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# Student Communication Improvements during an Industry-Sponsored Civil Engineering Senior Design Course

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## Introduction

Throughout the engineering profession, an emphasis on requiring strong communication abilities for engineering graduates has been shown in several studies [1,2]. Because of the emphasis on communication in engineering practice, "an ability to communicate effectively" is a core outcome competency within the ABET required program outcomes [3]. In a recent study of engineering graduates, communication skills were ranked with teamwork, data analysis, and problem solving as the four most important ABET outcome competencies[4].

The objective of this study was to identify which aspects of student communication skills were improved by changes to an industry-sponsored capstone senior design course and to what extent they were improved. While previous studies have indicated that industry-sponsored capstone senior design courses improve student understanding of design practice, no study to date has focused on analyzing the extent to which this industry experience improves the communication ability of the students.

The civil engineering senior design course at Southern Illinois University Edwardsville (SIUE) places students in unpaid internships with local engineering agencies and companies. Practicing engineers supervising the students have discussed the importance of accurate professional communications with faculty coordinating the course. Students in this course are required to complete communication skills assignments, such as writing memos, reports, and preparing periodic progress presentations of their work. The communication assignments used as the subject of the study in this paper were reviewed by engineering faculty, in consultation with practicing professional engineering sponsors, and the staff at the SIUE Writing Center.

## Previous Work

### Overall lessons from past capstone courses

Previous work examining the learning in engineering capstone courses has focused on team-based learning, problem-based learning, and impacts of the learning environment. To improve student teamwork experiences in any course, faculty have an opportunity to apply a wealth of knowledge from fields such as organizational or industrial psychology [5]. Some argue that effective team-based learning in capstone courses require that teams be heterogeneous and have shared goals, meaningful activities, timely internal feedback, and external comparisons and feedback [6]. Thus, for faculty to facilitate an effective team-based learning experience, they must be very deliberate in the planning of team projects, milestones, activities, feedback methods, and timing.

Other research has focused on problem-based learning approaches. One study, focusing on a structural engineering capstone course, found that a problem-based learning format required significantly more time due to the additional feedback for students, and that a team-building exercise could strengthen communication between student teams and the instructor [7]. Problem-based learning has also been implemented into an entire civil engineering curriculum at the

University of Colorado, reporting promising evidence for future pursuit [8]. Some report that students gain twice the learning from problem-based learning compared to traditional lecture [9].

Several key studies examined the impact of the learning environment. Grulke et al. found that students in a professional and technologically-equipped workspace performed significantly better on technical content and communication than students asked to complete their project in available space in campus engineering buildings [10]. Dinsmore et al. focused on how changing the student learning environment from traditional classroom lectures to a student team project changes declarative, procedural, or principled knowledge [11]. In this context, declarative knowledge includes understanding engineering terms such as benefit-cost analysis, procedural knowledge applies to understanding processes such as pavement design, and principled knowledge is being able to explain the concepts behind the design. This study examined an engineering design course using student teams guided by faculty. While this course did improve declarative knowledge more than traditional lecture courses, the course change did not foster any improvements in the students' procedural or principled knowledge. These authors noted that the lack of improvement in principled knowledge is particularly distressing as it may disadvantage students entering industry. Perhaps to address this challenge to open-ended design classes, others found that including open-ended questions in junior-level lab classes can support capstone classes [12].

The results from these previous studies indicate that team- and problem-based learning environments can improve declarative knowledge but require more faculty time. Further, changing the learning environment to a more-professional setting can also improve communication and help students connect key concepts of their principled knowledge. Thus, many engineering senior design courses have investigated collaboration with local industry to sponsor team- and problem-based student design projects.

Lessons from capstone industry projects

There is a wealth of knowledge about challenges and best practices for industry-sponsored capstone design courses. These studies evaluate courses that include industry-supervised work, international projects, and multidisciplinary projects. Table 1 shows a compilation of industry-sponsored capstone design courses that include Civil Engineering students, either separately or in a multidisciplinary project. The authors note that this compilation is not exhaustive; rather, it shows a sample of Civil Engineering programs that have published journal or conference papers about their industry-sponsored capstone courses.

**Table 1: Reviewed Industry-Sponsored Capstone Design Courses Including Civil Students**

| School (source) | Semesters | Annual Enrollment | Engineering Discipline(s) | Student Group Size | Sponsor Support |
|---|---|---|---|---|---|
| **Brigham Young University [13]** | 2 | NR | Civil | 3-4 | Project Idea, Mentoring, and Funding |
| **Grand Valley State University [14,15]** | 2 | NR | Multidisciplinary | 6 | Mentoring and Funding |
| **Harvey Mudd College [15]** | 2 | NR | Multidisciplinary | 4-5 | Project Idea, Mentoring, and Funding |
| **Lake Superior State University [16]** | 2 | 75 | Multidisciplinary | 4-8 | Funding and Mentoring |
| **Lehigh University [15]** | 2 | 192 | Multidisciplinary | NR | Project Idea, Mentoring, and Funding |
| **Michigan Technological University [15]** | 4+ | NR | Multidisciplinary | 15-70 | Mentoring |
| **(The) Ohio State University [17]** | 2 | 70-80 | Multidisciplinary | 4-5 | Mentoring |
| **(The) Pennsylvania State University [15]** | 2 | NR | Multidisciplinary | NR | Project idea, Assessment |
| **Rowan University [18]** | 2 | 15 | Civil | 4-5 | Project Idea and Mentoring |
| **University of Arizona [19]** | 2 | 300 | Multidisciplinary | 3-6 | Project Idea, Mentoring, and Funding |
| **University of Florida [20]** | 2 | NR | Multidisciplinary | "small" | Mentoring |
| **University of Idaho [15]** | 2 | NR | Multidisciplinary | NR | Project Idea, Mentoring, and Funding |
| **University of Kentucky [6]** | 1 | NR | Civil | 4-6 | Project Idea and Mentoring |

The University of Kentucky's capstone course includes projects in coordination with local industry. During this project, students learned more about the true management of a project, how to work with clients and senior engineers, and how the design process fits within the larger framework of the business world and the local community. While scheduling and coordination were noted as significant challenges, the largest challenge to this program was selecting projects that were the correct scope and timing for each semester's students [6].

Other studies have focused on the benefit of local industry feedback. In particular, industry partners in engineering design courses can help evaluate student competency gaps by assisting in capstone design courses [21,22,23]. One method of identifying these gaps is through before and after surveys focused on identifying the technical skills required of new graduates [21]. Ingalsbe and Godbey state that, "the capstone course experience provides a pivotal opportunity for employers, educators, and students to share opinions concerning the strengths and opportunities for improvement in the program" [21]. Including industry in student engineering design courses requires more faculty time to coordinate projects and poses challenges to identifying appropriate projects. Because of these challenges, some programs chose only to involve industry members as mentors for faculty-developed projects [24] and both students and sponsors prefer a one-semester course [25]. Studies have shown that multiple types of industry participation and feedback all can provide a positive value to both students and departments. Specifically, research indicates that industry-sponsored capstone projects can improve student team-work skills [26], and communication skills [27,28] (to be discussed in the next subsection), in addition to the technical content of their design project.

Several schools use international senior design projects to expose students to the global impact and reality of engineering design. The Rose-Hulman Institute of Technology [29], Purdue [30], and Florida State [31] have an international senior design project coordinating with Engineers Without Borders. International experience can benefit students by introducing them to international design codes and by providing experience in the global work force and with local industry partners [29]. Challenges can include student adaptation to new learning and cultural environments, access to local design codes [29], keeping regular team communication, and finding industry partners with adequate time [31]. Best practices include providing students with more than two weeks to decide on participation, requiring regular web-camera (or similar) communication with international team members, and expanding teams to include multi-disciplinary components[31].

Several other studies have focused on the impact of multi-disciplinary design courses, where multidisciplinary is considered involving more than one engineering department. Multi-disciplinary engineering senior design projects exists at Lake Superior State University [32,16] and Purdue University [30], where local industry helps identify and select appropriate projects.

Several Universities offer a multi-disciplinary, industry-sponsored, capstone design course. Because this type of course integrates students from across disciplinary boundaries, equitably assigning qualified students to preferred projects becomes a challenging task. To reduce the time required to make the teams some developed software to match student qualifications, abilities (GPA), and desires with the existing pool of projects, thus creating equally matched teams. The software allowed instructors to save a significant amount of time, albeit their involvement is still critical to ensure a quality final team selection[19]. Others have noted that the best teams have been made using a blend of instructor decisions and student self-selections [33].

Despite differing disciplines, program sizes, and course designs, this review of industry-sponsored engineering capstone design courses reveals several key themes. First, the arrangement of student teams and the timing of industry participation can be challenging and time-consuming. Next, students learn both hard and soft skills as a result of industry-sponsorship of these projects. Also, including multiple disciplines and countries can increase student learning, but may pose unique challenges as well.

**Previous work on Communication Skills in the Engineering Curriculum**

There exists broad agreement that communication is important to foster in engineering students[34]. Although some academic programs include communication skills education in multiple courses, most include communication only in stand-alone courses[35]. Evidence suggests a trend towards increasing emphasis of communication across the curriculum[36], but common challenges include lack of resources[37]. These studies have frequently examined either written communication or verbal communication.

Although evidence suggests that student improvement in written communication requires inclusion throughout the curriculum, instructional design of those assignments[38] and instructor interactions with students[28] are just as important. Several studies suggest using portfolios to help students improve their writing in both engineering courses[1] and communication courses[39].

Recent work also suggests that using behavioral-driven-development in capstone courses could improve project-team communication[27]. Others echo these findings, noting the importance of deliberate and well-constructed activities for faculty-student interaction to improve student presentation abilities[28].

Despite the breadth of previous research on engineering student communication and industry-sponsored capstone projects, no evidence has addressed the question of *how* student writing skills are improved during an industry-sponsored capstone course. The following sections describe the method applied and the findings indicated by the results.

## Background on the Case Study Course

The civil engineering senior design class at SIUE was developed as a direct expression of the needs of local employers through discussions at the annual Industrial and Professional Advisory Committee (IPAC) meetings. In these meetings it was clear that students would benefit from a required onsite engineering experience that was supervised by practicing engineers.

Previously, the senior design course had been a catch-all for university and ABET assessment needs. The civil engineering capstone design class was used to not only provide engineering students with a capstone design experience, but also to satisfy the university requirement of a culminating senior experience that could be used to assess the performance of seniors regarding the departmental and university objectives.

As ABET continues to revise engineering accreditation criteria, the capstone course has become an ideal source of assessment for almost all of the departmental outcomes. Outcome assignments, wherein departmental expectations for student performance were evaluated on a student-by-student basis, were added to the course. These assignments were originally given to every student each semester, but the frequency was eventually lessened to assess each outcome only every two years based on recommendations from ABET[40]. Based on the current Civil Engineering Program Criteria[3], and the eight-year cycle of updates proposed by the American Society of Civil Engineering[41], the level of assessment will remain constant for the foreseeable future.

Thus, there was a challenge in introducing significant industry involvement in a course that had frequent assignments and rigorous assessment requirements. It became clear to the coordinating faculty that a hands-off internship would not satisfy the needs for ABET assessment. There would need to be direct faculty involvement in the course, with faculty still providing some supervision in order to help coordinate an active assessment schedule.

## Project Guidelines for Industry-Sponsored Senior Design Course

Students in the class are all seniors, most in their final semester, and thus have considerable academic experience. In order to avoid unevenly matched teams, faculty follow best practices[31] to divide students into groups of one to four based on their interest (environmental, geotechnical, structural, or transportation engineering), knowledge of past student performance, and anticipated projects. The student project focuses in predominantly one specialization in Civil Engineering to allow for flexibility of placement of students at real-world consulting firms. Multidisciplinary group work required by the ABET outcomes is covered elsewhere in the program. An appropriate group is sent to work at the jobsite or office three hours, most weeks of the semester. Although other schools require 100 hours of industry-sponsored work[21]; this program required 24 hours of industry-supervised project work at host company/agency offices and 30 hours of faculty-supported project work on campus to account for assessment tasks and other assignments.

It is not required that the students be paid. The onsite experience they receive partially counts towards their requirements for completing the course CE 493 Engineering Design. The following four guidelines encompass the expectations for the industry-sponsored portion of the course.

1. **Appropriate project selected**: This is coordinated with a contact person at least a month before the start of the semester (mid-July for fall and early December for spring) to identify an appropriate project. Projects need to have a significant deliverable at the end of the 15-week semester so that the students can write a report on their work and make a presentation at the university.
2. **Administration:** During at least 30 minutes of the three hours that students work in the host company's/agency's office a supervising engineer (PE or SE) needs to be available to answer the students' questions. A name and contact information are necessary so the faculty can keep in touch as needed.
3. **Workspace**: Students need to be provided workspace (desk, conference table, etc.) for their three hour office attendance sessions.
4. **Reference material:** Students need to have access to necessary design references and other pertinent information for the project, while in the office.

In addition to the three hour sessions the students spend in the office of their engineering host company/agency, they are required to attend class and keep the faculty informed of their progress. Most semesters, the class meets during two 50-minute periods and their schedule has a three-hour block on Fridays. The time on Fridays is used for meeting host companies/agencies, working in their groups, or making progress presentations. During class periods, different topics are covered. A team-building exercise is included to help foster open communication within groups and with the instructor, as recommended by previous research[7]. Students are also required to turn in progress memos and run mock client meetings with instructors. Although most students are members of student chapters of professional organizations, one course requirement is to attend a professional meeting, meet local professional engineers, and write a memo about the experience. Because student learning occurs largely outside of the classroom[42], these meetings introduce students to topics presented from an industry perspective. Additionally, students often identify job leads and maintain the Department's visibility.

The requirements for memos and mock client meetings provide students with timely feedback on their project progress. Some suggest that requiring students to turn in memos reporting their progress can reduce the amount of work left until the deadline[43]. In addition, the mock client meetings reinforce the deadline expectations, provide an opportunity for students to present their progress, discuss key challenges, and receive instant feedback on their progress and plans.

All of the faculty working with the students are licensed PE's or SE's and are able to help them with some of the engineering questions that arise while they are away from their host company's/agency's office. Also, the University has some resources that might not be readily available in some office locations (e.g., research laboratories, instrumentation, and finite element programs) that can be used to further investigate questions that arise.

Some companies have identified excellent student projects, yet there were proprietary or confidentiality concerns. To address these challenges, presentations and reports were authored for "faculty eyes only." Otherwise, presentations are open and reports may be used for accreditation purposes.

Before changing the course to industry-sponsored, projects were developed by instructors, and they usually included components of real world projects that were future endeavors. However, to make the projects interdisciplinary – covering environmental, geotechnical, structural, and transportation engineering aspects, they often were weak in at least one area. Occasionally external clients would talk to the class, or local design companies would consider the findings in their future design. However, the new format provides students the opportunity to work on current projects, experience common changes that take place in the design process, and possibly see the constructed products of their design in the near future. The projects used during the industry-sponsored semesters were an interesting mix and are summarized in Table 2.

**Table 2. Example Projects under the Industry-Sponsored Course Format**

| Engineering Discipline | Projects |
|---|---|
| Environmental | Sewer line to replace septic systems, Site remediation, Trouble-shooting operational issues at a wastewater treatment plant, Water supply system for a village in Guatemala. |
| Structural | Historical building truss analysis, Parking garage renovation, New bridge designs, New building designs, Trail bridge design. |
| Transportation | Interstate interchange designs, Great Streets designs, Bike trail design, Parking lot designs, and Rural intersection realignment. |
| Geotechnical | Site improvements for a "big box store" parking lot. |

## Study Methods

To answer the research questions, the authors employed student surveys, followed by assessment of student writing samples with a rubric. The students were surveyed two semesters before (n = 45 students) the implementation of industry-sponsored capstone design projects and seven semesters afterwards (n = 131 students). The student survey sought to identify how the industry-sponsored course helped them improve and in what area.

After finding evidence that student-reported communication skills significantly ($\alpha$=0.10) improved with industry sponsorship, the researchers collected and analyzed writing samples during two semesters (fall 2013 and spring 2014) with industry-sponsored projects (n = 28). Faculty worked with the staff at the university writing center, selected a rubric to evaluate student writing samples, and collected samples at the beginning and end of each course for two semesters.

The rubric chosen illustrates a clear method of making the assessment process efficient. However, as rubric design can often be a complicated and tedious endeavor many rubrics stop after establishing performance criteria. Yet, Wolf and Stevens[44] state that "the best rubrics include another step in which each of the cells in the matrix contains a description of the performance at that level" (n.p.). Therefore, the rubric chosen by the authors focused on clear, measurable goals that articulated the desired learning outcomes. With these outcomes identified the authors were able to assess each writing sample accurately and measure the various performance levels equally across all samples.

Work found in Dannelle Stevens and Antonia Levi's book, *Introduction to Rubrics: An Assessment Tool to Save Grading Time, Convey Effective Feedback, and Promote Student Learning*[45], guided the selection of the rubric, see Table 2. Although it was actually a hybrid of a variety of rubrics, through various discussions it seemed to best illustrate our desired evaluation criteria. Much like in Alaimo, Bean, Langenhan and Nichols[46] this rubric contained clear criteria that produced data on which the authors could quickly evaluate and use in their respective data sets. The points in the rubric add to a maximum of two so that the five writing assignments would sum to 10 points of the course grade. The faculty teaching the course during this analysis agreed on the distribution between the three categories, based on their experience as licensed professional engineers. Informed consent documents were reviewed by the students and participation in no-way impacted grading. The writing samples from the students that did not consent were graded by the same faculty member, but not included in the study data set.

**Table 2: Writing Evaluation Rubric Applied to Student Writing Samples**

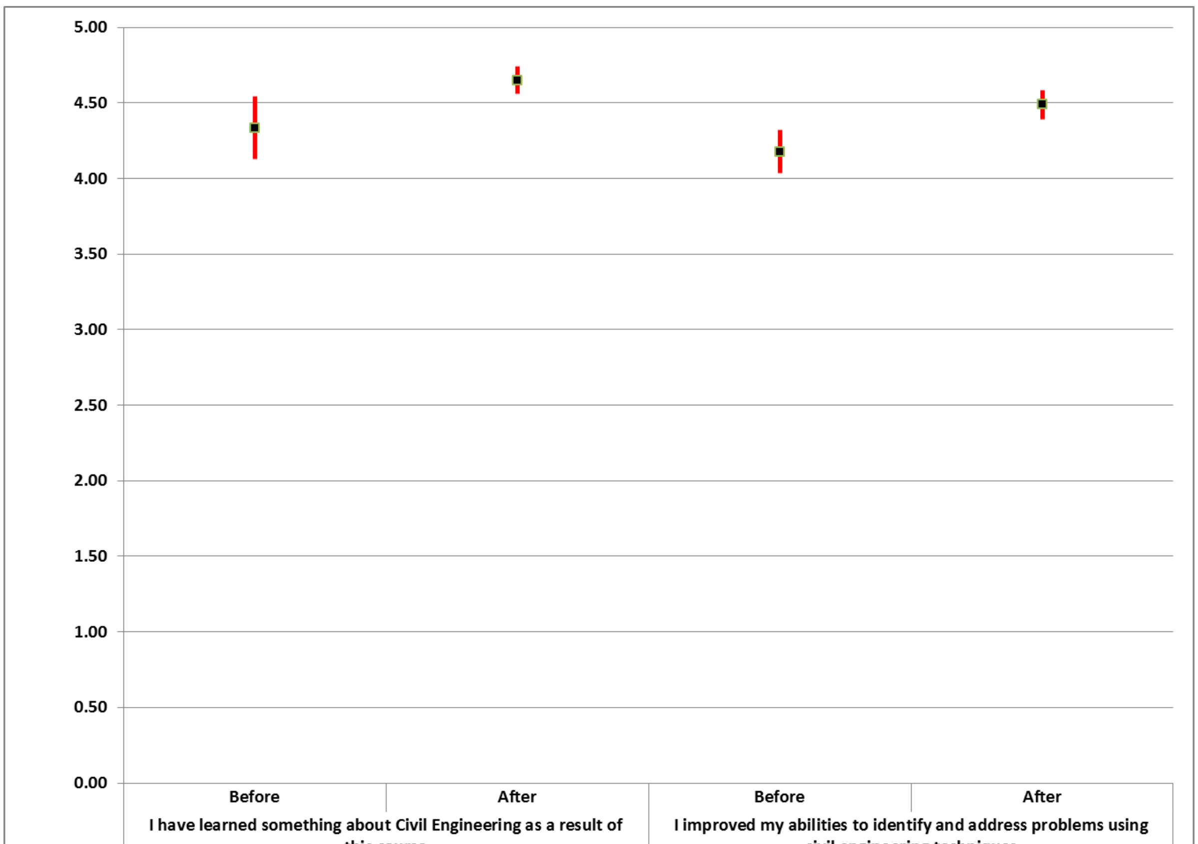
| | | Unacceptable | Novice | Competent | Proficient |
|---|---|---|---|---|---|
| **Points** | Grammar and Spelling | 0 | 0.2 | 0.4 | 0.6 |
| **Description** | | Three or more typos or unacceptably written | Two typos/errors or unprofessionally written; distracting errors | No more than one typo/error and somewhat professional; quality grammar and mechanics | No grammatical errors or typos were present, professionally written illustrating a clear command of the language |
| **Points** | Content | 0 | 0.27 | 0.53 | 0.8 |
| **Description** | | The content lacks a clearly developed argument; unacceptable support with examples | Several items unaddressed in the argument, requires further examples | Minor items could use improvement, but overall acceptable | Clearly developed argument that addresses the purpose of the memo, Supported topic using examples |
| **Points** | Organization | 0 | 0.2 | 0.4 | 0.6 |
| **Description** | | Confusing, no logic, organization lacks, difficult transitions | Moderate support/logic, transitions and organization | Good evidence/logic, support, transitions and organization | Excellent show of logic, evidence and support, well organized, excellent transitions, message flows |

The last part of the analysis included statistical tools and hypothesis testing. Most tests evaluated student responses and performance before and after the course. Other tests compared the student responses between those completing a faculty-led senior design project verses an industry-sponsored project. Last, a paired t-test helped differentiate between student writing performance before and after an industry-sponsored senior design project.

## Survey Results and Discussion

To assess the impact of the change to industry sponsored projects, instructors used surveys of students and employers. The student survey was conducted two semesters before industry-sponsored projects were introduced (fall 2008 and spring 2009) and seven semesters after, fall 2009 to fall 2012; not including summers. Different students enrolled in the course each semester and none repeated. Details about the survey development and initial application is described by the authors' previous paper, xx et al.[xx]. Student enrollment averaged 20 across all semesters and the response rate was nearly 100% for all exit surveys.

Other researchers have consistently found that students over-estimate their abilities [9,47] particularly on exit surveys[1]. The before-and-after comparison chosen for this study identifies the relative difference in these ratings and helps normalize the ratings to address this issue of over-estimating. Additionally, because there was a larger sample size for the "after" sample, using confidence intervals helps address this uncertainty. The students reported a significantly higher (α=0.05) response to the statements, "I have learned something about Civil Engineering as a result of this course," and "I improved my abilities to identify and address problems using civil engineering techniques;" providing strong evidence of improvements in these categories after industry-sponsorship. Figure 1 shows these areas where students reported a significantly higher response after the implementation of the industry-sponsored capstone design format. The bars in Figure 1 show the 95-percent confidence intervals of the average rating for each class format. When the "before" bar was entirely lower than the "after" bar, a significant improvement was confirmed. Note that the ratings corresponded to survey responses as follows: 5 = strongly agree, 4 = agree, 3 = neither agree or disagree, 2 = disagree, and 1 = strongly disagree.




| | Before | After | Before | After |
|---|---|---|---|---|
| | I have learned something about Civil Engineering as a result of this course | | I improved my abilities to identify and address problems using civil engineering techniques | |
| High | 4.54 | 4.74 | 4.32 | 4.58 |
| Low | 4.13 | 4.56 | 4.03 | 4.39 |
| ■ Average | 4.33 | 4.65 | 4.18 | 4.49 |

**Figure 1: Student-Stated Improvements from Industry-Sponsored Capstone Course (α=0.05)**

In addition to these findings, there was weak evidence (α=0.10) of improvements in two other areas. Students reported higher ratings to the statements, "I now have a more-clear idea of the roles civil engineers play in the public and private sectors," and "I improved my written and oral communication skills as a result of this course." A review of both these statistics demonstrated that confidence intervals were broader with the "before" data set, possibly because the sample size was smaller than the "after" data set.

The authors note that the exit surveys also asked students to rate if, "… this course has been effective at making me a better civil engineer," and if "This course has increased my interest in Civil Engineering." The average responses to these questions were all higher after the implementation of the industry-sponsored projects, but none of the increases were statistically significant (α ≥ 0.10).

To deepen understanding of a student's possible improved written and oral communications, the authors investigated which components of their communication were improving with industry-sponsored capstone projects. The summarized results from the technical writing sample evaluations from civil engineering industry-sponsored projects are shown in Figure 2, where before indicates the student performance at the beginning of the semester and after indicates the end of the semester. Note that the response performance has been normalized, between zero and one, in each category. As indicated, student performance significantly improved in grammar and spelling and organization. Yet, although the average content rating within student writing samples did improve there was no statistical evidence to draw conclusions. The authors do note that grammar, spelling, and writing organization all relate to professionalism.

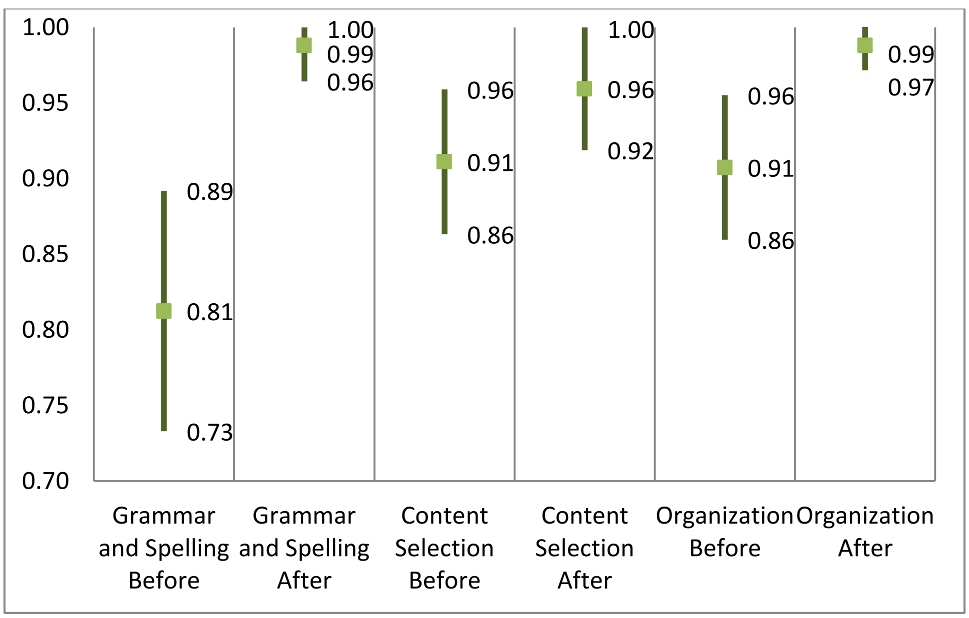



**Figure 2: Normalized Writing Performance Before and After an Industry Sponsored Capstone Course**

Further analysis of the student writing performance focused on each writing metric individually. The improvement of student spelling and grammar varied between semesters. Based on the T-test results, shown in Table 3, there was statistical evidence of improvement each semester that ranged between 92.2 and 99.6 percent confidence. Combining the results for both semesters suggests (>99%) overwhelming evidence of improved performance in this category. Note that a score of 0.5 indicated full credit for the category of "grammar and spelling."

**Table 3: T-Test Results for Average Increase in Student Performance in Grammar and Spelling**

| | Fall 2013 | Spring 2014 | Combined |
|---|---|---|---|
| **mean** | 0.050 | 0.120 | 0.088 |
| **std. dev.** | 0.119 | 0.147 | 0.137 |
| **n** | 13 | 17 | 28 |
| **t-statistic** | 1.515 | 3.358 | 3.375 |
| **p-value** | 0.078 | 0.004 | 0.001 |

Evaluating student writing performance with respect to the content that they chose to include again revealed some differences between the semesters, but with the same overall result as Figure 2. The T-test results are displayed in Table 4 and show that the difference in student before-and-after performance was supported by between 67.8 and 99.5 percent confidence. Yet, combining both semesters suggests that there was no evidence for improvement. Qualitative review of the student performance suggests that they performed well both before and after. Note that the category of content had a maximum score of 0.8.

**Table 4: T-Test Results for Average Increase in Student Performance in Writing Content**

| | Fall 2013 | Spring 2014 | Combined |
|---|---|---|---|
| **mean** | 0.083 | -0.011 | 0.034 |
| **std. dev.** | 0.170 | 0.093 | 0.143 |
| **n** | 13 | 17 | 28 |
| **t-statistic** | 1.760 | -0.503 | 1.250 |
| **p-value** | 0.052 | 0.322 | 0.115 |

Finally, the authors conducted a T-test of student performance organizing their writing. The results indicated a rather consistent performance improvement across the two semesters, resulting in 98.7 percent confidence that there was a difference in the before and after performance. When combined, the results provide overwhelming statistical evidence (>99%) that students improved these skills.

**Table 5: T-Test Results for Average Increase in Student Performance in Writing Organization**

| | Fall 2013 | Spring 2014 | Combined |
|---|---|---|---|
| **mean** | 0.062 | 0.053 | 0.059 |
| **std. dev.** | 0.087 | 0.083 | 0.084 |
| **n** | 13 | 17 | 28 |
| **t-statistic** | 2.551 | 2.637 | 3.716 |
| **p-value** | 0.013 | 0.013 | 0.001 |

Overall, these findings suggest that students across several semesters consider the industry-sponsored capstone course format to provide several benefits to their education. These benefits were initially reported in broad categories, such as "written and oral communications." Instructors of the course did not report any significant changes in the oral communication abilities of students before and after changing the format to industry-sponsored capstone project; thus, the authors decided to investigate student writing performance. The writing analysis findings show how written communication changes during an industry sponsored capstone course. These results support previous work[1], finding that industry participation was essential to encourage students to improve their professional communication skills. Future work could clarify how much of these improvements were from the industry participation or from other sources.

## Conclusions

The authors examined longitudinal data related to self-reported improvements from a civil engineering capstone course. These findings led to an analysis of student writing samples, thus finding that students significantly improved their written communication skills during an industry-sponsored senior design class, and further suggested more improvement with industry participation than in a class without industry participation. Specifically, students improved in the areas of grammar, spelling, and organization of content. These findings suggest that industry-sponsored projects help students recognize the relationship between professionalism and organized and error-free correspondence.

Faculty teaching senior design courses could find value in these conclusions, especially those in civil engineering. Future work could investigate the components of the course to identify which are most important to improve student communication abilities.

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