 34, 35] but summarized in this section.

Student Perceptions

Course assessment at the end of the 2004 and 2005 SEC I offerings demonstrated improvements in student's perception of the course. Specifically, students response to the statements "this course assisted me in developing multidisciplinary engineering design skills," and "This course helped make me make the link between engineering design and writing" both improved, as shown in Table 4.

Design Performance

Student performances have improved as well as their perceptions. A cumulative density function plot of Hoistinator performance scores from the fall 2003, 2004 and 2005 semesters is shown in Figure 4. The fall 2005 semester was the first year that was taught with the revised design content. To ensure consistent comparisons, all scores on this plot are using the 2004 performance score. There is a slight improvement in the scores from 2003 to 2004. However, there is a significant improvement in the 2005 scores, even though these students were not aware of the 2004 performance equation. While it is likely that some improvement might come from student teams receiving advice from older students who had been involved in previous years and faculty

Question	Mean Response: 5 = strong agree, 1 = strong disagree	
	2004	2005
This course assisted me in developing teamwork skills	**3.82**	**4.32**
This course assisted me in developing multidisciplinary engineering design skills.	**3.70**	**4.06**
This course assisted me in developing project management skills	**3.93**	**4.24**
This course helped me make the link between engineering design and writing.	3.89	4.02
Number of respondents	104	108

Boldface indicates that the difference between 2004 and 2005 responses was statistically significant (95% confidence) for that indicator.

Table 4. Selected results of student course evaluations [33, 34].

Desired Outcome	2005	2006
Students design and conduct appropriate experiments that effectively use limited resources to obtain the necessary information.	**2.00**	**2.73**
Students demonstrate the ability to identify, formulate and solve engineering problems (ABET - E).	**2.31**	**2.90**
Students have the ability to use techniques, skills, and modern engineering tools necessary for engineering practice (ABET - K). Students apply fundamental principles of engineering to solve engineering problems.	2.17	2.83
Students demonstrate effective oral and written communication skills (ABET - G). Students will write effective documents including memos, e-mails, business letters, technical reports, operations manuals, and descriptions of systems, process, or components.	**2.04**	**2.83**
Number of Reports	9	12

Boldface indicates that the difference between 2005 and 2006 performance was statistically significant (95% confidence) for that indicator.

Table 5. Learning outcomes for Sophomore Engineering Clinic II, and mean performance of spring 2005 and spring cohorts with respect to each outcome (4= best, 1 = worst) [33, 34].

Desired Outcome	2007	2008
Students design and conduct appropriate experiments that effectively use limited resources to obtain the necessary information.	3.50	3.75
Students demonstrate the ability to identify, formulate and solve engineering problems (ABET - E).	3.25	3.75
Students have the ability to use techniques, skills, and modern engineering tools necessary for engineering practice (ABET - K). Students apply fundamental principles of engineering to solve engineering problems.	3.68	3.88
Students demonstrate effective oral and written communication skills (ABET - G). Students will write effective documents including memos, e-mails, business letters, technical reports, operations manuals, and descriptions of systems, process, or components.	3.25	3.67
Number of Reports	4	4

Table 6. Learning outcomes for ChE Senior Capstone Design, and mean performance of spring 2005 and spring cohorts with respect to each outcome (4 = best, 1 = worst) [35].

members developing more insight into the design process over time, it is likely that the year-to-year improvement resulting from these effects would diminish over time. However, the improvement that was observed between 2004 and 2005 was much greater than that observed between 2003 and 2004. This trend suggests that the improvements in design performance for 2005 did in fact result from the revised course.

Writing Performance

Reports from a spring clinic project that was run from 2004 through 2006 [35] were used to assess the effect of the modified instructional approach during the fall semesters. Reports from spring 2005 and spring 2006, the last year before, and the first year after the changes to the design instruction, were evaluated. The project was run essentially unchanged during these years. The reports were evaluated using rubrics that were designed to evaluate key ABET objectives and have been shown to be objective and repeatable [37]. Ten categories were identified from these rubrics as being applicable to the spring semester reports. The reports from 2006 were better than the reports in 2005 in every category that was evaluated. Many of the improvements were statistically significant to a 95% confidence level. The results from four categories, felt to be especially related to topics covered in SEC I, are summarized in Table 5. Similar evaluations were performed on ChE senior capstone design reports for the two cohorts [35]. These results are summarized in Table 6. Although the limited sample size precluded any results from being statistically significant, the trend of improved performance in the cohort that took the revised SEC I course remains. These results demonstrate that the revised version of SEC I has led to lasting improvements in engineering students.

Implications for Other Institutions

This course has been developed for a cohort of approximately 120 students. However, it is worth speculating on how this approach might scale up to accommodate larger cohorts, and how some aspects of the course could be achieved with relatively fewer faculty resources. The aspects of the course can be broken into instruction (both writing and design); laboratory and shop time; evaluation and feedback of technical writing; and course organization.

Technical writing sections of approximately 20 students are typical even for large universities, so larger cohorts would require more technical writing sections. As taught in SEC I, formal design instruction is closely interwoven with laboratory time, with multiple engineering faculty on hand throughout. While the authors consider this situation ideal, it might be necessary to reduce engineering faculty contact relative to the cohort size to allow this approach to be implemented at other institutions. For a larger cohort, it might be reasonable to have the formal design instruction

separated from the design laboratory experience, and presented to a large class of students in the form of a single fifty minute lecture once a week.

The design laboratory experience requires dedicated project space. Larger cohorts would likely require additional laboratory sections of design laboratory to keep the size near 60 students. The crane project places significant demand on the machine shop, especially near the end of the semester. It is likely that this demand would prove to be prohibitive for larger cohorts. A new project, based on a wind turbine has been introduced [28], which has completely eliminated the need for mid-semester machining.

A particular strength of SEC I is the significant feedback that students receive on their writing from both writing arts and engineering faculty. Unfortunately, providing this feedback does take time. A larger cohort would require one of the following: a corresponding increase in the number of engineering faculty; a greater portion of engineering faculty time spent grading (possibly offset by a decrease in accessibility during lab sections to keep workload comparable), or a decrease in the amount of feedback that the engineering faculty provide to the students.

Offering this course to a larger cohort would require a significant amount of coordination between multiple instructors. However, it is likely that it will become increasingly important to start with a well-defined pedagogical framework for both design and writing instruction as both the cohort size and the number of instructors increases.

CONCLUSIONS

The faculty at Rowan have adopted a model for teaching communication and design in an integrated manner. Students are presented with the concepts and vocabulary to understand their designing, and then asked to discuss their designing in written reports. In this sense, writing informs design instruction as much as design informs the writing instruction. Furthermore, the design projects are chosen such that they increase in complexity and duration, allowing students to master certain design skills before moving on to other skills.

While this approach has been challenging to implement and deliver, students benefit from such an approach both in terms of their engineering knowledge and in their rhetorical sophistication. While some aspects of the approach might depend on the Rowan University College of Engineering curriculum, elements of it can be incorporated into diverse curricula, we believe, with good results. As workplace demands and educational practices evolve, an integrated approach that reflects real-world practice and accreditation realities provides instructional flexibility that prepares students to succeed in fast-changing, communication- rich environments.

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AUTHORS

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Roberta Harvey earned her Ph.D. in English in 2001 from the University of Wisconsin-Milwaukee and is an Associate Professor in the Department of Writing Arts at Rowan University. She has been teaching writing in engineering for over fifteen years and has been part of the Sophomore Engineering Clinic team for ten years. She also teaches a writing course for biology majors and serves as Coordinator of the First-Year Writing Program at Rowan University.

Paris von Lockette has a strong interest in undergraduate education. This interest began while working as an instructor in the PREP program in San Antonio as an undergraduate himself. PREP provides introductions to college level physics and math for high school students who express an interest in engineering. Since his appointment at Rowan, he has co-authored papers for the proceedings of ASEE's Annual Conferences and attended workshops on effective engineering education. In addition to educational interests, Dr. von Lockette is an active researcher in the field of smart materials and structures.

APPENDIX A

Sophomore Clinic I • Fall 2007

Assignment 5: Final Design Report

At the conclusion of a design project, the actual deliverable is often not the physical object itself, but rather a detailed written account of the process and results. The final design report is usually addressed to a client and thoroughly explains the work that was done. Although your work this semester will also be represented by the crane and its performance, the final design report provides an equally important means by which your achievements in the course will be assessed.

Unlike your previous reports, which were written in memorandum format, this will be what is called a **formal report**. Formal reports are "formal" in two ways. Because the final design report is the final product, it has a very official look; it includes elements that enhance its presentation. Most final design reports are also quite long. Therefore, to make the report easier to read, it has a standard structure.

What makes a formal report "formal"?

- ❑ Official look
- ❑ Standard structure

This report will be **team-written**. You will need to work closely together to coordinate the various tasks of the report and make sure all the requested information is included. Designation of one or two people to manage production of the "master document" is recommended. Be sure you also arrange procedures for sharing information needed by other team members.

This report, like the rocket design report, will have one reader who reads only the executive summary and conclusions and looks at the figures and tables. Another engineering reader will read the entire report plus any appendices that are referenced in the main body of the report, and your writing instructor will read the body of the report but not the appendices.

Due Dates

This is due **Monday, December 17, at 4 p.m.** if you are in the **Monday** lab sections (1, 3, and 5) and **Wednesday, December 19, at 1 p.m.** if you are in the **Thursday** lab sections (2, 4, and 6). You will receive specific submission instructions from your writing instructor. Reviews of drafts are optional and should be arranged with your writing instructor and the engineering faculty as needed.

Purpose

The objectives of this assignment are for you to:

- Present a technical description of a final product
- Explain the design process that led to the final product
- Present and discuss performance results
- Compare your crane's actual performance to your predictions
- Offer conclusions about your process and performance
- Learn the conventions and standard components of formal reports
- Use figures and tables to present technical information
- Follow document specifications
- Organize the production of a formal team-written report

Report Sections and Content

Letter of transmittal

The letter of transmittal announces the delivery of the final report. It is a formal business letter, addressed to the recipient(s) of the report, that accompanies the final report and briefly explains what the report is and why it is being submitted. Letters of transmittal sometimes address special circumstances that are not covered in the report, highlight key findings or recommendations, and/or give further contact information. Address the letter to the Sophomore Engineering Clinic Faculty, or list all of the names, including your writing instructor. The letter of transmittal should be **signed by every team member**.

Cover page

Create a cover page showing the title of the project, team number and list of members, the name of the course, your section number and writing instructor, and the date submitted. You may also "customize" or embellish your cover page if you wish.

Executive Summary

Present a concise "stand-alone" explanation of the purpose of the project that includes **all essential facts** about the design problem and the design solution. Remember that, in addition to providing a preview of the report, the executive summary is also written for **readers who are not reading the body of the report**. Refer to relevant figures and tables in the text so they can be found with ease. Executive summaries are usually about 1/10 the length of the complete document. Include a heading for this section.

Acknowledgments

On a new page, identify and express appreciation for contributions made by persons other than your team members—for example, faculty you consulted or technical personnel who assisted you. Include a heading for this section.

Introduction

On a new page, explain what the report pertains to and how it is structured. Refer to particular sections and briefly indicate what is discussed. Include a reference to Appendix A, which will be the list of personnel and summary of team member contributions. Remember that the introduction is a **navigational guide** to readers who want to know what to expect and/or readers who may want to go directly to certain sections.

In formal reports, a heading should be provided for the Introduction. All subsequent sections, up until the Appendices, should also include a heading and continue on the same page as the preceding section. Subheadings should be used as needed to distinguish different content focuses within the major sections.

Design Process

This section reviews the design process with an emphasis on the thought process and the data that inform your final design. Begin with the definition of the design problem. Then describe the process by which you chose and optimized your final design. At the beginning of this discussion, you should refer the reader to the Final Design section and the figure showing your final design. In particular, identify the information you had available to you when you chose the truss family you optimized and explain the basis for your decision.

Include figures showing at least two other truss families that you considered; part of your discussion here should address the criteria and data that led you to **eliminate** these design possibilities. Explain the additional design work you undertook to further optimize your final design. Plots showing the data from your parametric studies should be integrated into this discussion and their impact on your final design should be explained. Additionally, provide the relevant parameters for the plastic that were measured on the MTS machine. One or more sets of data that you used to predict load-deflection relationships and failure load for critical plastic members would be helpful. The raw data that are presented on the wiki might or might not be appropriate for making your prediction. It is possible that you will need to consider the relationships between multiple sets of data to extract the pertinent information. Be sure to summarize and show all relevant data in figures or tables in the body of the report.

Final Design
Present a complete technical description of your final crane design, including structure, function, and materials. Include a table showing materials used and resulting cost of the structure. Be sure to point out design innovations that proved crucial to your crane's performance. This discussion must be accompanied by a SolidWorks side-view of your design with labels and dimensions for all major parts and all truss members. This figure should be a SolidWorks *drawing*, not a screen-shot of an assembly. Include a table of member forces for a defined load and identify which members are in tension and which are in compression. Additional figures, such as "close-up" views of selected parts, may be used where appropriate.

Results and Discussion
Summarize the results of your crane's performance at the final competition. Show all lifts and relevant data for each one. If appropriate, provide a qualitative description of your crane's performance as well. Use figures and tables where appropriate to effectively present results. Show the performance equation with final values included and calculate your final score. Compare your calculated projection of the crane's performance to your actual results and, if applicable, offer your conjectures about any differences. Compare your crane's design and/or performance to others you observed.

Conclusions
The conclusions provide further evaluation of and final reflections on the results, **not only for readers who have read the entire report, but also for those who are reading only the executive summary and the conclusions**. This section should begin with a summary of the results of the crane lifts and a review of the results of the performance equation. Summarize your comparison of the actual results to the expected results and provide your evaluation of the actual results according to a relevant performance criterion. Refer to any relevant figures or tables in the body of the report. Finally, discuss what you would do differently to optimize this design, and/or identify any sources of error that impacted performance

Appendices

A. List of personnel and summary of specific contributions to the project, including how individual tasks related to the overall goal and to tasks being performed by other team members

B. Structural and failure analysis calculations for your final design (must show free-body diagrams and sample or hand calculations in addition to Matlab results)

C., D., etc. Any supplemental material that some readers might want to see in addition to the essential data presented in the body of the report (specs not directly relevant to the design problem, preliminary sketches, raw data). A reader will not typically read your appendices from start to finish. Instead, a reader will read the main body of the report, and look for information in the appendices as needed. Be sure to refer to these appendices in the body of the report.

Document Specifications

A separate Style Sheet will be provided with specific format instructions.

Additional Notes

- Appendices should not include any material that is important for understanding the report. Essential material should be included in the body.
- Think of this report as a **final exam**. You should apply as needed all skills and knowledge you have acquired during the semester. Review lab and class handouts, your own previous reports, and your team notebook.

General Grading Criteria

Your grade will be based on your presentation of the final product and performance results, your insights into the design process, and your adherence to document specifications.

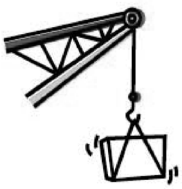
Please turn in 3 copies of this report.

Adapted from

The MIT Guide to Science and Engineering Communication
(J.G. Paradis and M.L. Zimmerman, 2nd ed., MIT Press, 2002);

A Guide to Writing as an Engineer
(D. Beer and D. McMurrey, 2nd ed., John Wiley & Sons, 2005); and

Scientific and Technical Reports—Preparation, Presentation, and Preservation
(National Information Standards Organization, ANSI/NISO Z39.18-2005)



Appendix B

Sophomore Clinic I
Grading Criteria for Assignment 5: Final Design Report on Crane Project

Demonstrates awareness of audience and purpose	**25**	
❑ Provides key information regarding the project goal, the design approach, and the design solution in the executive summary		
❑ Employs appropriate technical style and tone for designated audience; uses first-person **sparingly** and only where necessary for clarity		
❑ Includes appropriate level of detail in the body of the report for designated audience and genre; **does not assume that reader already understands what is being discussed**		
❑ Summarizes and evaluates performance results in the conclusion		
❑ Includes essential figures and tables of results in the body of the report; includes requested information in appendices and refers to it in the report		
Demonstrates ability to present technical information	**15**	
❑ Provides complete and logically organized technical description of crane, using specific dimensions, precise language, and correct terminology		
❑ Uses figures and/or tables effectively to highlight features of the design, including SolidWorks side-view, table of member forces, and table of materials and costs		
❑ Uses figures and tables effectively to show data that informed design optimization		
Demonstrates understanding of design practices and ability to apply specific design methods	**35**	
❑ Summarizes project goal and identifies parameters and constraints		
❑ Explains basis for choice of truss family and shows at least 2 ideas that were eliminated		
❑ Explains procedures for optimizing final design		
❑ Describes role of MATLAB in optimization, including how the program was used to determine the optimal truss within the chosen truss family and what steps were taken to verify that MATLAB results were valid		
❑ Explains how data were interpreted to make design decisions		
❑ Provides a quantitative prediction of the performance of the truss and rationale for the prediction and identifies assumptions made for purposes of analysis		
❑ Provides a quantitative comparison of lift results to predictions based on analysis; offers insightful failure analysis if applicable		
Demonstrates ability to follow document specifications and meet requirements	**15**	
❑ Organizes content according to specified subsections and follows appropriate conventions for each (content, tense, grammatical structure)		
❑ Follows document format instructions (including letter format, fonts, margins, labeling of figures and tables, and other specifications given in the **Style Sheet**)		
❑ Proofreads and corrects errors (spelling, grammar, punctuation)		
Demonstrates effective communication and teamwork	**10**	
❑ Shows evidence of collaboration, exchange, and contributions from all team members **(wiki and individual contributions section of report)**		
❑ Documents design project work, including ideas, data, and other requested content **(wiki)**		
Total		

Third Reader Only

Grading Criteria for Assignment 5: Final Design Report on Crane Project

Demonstrates awareness of audience and purpose	**50**	
❑ Provides key information regarding the design problem, the design approach, and the design solution in the **executive summary**		
○ Explains goal of project in terms of optimization and identifies how achievement of the goal was evaluated		
○ Identifies parameters and constraints		
○ Summarizes approach to optimization		
○ Provides relevant performance results to describe design solution and offers a measure of the project's success		
○ Refers to relevant figures and tables		
❑ Summarizes and evaluates performance results in the **conclusions**		
○ Summarizes optimization process		
○ Evaluates performance results by providing quantitative comparison of performance to predictions based on testing		
○ Offers conclusions about success of design solution		
○ Discusses how the optimization might have been approached differently and/or identifies sources of error that impacted performance		
○ Refers to relevant figures and tables		
Demonstrates ability to present technical information	**50**	
❑ Uses figures and tables effectively to highlight features of the **design solution**		
○ Provides SolidWorks side-view of the crane with labels and dimensions		
○ Shows table of materials and costs		
○ Shows summary of lift results		
○ Constructs figures and tables to maximize readability		
○ Includes concise, informative captions and labels as appropriate that allow figures to be interpreted independently of the report text		
❑ Uses figures and tables effectively to show data that informed **design optimization**		
○ Shows at least two figures of truss designs that were eliminated		
○ Identifies parameters of final design, including which were held constant and which were varied		
○ Illustrates relationship between data and optimized parameters		
○ Constructs figures and tables to maximize readability		
○ Includes concise, informative captions or titles as appropriate that allow figures and tables to be interpreted independently of the report text		
Total	**100**	