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A model for improving stakeholder-focused communication in undergraduate civil engineering

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Abstract

The motivation for this study is to examine the impact of a novel stakeholder-focused civil engineering communication course on students' self-reported communication proficiency. Civil and environmental engineering projects are often publicly funded; public participation is often required as part of the project cycle and meaningful engagement of a variety of stakeholders is critical to project success. However, the inclusion of a stakeholder-focused communication class, taught by engineering faculty for engineering students, is the exception rather than the rule. The purpose of this work was to determine the effectiveness of this new course – the development of which was supported by a departmental external advisory committee of engineers in industry, government, and academia – to train engineers entering practice in critical communication skills. Self-reported communication proficiency was assessed through pre- and post-course survey instruments issued at the beginning and end of the semester. Students were asked to report their familiarity with a variety of communication tools and their proficiency in written and in-person/oral communication. Data was evaluated for significance using a two-sample t-test assuming unequal variances. Data collected over three years indicate that the course results in a significant improvement in written and in-person/oral communication skills, though in-person/oral communication skills do not improve to the same extent as written communications. This demonstrates that an intensive, stakeholder-focused civil engineering communication course can be effective in training students for entry into engineering practice and prepares them for interacting with a range of stakeholders in civil engineering projects.

Introduction

Today, the practice of civil engineering encompasses more than a sound understanding of statics, fluid mechanics, and linear algebra. Sustainability, cross-disciplinary knowledge, project management, and other skills are critical for today's engineering graduates to be competitive in a workplace that can range from global to hyper-local. Among these critical competencies is the suite of written and in-person communication skills that the American Society of Civil Engineers includes in the most recent revision of the Civil Engineering Body of Knowledge (ASCE BOK3) [1]. "Excellent written and oral communication skills" have been recognized as critical to engineering since the 1990s and are included in nearly every engineering-related job vacancy today [2]. Communication and interpersonal skills become even more important for progressively higher leadership and management responsibilities in the workplace. Accreditation organizations such as ABET clearly recognize the need for students to be able to demonstrate communication skills as part of Student Outcome 3, and undergraduate civil engineering programs must demonstrate how they incorporate and assess their students' communication skills [3].

History is replete with examples of infrastructure being used as a tool – both intentionally and via so-called "benign neglect" – that creates or perpetuates structural inequities [4]-[8]. It is imperative that civil engineers recognize the impact of their work on people and normalize the meaningful involvement of stakeholders in site development, transportation, energy, and other infrastructure projects. Community members must have access to and influence in decision-making around these projects to advance procedural justice and begin to counteract the history of disparate impacts of civil engineering projects. Effective communication with stakeholders is critical to meaningful involvement and developing trust [9]-[11].

Communication in the civil engineering curriculum

A technical writing class has been part of the University of Delaware's civil engineering curriculum since at least the early 1990s; about a decade later, an additional public speaking course was added [12], [13]. Despite this curricular focus on communication, the Department of Civil and Environmental Engineering, in consultation with its External Advisory Committee, identified that additional efforts were needed to develop effective communication skills in graduates. As a result, a novel course, *Communicating with Stakeholders in Engineering*, was developed and added to the civil engineering curriculum to address the needs of industry and society. This course is unique in undergraduate civil engineering curricula and, generally, incorporation of engineering communication classes is the exception – rather than the rule – for engineering programs. Although it has been criticized, the US News and World Report top ten ranked programs in the US for undergraduate civil engineering were evaluated; only the University of Texas – Austin and Purdue University required communication courses that were offered from within civil engineering departments [14]-[17].

A new course to develop communication competencies

The *Communicating with Stakeholders in Engineering* course has been described in detail elsewhere [18]. The course is required of second-year civil engineering students and is available as a technical elective to other engineering disciplines. The course introduces public participation principles – including the IAP2 Public Participation Spectrum – and tools, like the US EPA EJSCREEN Mapper, to understand stakeholder groups [19], [20]. The course also focuses on understanding stakeholder interests in projects, the importance of incorporating stakeholder feedback into projects, and developing appropriate communications – from fact sheets to social media campaigns to public meetings – to ensure information about civil engineering projects is received, understood, and acted on by the audience. The course is highly interactive, with small group activities, polling, and other in-class interactions in every class meeting. The course is also regularly updated to address current events in civil engineering that have a critical communication component. For example, in spring 2023, the Norfolk Southern train derailment in East Palestine, Ohio, and the Philadelphia Water Department's tracking of a latex product spill in a tributary to the Delaware River were analyzed from a communication perspective [21], [22]. In addition to the small-group in-class activities, the course includes reflective activities,

homework assignments, and a culminating semester project with both group and individual components to provide students with practice in creating a multitude of communication products that – together – result in a comprehensive project communication plan. The course employs a hybrid specifications-/point-based grading approach [23]. Additionally, a limited number of revisions are available for students to improve their work in response to written and video feedback on assignments; feedback and opportunities to implement feedback are valuable to learning [24], [25].

In light of this investment in course development and curricular change, the goal of this work is to assess the impact of the course on civil engineering students to understand whether it has been effective in improving students' written and in-person communication skills so that they may enter practice with greater capacity to effectively engage project stakeholders.

Materials and methods

IRB review

This course was first required of students in spring semester 2021. To prepare to collect data, an IRB application was made in early 2021 (IRBNet ID Number 1717434-1, *Assessment of student experience and perceived competency in engineering education*). The IRB exempt letter was published on February 18, 2021, and will persist until and unless changes are made to the information collection process. This exemption applied throughout the duration of this study which included the course offerings in spring 2022 and spring 2023.

Course enrollment, format, and survey details

Details of each of the three course offerings are presented in Table 1. Data was gathered through a survey instrument disseminated through an anonymous Google Form at the beginning and end of each semester. Students were able to respond only once to each pre- and post-survey.

The pre-course survey included three questions. The first question asked *How would you rate your experience creating the following communication materials?* Students were asked about their experience in creating ten types of communication products or tools: professional emails; reports and research papers; fact sheets, pamphlets, or brochures; technical posters; PowerPoint or Google Slides presentations; professional social media posts; web pages; message maps; communication plans; and evaluation plans. Students were asked to rate their experience on a three-point scale of *no experience*, *some experience*, or *extensive experience*.

The final two questions were included on both the pre- and post-course surveys; students self-rated on a scale of 1-10, with 1 representing *extremely poor* ability, and 10 representing that students were *expert/able to train others*. These two questions focused on written communication (*How would you rate your ability to produce effective, audience-focused written communications [for example: emails, reports, fact sheets, research papers, other written documents]?*) and oral/in-person communication (*How would you rate your ability to*

communicate effectively with specific audiences through in-person formats [for example: formal presentations, including speaking and preparation of presentation materials, informal in-person discussions, other formats which require presentation of material to a live audience]?).

These questions were presented to students taking the course in spring 2021, spring 2022, and spring 2023. Details of course size, format, survey availability period, and incentives offered for responding to the survey are also presented in Table 1. Response data was analyzed in Microsoft Excel using a two-sample t-test assuming unequal variances.

Table 1. Details of CIEG 411, *Communicating with Stakeholders in Engineering*, and course pre- and post-surveys.

	Spring 2021	**Spring 2022**	**Spring 2023**
# of students	53 (2 sections: 29/24)	66	67
# of respondents (pre/post)	25/9	14/22	58/65
Course format	Online, synchronous Cameras mostly off	In-person (masked/COVID) Deep, narrow room with students at long tables and inflexible seating	In-person Large classroom with hexagonal, 6-person tables
Survey availability	Anonymous Google form available first week of class for pre- survey and last week of class for post-survey; surveys available for 5-9 days		
Incentive for responding	None	None	Minimal extra credit

Results

Pre-course familiarity with communication products

The results of the pre-course survey question on familiarity with communication products are presented in Figures 1-3. At the beginning of the semester, students consistently rated themselves as most experienced with presentations in PowerPoint or Google Slides. This is not surprising, as today, students are introduced to creating Google Slides as early as elementary school. Students also reported having at least some experience with technical posters, fact sheets (and similar written documents), reports/research papers, and professional emails. The least familiar communication products were professional social media posts, web pages, message maps, communication plans, and evaluation plans.

Figure 1. Responses to spring 2021 pre-course survey baseline question.

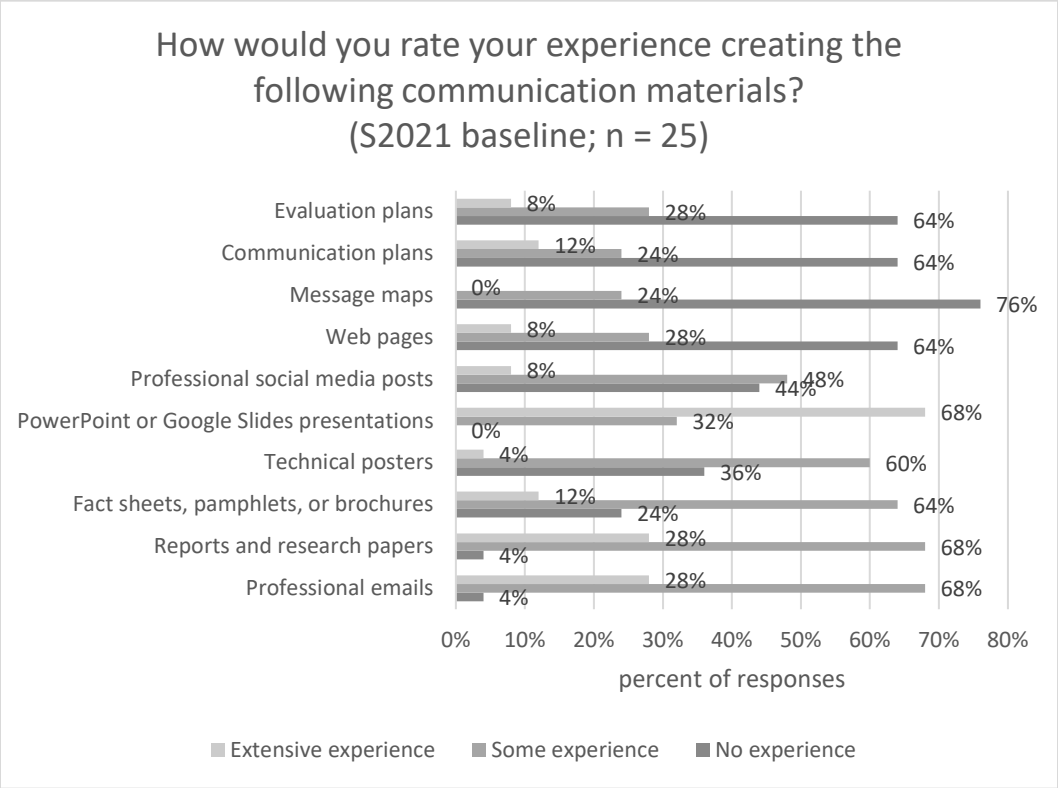


Figure 2. Responses to spring 2022 pre-course survey baseline question.

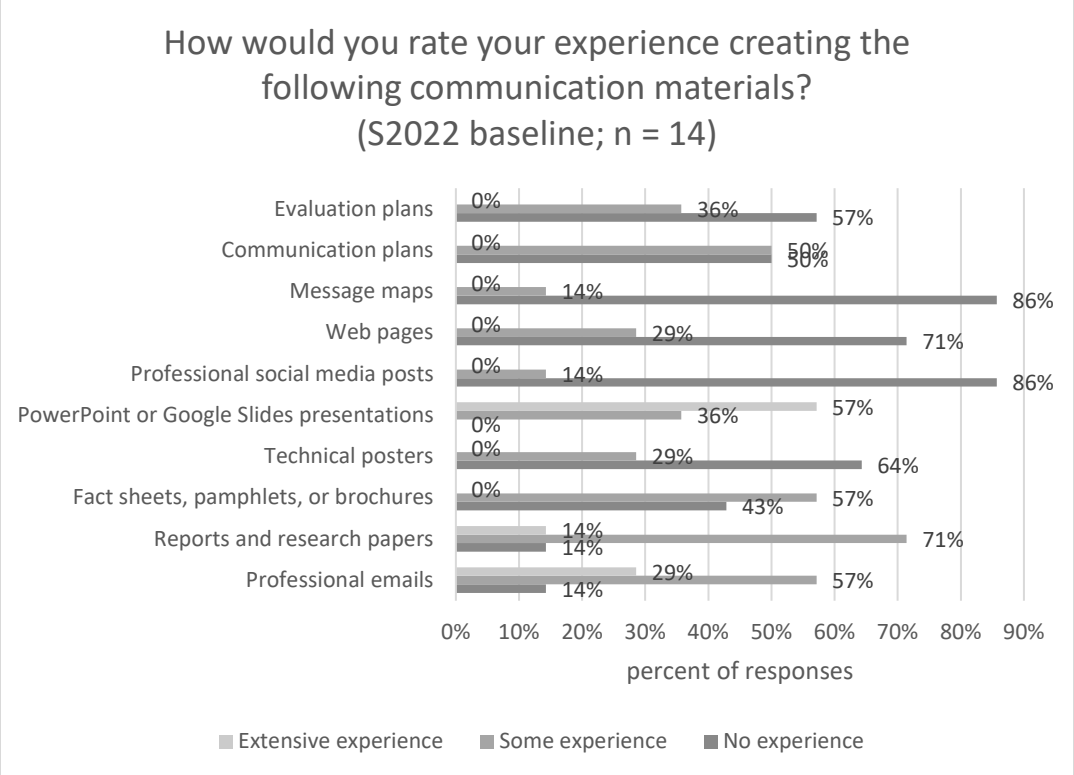
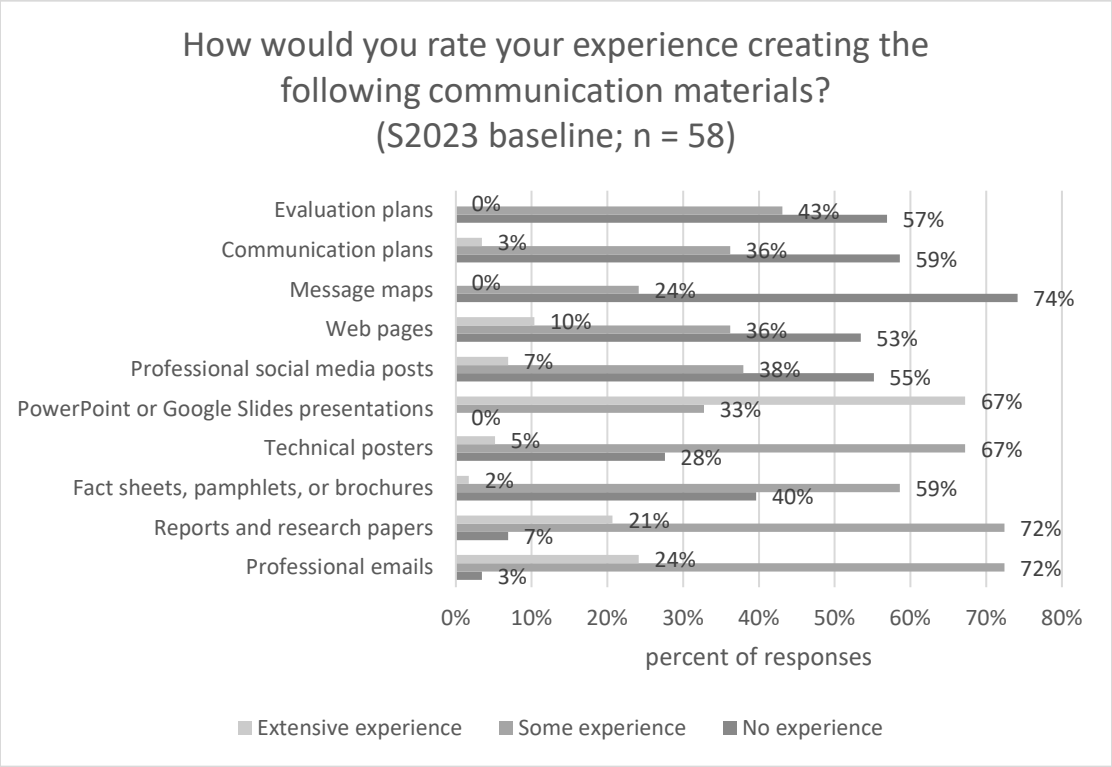


Figure 3. Responses to spring 2023 pre-course survey baseline question.



Pre- and post-course perceived ability

A summary of pre- and post-course survey responses from the final two self-evaluation questions is presented in Table 2. In response to the question on perceived ability to produce written communications, in the three semesters included in the analysis, students increased between 1.76 and 2.03 points on the 10-point scale between the pre- and post-course surveys. For the question on oral/in-person communications, student responses indicate a self-reported increase in ability between 1.4 and 1.56 points on the 10-point scale. There was statistically significant increase at the $p = 0.05$ level in self-reported written and oral communication skills every semester, and in the aggregate of all respondents to the pre- and post-course survey over this three-year period.

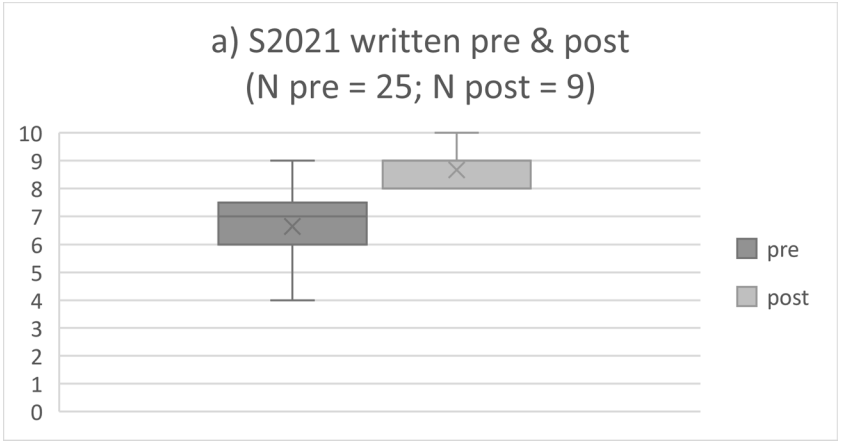
Table 2. Summary of data collected in pre- and post-course surveys.

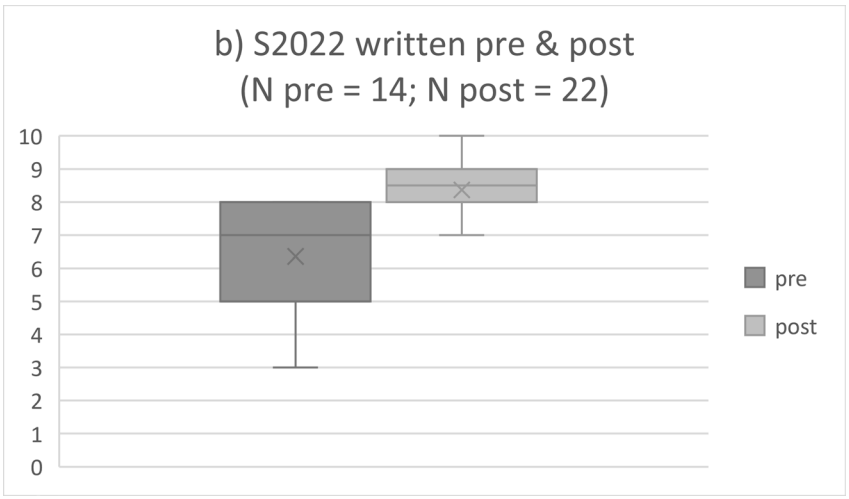
	Written		Oral		t-Test: Two-Sample Assuming Unequal Variances *2-tail p values reported*		
	Pre Mean (SD)	**Post Mean (SD) [delta]**	**Pre Mean (SD)**	**Post Mean (SD) [delta]**	**N (pre/post)**	**Variance (pre/post)**	**Significant difference? (p = 0.05)**
Spring 2021	6.64 (1.35)	8.67 (0.71) [+2.03]	6.16 (1.93)	7.56 (0.88) [+1.4]	25/9	Written: 1.82/0.5	Yes *p = 5.29E-6*
						Oral: 3.72/0.78	Yes *p = 0.0073*
Spring 2022	6.35 (1.78)	8.36 (0.90) [+2.01]	6.21 (1.89)	7.77 (1.07) [+1.56]	14/22	Written: 3.17/0.81	Yes *p = 0.0011*
						Oral: 3.57/1.14	Yes *p = 0.011*
Spring 2023	6.46 (1.39)	8.22 (0.96) [+1.76]	6.24 (1.73)	7.69 (1.32) [+1.45]	58/65	Written: 1.94/0.92	Yes *p = 2.04E-12*
						Oral: 2.99/1.74	Yes *p = 1.07E-6*
All semesters	6.49 (1.43)	8.29 (0.93) [+1.8]	6.22 (1.79)	7.70 (1.22) [+1.48]	97/96	Written: 2.04/0.86	Yes *p = 1.05E-19*
						Oral: 3.19/1.49	Yes *p = 2.54E-10*

Figure 4 presents survey data from each semester in response to the question on perceived ability to produce written communication products. The box and whisker plots include the response median (line); the mean of responses (X); the interquartile range (IQR, indicated by the box). The ends of the whiskers represent minimum and maximum values that are not determined to be outliers. Outliers were only identified in the spring 2023 written communication survey results (noted by the points on Figure 4c). Outliers are designated as such if they have values 1.5x the IQR larger than the third quartile or 1.5x the IQR smaller than the first quartile.

Figure 5 presents the survey responses to the question on perceived ability to produce oral or in-person communications. These graphs illustrate the increase in perceived ability to create both types of communications – written and oral – as well as the less notable increase in perceived ability to produce oral products, as compared to written communications. As is clear from the graphs and the t-tests, although there was a significant increase in perceived in-person (oral) communication ability, it was less significant that students' perceived improvement in written communication formats.

Figure 4 a-c. Responses to the survey question *How would you rate your ability to produce effective, audience-focused written communications (for example: emails, reports, fact sheets, research papers, other written documents)?* For (a) spring 2021, (b) spring 2022, and (c) spring 2023.





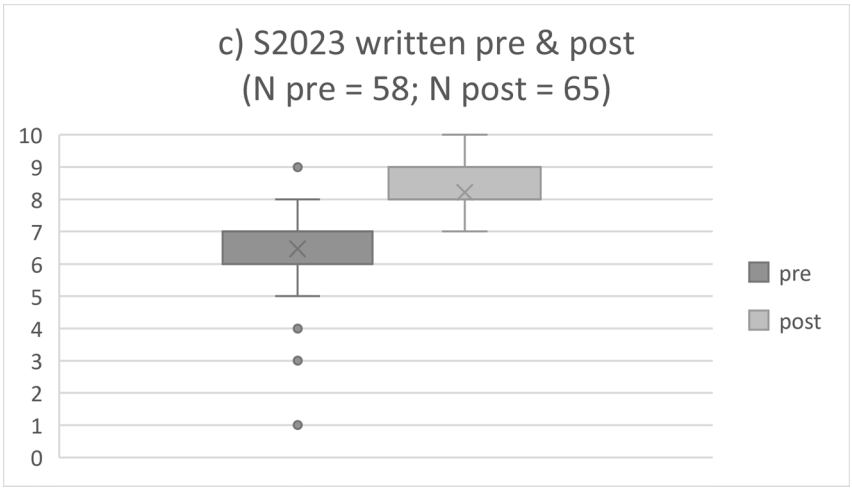
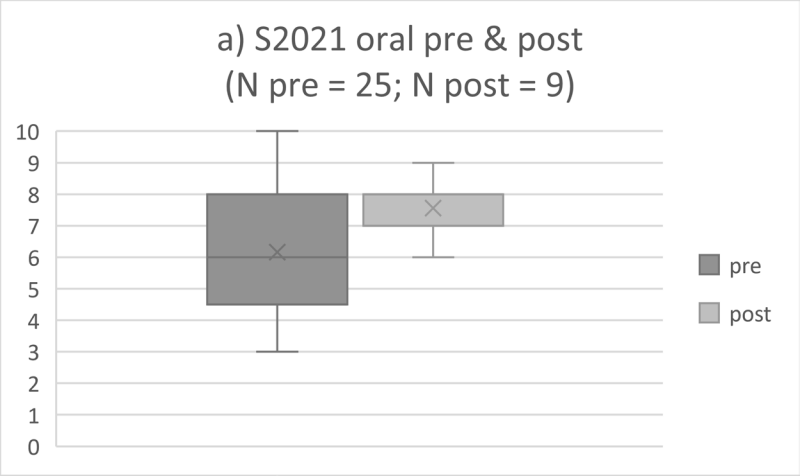
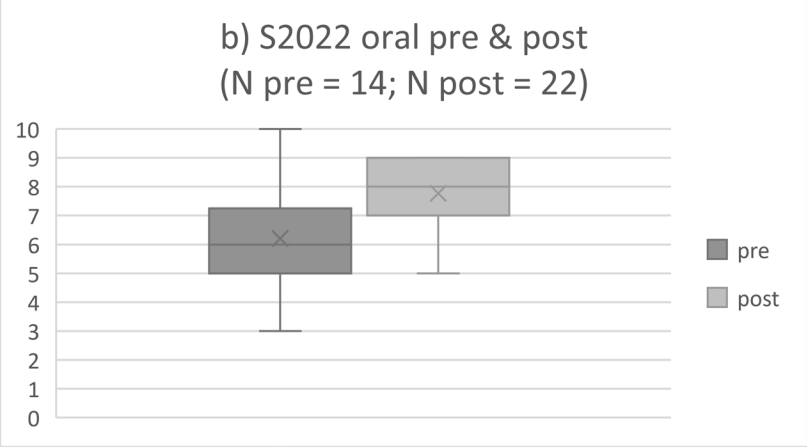
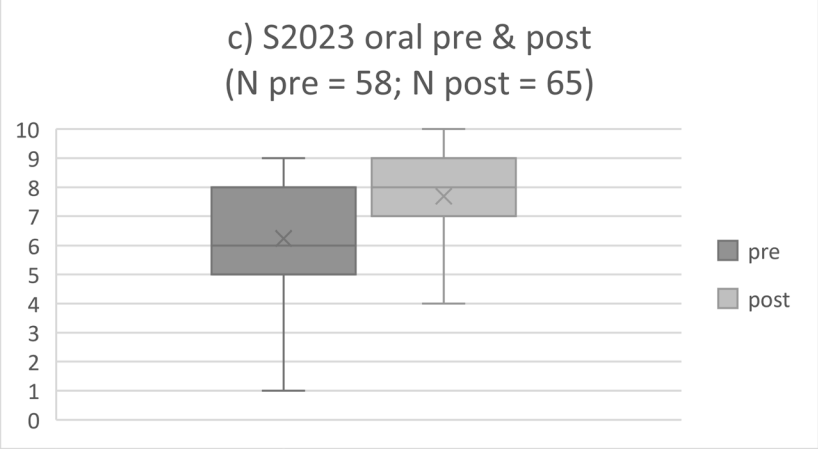


Figure 5 a-c. Responses to the survey question *How would you rate your ability to communicate effectively with specific audiences through in-person formats (for example: formal presentations, including speaking and preparation of presentation materials, informal in-person discussions, other formats which require presentation of material to a live audience)?* (a) spring 2021, (b) spring 2022, and (c) spring 2023.







Discussion

Course impact

These results indicate that the content and format of this course has been effective in increasing students' self-perceived ability to communicate in written and in-person formats. Each semester, students' self-assessments indicate that they believe their communication skills have improved. There appears to be less of an impact on oral/in-person communication formats than on written communications. Individual and group presentations, and presentations mimicking open house or public meeting sessions take more time to develop, present, assess, and revise, straining at the time available in an academic semester. Although there are several opportunities to practice oral communication in the course, there are admittedly fewer opportunities, potentially contributing to the observation of a smaller improvement in this skillset.

In this course, students progress through all six levels of achievement in the cognitive domain of communication specified in the ASCE BOK3 [1]. Students are required to remember, comprehend, and apply communication skills, as expected for undergraduates. However, this course also exposes students to higher levels of Bloom's taxonomy [26]. For example, students go beyond demonstration of recall via definitions and explanations to higher-order demonstrations of knowledge through analysis of different types of written communications and presentations and synthesis of material to develop a comprehensive communication plan for a notional engineering project. Students also develop and apply logic models to evaluate communication effectiveness. In addition, students in this class gain practice in skills that ASCE's BOK3 envisions students developing after graduation with mentored experience.

In addition, students in this course demonstrate abilities related to the affective domain, which the ASCE BOK3 identifies as equally important to cognitive domain development. For example, students practice and display effective communications tailored to audience needs. Students also hear from civil engineers in practice about different ways that communication shapes their work with clients, the public, and peers in the workplace. The finding of an increase in self-reported ability to communicate may also lead students, upon their entry into practice, to place greater value in engineers' responsibility to be effective communicators.

Limitations

This study relies on self-reporting, resulting in possible biases; students may feel more inclined to respond if they believe they have improved, or they may report that they feel they have improved because they feel improvement is expected of them. Reporting bias may be less likely with the incentive offered for responding to the surveys in spring 2023. This study does not examine whether self-assessed communication skills persist beyond this course or into the workplace. The anonymity of the self-reporting does not allow correlation of results with major, year of study, grade point average, or previous communication coursework. Finally, the students

in this course, to date, have had significant interruptions to their college experience due to the COVID-19 pandemic; the impact of this interruption is not assessed in this work.

Conclusions

Of course, further research related to this course could provide additional insights. The course will never be static: new tools and new case studies highlighting connections between civil engineering and effective communication will be incorporated into the course. Connections to other classes in the undergraduate civil engineering curriculum can also be created to ensure communication practice beyond the conclusion of this course. Employer surveys could assess whether students trained in this course are carrying communication skills into the engineering workplace. However, even without additional study, the findings presented here indicate that other undergraduate civil engineering programs can incorporate aspects of this course into their curricula confident the changes can contribute to improvements in at least some aspects of communication.

Every civil engineer entering practice will be expected to be not only technically competent but also able to communicate their work with a variety of audiences – from their supervisor to the elected official that helped secure project funding to the parent offering suggestions about the design of a dedicated bike lane for neighborhood children who cycle to school. Civil engineers today have a responsibility to evaluate audience information needs, consider them thoughtfully, incorporate stakeholder feedback into project design where possible, and communicate effectively and ethically. This course addresses an emerging and important aspect of civil engineering practice and is breaking new ground in engineering education.

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