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How Student Written Communication Skills Benefit During Participation in an Industry-Sponsored Civil Engineering Capstone Course

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Abstract

Because many engineering programs use capstone design courses and value strong communication abilities, authors sought to identify how student written communication skills changed because of industry-sponsored capstone design projects. A student exit survey was collected at the end of the capstone design course during faculty-led projects and projects led by practicing engineers in industry. These results led the researchers to subsequently evaluate two semesters of before-and-after writing samples using a rubric. Student surveys suggested a statistically significant increase in learning about professional issues, problem solving, and written/oral communication. Evaluation of student writing samples suggests that the students significantly improved their grammar/spelling and their organization of content during the course. These findings suggest that industry-sponsored projects help students recognize the relation between professionalism and correspondence that is organized and void of grammar and spelling errors.

Keywords: Student communication skills, written communications, civil engineering, capstone courses

Introduction

Emphasis on requiring strong communication abilities for engineering graduates has been shown in several studies across engineering disciplines (Milke, et al. 2013, Nicometo, et al. 2010). 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 (ABET Inc. 2013). 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 (Passow 2012).

The purpose of this study was to identify how student written communication skills were improved by changing to an industry-sponsored capstone design course from a capstone course with faculty-developed design projects. While previous studies have indicated that industry-sponsored capstone 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 written communication ability of the students.

The civil engineering senior design course at Southern Illinois University Edwardsville places students in unpaid internships with local engineering companies and agencies. Practicing engineers supervising the students have discussed the importance of clear and effective 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 were guided by lectures from faculty and feedback from their sponsors who are practicing professional engineers. The faculty assessed student written communication samples using a rubric developed and refined in consultation with the staff at the University's Writing Center. The Writing Center assisted students to strengthen their text by discussing with each student the intended audience and message of each document, and then provided feedback and direction regarding the organizational strategies and rhetorical choices.

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. According to a 2005 survey of capstone courses nationwide, a one-to-two semester course with 4-6 students per team engaging simultaneously in classes and project components remained popular (Howe 2010). 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 (Borrego, et al. 2002). 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 (Yost and Lane 2007). 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 (Quinn and Albano 2008). Problem-based learning has also been implemented into an entire civil engineering curriculum at the University of Colorado, reporting promising evidence for future pursuit (Chinowsky, et al. 2006). Some report that students gain twice the learning from problem-based learning compared to traditional lecture (Yadav, et al. 2011).

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 (Grulke, Beert and Lane 2001). 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 (Dinsmore, Alexander and Loughlin 2008). In this context, declarative knowledge includes understanding engineering terms such as cost-benefit 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. Although 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 courses, others found that including open-ended questions in junior-level lab courses could support capstone courses (Palmer and Hegab 2010).

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 capstone 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 course findings.

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

School (source)	Semesters	Program Enrollment	Engineering Discipline(s)	Student Group Size	Support from Industry Sponsor
Brigham Young University (Nelson, Hollenbaugh and Borup 2014)	2	NR	Civil	3-4	Project Idea, Mentoring, and Funding
Calvin College (Brouwer, Sykes and VanderLeest 2011)	2	NR	Multidisciplinary	NR	Mentoring
Grand Valley State University (Pung and Jack 2014, National Academy of Engineering, AMD 2012)	2	NR	Multidisciplinary	6	Mentoring and Funding
Harvey Mudd College (National Academy of Engineering, AMD 2012)	2	NR	Multidisciplinary	4-5	Project Idea, Mentoring, and Funding
Lake Superior State University (Schmaltz, et al. 2001)	2	75	Multidisciplinary	4-8	Funding and Mentoring
Lehigh University (National Academy of Engineering, AMD 2012)	2	192	Multidisciplinary	NR	Project Idea, Mentoring, and Funding
Michigan Technological University (National Academy of Engineering, AMD 2012)	4+	NR	Multidisciplinary	15-70	Mentoring
Purdue University (Drnevich 2005)	1	30-100/semester	Civil	4-6	Designing Course and Providing Feedback
Stevens Institute of Technology (Sheppard, et al. 2011)	2	NR	Multidisciplinary	4-5	Design Requirements, Reviewing Progress
(The) Ohio State University (Allenstein, Whitfield and Rhoads 2012)	2	70-80	Multidisciplinary	4-5	Mentoring
(The) Pennsylvania State University (National Academy of Engineering, AMD 2012)	2	NR	Multidisciplinary	NR	Project idea, Assessment
Rowan University (Cleary and Jahan 2001)	2	15	Civil	4-5	Project Idea and Mentoring
United States Coast Guard Academy (Jackson, et al. 2010)	1	NR	Civil	3-5	Funding and Mentoring
University of Arizona (Lopez, Aronson and Carstensen 2008)	2	300	Multidisciplinary	3-6	Project Idea, Mentoring, and Funding
University of Florida (Stanfill and Rigby 2014)	2	NR	Multidisciplinary	“small”	Mentoring
University of Idaho (National Academy of Engineering, AMD 2012)	2	NR	Multidisciplinary	NR	Project Idea, Mentoring, and Funding
University of Kentucky (Yost and Lane 2007)	1	NR	Civil	4-6	Project Idea and Mentoring
University of Minnesota Duluth	1	NR	Civil	4	Project Idea,

(Saftner, et al. 2013)					Mentoring, and Assessment
Wentworth Institute of Technology (Duggan, Davidson and Anderson 2012)	2	NR	Civil	5	Mentoring, Project Reviewing
Western Michigan University (Aktan, Polasek and Phillips 2011)	2	NR	Civil	3-4	Funding, Guidance, and Mentoring

(NR = not reported in reviewed publication)

The University of Kentucky's capstone course includes projects in coordination with local industry. During this project, students learned more about the real-world 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. Although 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 (Yost and Lane 2007).

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 (Ingalsbe and Godbey 2005, Barnett and Burtner 2003, Davis 2004). One method of identifying these gaps is through before and after surveys focused on identifying the technical skills required of new graduates (Ingalsbe and Godbey 2005). 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" (Ingalsbe and Godbey 2005, p2). Including industry in student engineering design courses requires more faculty time to coordinate projects and poses challenges to identifying appropriate projects. To address these challenges, some programs chose only to involve industry members as mentors for faculty-developed projects (Akili 2010) and both students and sponsors prefer a one-semester course (Griffin, Griffin and Llewellyn 2004). 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 (Steinlicht and Garry 2014), and communication skills (Goulart 2014, Paretti 2008) (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 (Aidoo, et al. 2007), Purdue (Richardson and Blackwell 2010), Florida State (Ordonez, et al. 2006), and Villanova University (Dinehart and Gross 2010) have offered an international senior design project, several that coordinated 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 industry partners (Aidoo, et al. 2007). Additionally, the students sometimes get a chance to work on a project under extreme financial constraints due to the client being from a rural area in a developing country (Dinehart and Gross 2010). Challenges can include student adaptation to new learning and cultural environments, access to local design codes (Aidoo, et al. 2007), keeping regular team communication, and finding industry partners with adequate time (Ordonez, et al. 2006). 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 multidisciplinary components (Ordonez, et al. 2006).

Several other studies have focused on the impact of multidisciplinary design courses, where multi-disciplinary is considered involving more than one engineering department. Multidisciplinary engineering senior design projects exist at many universities in many varieties, see Table 1.

Several universities offer a multidisciplinary, 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 (Lopez, Aronson and Carstensen 2008). Others have noted that the best teams have been made using a blend of instructor decisions and student self-selections (Ferguson and Sanger 2011).

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 technical 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 (Plumb and Scott 2002). Prior practice was to emphasize engineering communication skills in a single technical writing course (Pappas, et al. 2004). More recent evidence suggests a trend towards increasing emphasis of communication across the curriculum (Ford and Riley 2003, Troy, et al. 2014), but common challenges include lack of resources (Leydens and Schneider 2009) and lack of faculty motivation (Troy, et al. 2014). 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 (Yalvac, et al. 2007) and instructor interactions with students (Paretti 2008) are just as important. Several studies suggest using portfolios to help students improve their writing in both engineering courses (Milke, et al. 2013) and communication courses (Johnson 2006).

Recent work also suggests that using behavioral-driven-development in capstone courses could improve project-team communication (Goulart 2014). Others echo these findings, noting the importance of deliberate and well-constructed activities for faculty-student interaction to improve student presentation abilities (Paretti 2008).

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 capstone design course at Southern Illinois University Edwardsville was developed as a direct expression of the needs of local employers through discussions at the Department's Industrial and Professional Advisory Committee 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 course 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 changed to assess each outcome only every two years based on recommendations from ABET (Rodgers 2002). Based on the current Civil Engineering Program Criteria (ABET Inc. 2013), and the eight-year cycle of updates proposed by the American Society of Civil Engineering (Estes and Lenox 2014), 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 the Industry-Sponsored Senior Design Course

Students in the course are all seniors, most in their final semester, and thus have completed considerable academic studies. In order to avoid unevenly matched teams, faculty follow best practices (Ordonez, et al. 2006) to divide students into groups of one to four based on their interest (environmental, geotechnical, structural, or transportation engineering), faculty knowledge of past student performance, and anticipated projects proposed by industry partners. The student project focuses in predominantly one specialization in Civil Engineering, providing students with more depth than multidisciplinary projects and allowing flexibility for placement of students at real-world consulting firms and public agencies. Multidisciplinary group work required by the ABET outcomes is covered elsewhere in the program. An appropriate group is sent to work at the job site or office of an industry sponsor company/agency three hours, most weeks of the semester. The course studied herein was three credits during one semester. Although other schools require 100 hours of industry-sponsored work (Ingalsbe and Godbey 2005), 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**: The project selection is coordinated with a contact person at the host company/agency, at least a month before the start of the semester. 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. **Student Mentoring:** During at least 30 minutes of the three hours that students work in the host company/agency office a supervising engineer (licensed professional engineer (PE) or structural engineer (SE)) needs to be available to answer the students' questions. A name and contact information are necessary so the faculty and students can keep in touch as needed. The host company/agency will take the lead in guiding each student group through their design project.
3. **Workspace**: Students need to be provided workspace (desk, conference table, etc.) at the host company/agency for their three hour office attendance sessions. Space, computers, and software are available on campus during regularly-scheduled class periods.
4. **Reference material:** Students need to have access to necessary design references and other pertinent information for the project, while in the host company/agency office. The faculty maintain a library of common references available to students in the classroom. Additional references are also available from other faculty members' libraries.

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 faculty, as recommended by previous research (Quinn and Albano 2008). Students are also required to turn in progress memos and run mock client meetings with course faculty. Although most students are members of student chapters of professional organizations, one course requirement is to attend a professional meeting, meet local PEs, and write a memo about the experience. Because student learning occurs largely outside of the classroom (Strauss and Terenzini 2001), 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 (Moor and Drake 2001). 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 PEs or SEs and are able to help them with some of the engineering questions that arise while they are away from their host company/agency 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 faculty, 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 or unrealistic 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 varied and examples 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, and 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 evaluate student written communications, 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 areas.

After finding evidence that student-reported written and verbal communication skills significantly improved with industry sponsorship (p-value=0.0078, see the next section for details), the faculty who taught the course discussed and agreed that they saw no change in the verbal communication abilities of students before and after changing the course format to include industry sponsorship. Instead, the researchers chose to study the changes in written communication skills in an industry-sponsored capstone course. During this study, researchers collected and analyzed writing samples during two semesters (fall 2013 and spring 2014) with industry-sponsored projects (n = 28). Because the authors wanted to ensure that the developed rubric was founded on established pedagogy on the assessment of writing, the faculty worked with the staff at the university writing center to select a rubric to evaluate student writing samples. Because the faculty were each practicing engineers before their careers in academia and because of their continued relation with industry partners, no further review was solicited for the rubric. The authors 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 only establish performance criteria. Yet, Wolf and Stevens (2007) 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* (2005), 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 (2009) 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 PEs. Informed consent documents were reviewed by the students and participation in no-way impacted grading. The writing samples from the students who did not consent were graded by the same faculty member with the same rubric as other students, 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	Moderate support/logic, transitions and organization	Good evidence/logic, support, transitions and	Excellent show of logic, evidence and support, well organized,

	transitions	organization	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. A paired t-test helped differentiate between student writing performance before and after an industry-sponsored senior design project. Additionally, a Wilcox ranked sum test was used to compare the before and after performance of students across semesters. This statistical tool was chosen because of the varying sample sizes between semesters (Keller 2005).

Analysis, Findings, and Discussion

To assess the impact of the change to industry-sponsored projects, faculty 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 are described by the authors' previous paper, (Fries, Cross and Morgan 2010). 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 (Yadav, et al. 2011, Lundeberg and Mohan 2009) particularly on exit surveys (Milke, et al. 2013). The before-and-after comparison chosen for this study identifies the relative difference (between before and after) 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 statistics helps address this uncertainty. The students reported a significantly higher response to the statement, "I improved my written and oral communication skills as a result of this course." Although the before and after samples both included more than 30 responses, the sample sizes were not equal. Thus, researchers employed a z-test for two sample means, then the Wilcox Rank Sum Test to find a p-value and evaluate the possibility that the ratings were higher after the implementation of the industry-sponsored course format (one-tailed test). As shown in Table 3, the interpretation of the statistics indicates overwhelming evidence of a significant increase in student ratings. Note that the mean ratings corresponded to Likert survey responses as follows: 5 = strongly agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree, and 1 = strongly disagree.

Table 3: Analysis of Student Responses to, "I improved my written and oral communication skills as a result of this course"

	Before	After
Mean	4.053	4.561
Variance	1.240	0.352
Observations	38	130
Hypothesized Mean Difference	0	
z-Statistic	-2.421	
Wilcox Rank Sum Test P-value	0.008	

The survey also asked students to respond to the statements, "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," and "I now have a more-clear idea of the roles civil engineers play in the public and private sectors." Similarly to the analysis shown in Table 3, the researchers used a z-test for two sample means and the Wilcox Rank Sum Test to analyze the responses. As shown in Tables 4-6, student responses were significantly higher to these questions after industry-sponsorship was implemented into the course. A review of these statistics demonstrated that variance was almost always higher in the "before" data set, likely because the sample size was smaller than the "after" data set.

Table 4: Analysis of Student Responses to, "I have learned something about Civil Engineering as a result of this course"

	Before	After
Mean	4.333	4.648
Variance	0.499	0.230
Observations	45	131
Hypothesized Mean Difference	0	
z-Statistic	-2.781	
Wilcox Rank Sum Test P-value	0.003	

Table 5: Analysis of Student Responses to, "I improved my abilities to identify and address problems using civil engineering techniques"

	Before	After
Mean	4.178	4.488
Variance	0.240	0.256
Observations	45	131
Hypothesized Mean Difference	0	
z-Statistic	-3.640	

Wilcox Rank Sum Test P-value	0.001

Table 6: Analysis of Student Responses to, "I now have a more-clear idea of the roles civil engineers play in the public and private sectors"

	Before	After
Mean	4.053	4.488
Variance	0.484	0.256
Observations	38	130
Hypothesized Mean Difference	0	
z-Statistic	-2.931	
Wilcox Rank Sum Test P-value	0.002	

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=0.05).

To deepen understanding of a students' 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 1, 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, the average improvement in student writing sample content was not statistically significant. The authors do note that grammar and spelling, and writing organization all relate to professionalism.

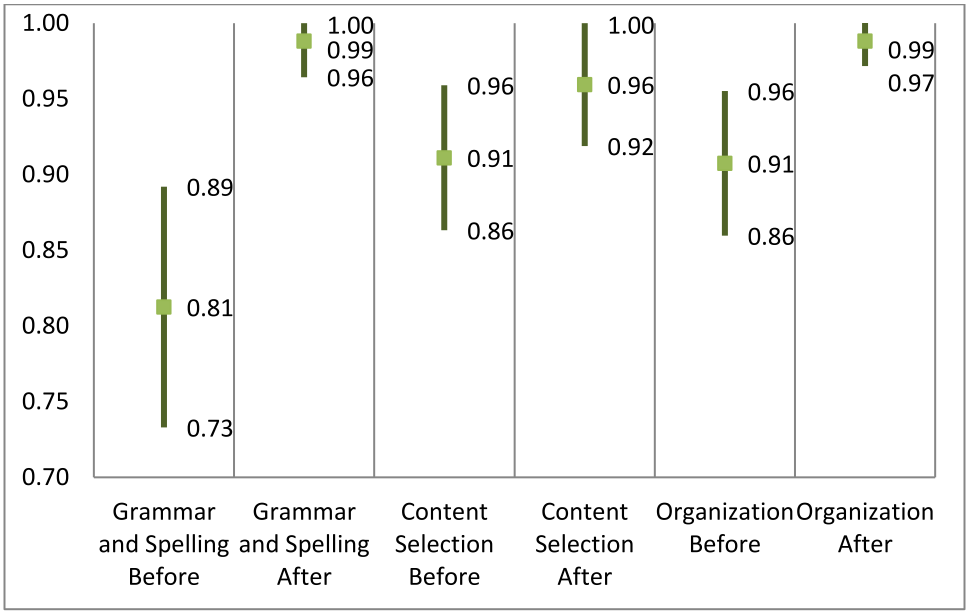

Figure 1: Normalized Writing Performance Before and After an Industry Sponsored Capstone Course

Further analysis of the student writing performance focused on each writing metric for each student individually. Because the sample sizes were less than 30, researchers used the t-test to identify a t-statistic. Next, because each student was evaluated at the beginning and end of the semester and because the data was ordinal, a Wilcox Signed Rank Sum Test was applied to evaluate the matched pairs (Keller 2005). The improvement of student spelling and grammar varied between semesters. Based on the T-test results, shown in Table 7, there was statistical evidence of improvement each semester. Combining the results for both semesters suggests overwhelming evidence of (p=0.0004) improved performance in this category. Note that a score of 0.5 indicated full credit for the category of "grammar and spelling" and an increase of 0.05 represents a 10% improvement.

Table 7: Analysis Results for Average Increase in Student Performance in Grammar and Spelling

	Fall 2013	Spring 2014	Combined
Mean Improvement	0.050	0.120	0.088
Variance	0.014	0.022	0.019
n	13	17	28
t-statistic	1.515	3.358	3.375
Wilcox Signed Rank Sum Test P-value	0.066	0.000	0.000

Evaluating student writing performance with respect to the content that they chose to include revealed some differences between the semesters, but with the same overall result as Figure 1. The analysis results are displayed in Table 8 and reinforce that the difference in student before-and-after performance was not always significant. For example, students during the fall 2013 semester did significantly improve the content in their writing, but not in the subsequent semester. Also, 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 and that a negative improvement indicates a decrease in performance.

Table 8: Analysis Results for Average Increase in Student Performance in Writing Content

	Fall 2013	Spring 2014	Combined
Mean Improvement	0.083	-0.011	0.034
Variance	0.029	0.009	0.020
n	13	17	28
t-statistic	1.760	-0.503	1.250
Wilcox Signed Rank Sum Test p-value	0.039	0.692	0.106

Finally, the authors conducted analysis of student performance organizing their writing. The results indicated a rather consistent performance improvement across the two semesters. When combined, the results provide overwhelming statistical evidence (p=0.0002) that students improved these skills, as shown in Table 9.

Table 9: Analysis Results for Average Increase in Student Performance in Writing Organization

	Fall 2013	Spring 2014	Combined
Mean	0.062	0.053	0.059
Variance	0.007	0.007	0.007
n	13	17	28
t-Statistic	2.551	2.637	3.716
Wilcox Signed Rank Sum Test p-Value	0.005	0.004	0.000

Overall, the exit survey findings suggest that students' communication skills improved more during a capstone course where practicing engineers led the students through a design project compared to a course where faculty developed and led the students through a design project. Throughout this study, the course material and requirements remained the same. For example, the course always required memos, meetings, reports, presentations, and attendance at a professional networking meeting. As an example, a student writing sample reporting on a network event during the "after" period is shown in Figure 2. Students completing their projects with the guidance of practicing engineers had more first-hand exposure to how practicing engineers communicated and groups often reviewed example reports created by their host company/agency. Perhaps it was these tangible examples of professional communication that caused their increase in reported communication skills.

> I was invited by the Society of Women Engineers (SWE) to attend the "Graduating Senior and Life Member Reception" on [redacted] Prior to going to the reception, I attended the SWE Region I Conference iCON14. At the conference, I was able to go to a career fair and network with [redacted], a Senior Recruiter from [redacted]. She was able to tell me about a [redacted] program they have at [redacted] called Operation Maintenance Trainee, OMT for short. She told me that I would be a good candidate for the [redacted]. Networking with [redacted] was a good step for me in my search for a career because I am interested in working in the [redacted] department. She was also able to give me information about what employers look for in their candidates.

Figure 2: Anonymized Example of Student Writing

These benefits were initially reported in broad categories, such as "written and oral communications," but these categories provide only some insight into the differences between these course formats. Through discussion, course faculty did not report any significant changes in the oral communication abilities of students before and after changing the format to include an industry-sponsored capstone project; thus, the authors decided to investigate student writing performance. The writing analysis findings show how much written communication changes during an industry sponsored capstone course. These results support previous work (Milke, et al. 2013), finding that industry participation helps 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

This paper describes analysis of longitudinal data related to self-reported student improvements from a civil engineering capstone course at a US university. These findings led to an analysis of student writing samples, subsequently finding that students significantly improved their written communication skills during an industry-sponsored capstone design course, and further suggested more improvement with industry participation than in a course without industry participation.

Specifically, students improved in the areas of grammar and 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.

Other studies of student growth regarding writing skills, such as (Haswell 2000), have asserted that normative growth can only be conclusive when investigating comparable texts under different conditions and contexts. And while (Johnstone, Ashbaugh and Warfield 2002) concluded that writing within a specific task domain incrementally improved students' writing skills, the authors of this study ultimately conclude that writing skills measurably improve with the assistance of industry experts. This conclusion is especially important considering that the students are able to gain valuable field experience and gain first-hand knowledge of how important good writing skills will be once on the job. Faculty teaching capstone design courses could find value in these conclusions, particularly those in civil engineering.

There exist several opportunities for continued exploration on this topic. Future work could investigate the components of the course material and student interactions with professionals to identify which are most important to improve student communication abilities. Although students all receive similar exposure to course material, student interactions with industry partners might vary considerably. For example, some students may take the lead in coordinating all meetings with their industry contact; thus, differences can occur within groups. Likewise, some industry partners prefer contact with email and others telephone; thus, differences can occur between industry hosts. Finally, certain projects require more interaction between students and industry partners; therefore, differences can exist because of the nature of the specific design project. If future research could identify the relation between these factors, perhaps faculty could provide more deliberate guidance to industry partners when selecting projects and discussing expectations.

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