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Technical Communication for Engineers: Improving Professional and Technical Skills

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Technical Communication for Engineers: Improving Professional and Technical Skills

The engineering profession, through discipline-specific strategic visions and the voices of industry, has begun to enhance the engineer's skill set beyond discipline-specific technical knowledge. As the demand has increased for engineers to improve their communication and professional skills, bridging the gap between analytical thinking and analytical communication has never been more important for our engineering students. Many professional engineering organizations have described their strategic vision for engineers to be able to communicate in a clear, concise manner. Professional communication skills and technical expertise are equally important in industry. However, traditional, humanities-based writing courses are often the sole formal writing preparation provided for engineering students. While the humanities offer courses that mandate expository, argumentative, and analytical writing, engineering students often overlook similar reasoning styles between engineering and the humanities due to the stark difference in content discussed. Additionally, technical writing within engineering, which includes published research, reports, presentations, among other knowledge products, is produced and organized according to differing conventions than those followed in the humanities. This paper discusses the design and implementation of a Technical Writing and Communication course, anchored in Project-based Learning (PBL), that seeks to improve areas of persistent communicative challenge for an engineering student population. Presenting results of lab scores and student surveys, this paper demonstrates engineering students' improved abilities to present information and convey meaning more precisely. As a result, this paper argues that a PBL approach to designing a technical writing and communication class offers engineering students exposure to and mastery of situated, professional, and STEM-specific writing and presentation tasks. Qualitative and quantitative student feedback is also discussed, showing the positive impact the course has on engineering, lab based courses as well as students' positive perceptions of the course for preparation of professional skills.

Introduction

Prior to the design and implementation of the technical writing and communication course at The Citadel, engineering curricula were supported by writing-intensive courses taught in the humanities, which also contribute to a student's general education requirements. The writing courses were developed over 40 years ago as a "one size fits all" answer to a large general education requirement at a small school that produced fewer than 60 engineers annually. With the growth of engineering students in the past decade, The Citadel developed the technical writing and communication course to meet the demand of engineering faculty and industry partners. While humanities-based writing courses continue to be included in engineering student development, these writing-intensive courses typically are taken in the first or second year, leaving engineering students without critical writing and communicative course supports as they move beyond their sophomore year.

In today's changing engineering curriculum, there is an opportunity to use writing to support engineering instructional goals and expected student learning outcomes. Evidence from a Canadian national survey of engineering graduates indicates that the need for technical writing is well-understood—most recent engineering graduates who participated in surveys and focus groups requested that more opportunities for engineering-based writing and presenting, coupled with in-depth feedback, be provided to future engineering students [1].

The implementation of writing in engineering education remains a challenge for two reasons. First, engineering educators have yet to reach a consensus about how writing should be taught and assessed. Goldsmith and Willey note that while there is broad agreement regarding expectations, there remains disagreement among engineering educators as to the role of writing in the curriculum, as well as who will teach it [2]. Second, while broad calls for increased exposure to the humanities is a common theme in engineering curricular design discussions [3], practically, it is difficult to see how this is to be implemented without merely adding another year to the existing, rigid course load requirements. Implementing the technical writing and communication course at The Citadel represents a cross-disciplinary effort between engineering and humanities, but it differs from other similar efforts in terms of content and focus [3]. This course prioritizes familiarity with engineering content and technical style, while also inviting engineering students to reflect upon, evaluate, and defend their organizational, design, and writing decisions.

Implementing a STEM-specific technical writing course also provides students with the opportunity to further engage with their disciplines and the opportunity improve upon any (accurate or inaccurate) negative self-perceptions of general written and verbal ability [2]. Goldsmith and Willey note in another study note that if sustainable writing practices were to be successfully introduced into engineering curricula, they would need to present writing as an authentic practice that engineers do daily, and one that stake-holders, engineers in industry, and engineering academics must do successfully [4].

The short discussion in the previous paragraph shows the dilemma that integrating writing into existing engineering curricula continues to be a challenge. The challenge is worth addressing—implementing a technical writing and communication course can provide two benefits: (i) tangible exposure to engineering writing conventions, and (ii) support for learning. Results from studies in cognitive and learning science show that writing, when employed in specific ways, enables students connect ideas, examine knowledge gaps, and enables long-term memory retrieval [5]. That said, engineering educators' efforts to employ these modes of writing have been mixed. Using so-called write-to-learn strategies in place of writing as a form of assessment, engineering educators devised a self-reflective writing prompt that was given iteratively to a Statics class, and required students to reflect on and evaluate their problem-solving approach [6]. However, this course change yielded no correlation with improved student performance on content-based exams. Authors speculate that implementation could have been the culprit, noting that their writing prompt did not require students to connect prior knowledge with new knowledge. Cognitive and learning science findings show that write-to-learn efforts are effective when two criteria are met: learner self-reflection and the ability to successfully connect old and new knowledge.

Technical writing and communication course

The need for engineering graduates to improve communication skills, both verbal and written, has been emphasized in multiple disciplines for several decades. The American Society of Civil

Engineers (ASCE) Vision 2025 suggests that "communications knowledge and skills are embedded in every civil engineer's education and encourage their continued enhancement throughout every civil engineer's career" [7]. The American Society of Mechanical Engineers (ASME) Vision 2030 states that mechanical engineers need enhanced skills, recommending that engineering curricula be designed to produce performance parity between engineering students' demonstrated technical skills and conventional professional skills, such as "effective communication, persuasiveness, diplomacy, and cultural awareness" [8]. Additionally, the report notes that both industry supervisors and early career engineers emphasize that graduates need stronger professional skills, e.g., interpersonal skills, negotiating, conflict management, innovation, and oral and written communication.

The need for effective communications permeates through every engineering discipline. The accrediting board for engineering programs in the U.S. and many schools abroad is ABET, and they define student outcomes as "what students are expected to know and be able to do by the time of graduation." One of the Student Outcomes is "(g) demonstrate an ability to communicate effectively" [9]. These strategic documents guide all engineering programs and are more than aspirational. They are meant to affect change, so implementing action to produce students with habitually effective communication skills starts with the faculty.

Conducting a needs-based assessment with engineering faculty at The Citadel, it was noted that engineering students struggled with producing conventional disciplinary documents as well as oral presentations. Specifically, distinguishing between broad categorical information and fine-grained details, STEM-wide conventions of document organization, and clear and concise writing were identified as areas that could benefit from improvement. Additional experiences creating and giving presentations as well as interacting with an audience were also identified as key experience targets.

Informed by these discussions, the technical writing and communication course discussed here uses a Project-based Learning (PBL) approach to provide sophomore-level exposure and mastery of the following three content categories: (i) technical writing conventions; (ii) project management tools; and (iii) authentic documents. In (i) technical writing conventions, students discuss and evaluate authentic documents for technical style; situational and audience awareness; potential for security vulnerabilities and liabilities; as well as possibilities for plagiarism and copyright infringement. Meanwhile, category (ii) project management tools provides a working familiarity with software applications that support the process of producing technical documents. These tools in (ii) can be categorized as follows: document design and templates, explored through LaTeX, Overleaf, and Word; proofing and editing tools, e.g., Grammarly, Expresso, and Google Docs; and source management tools, e.g., Google Scholar, Mendeley, and Zotero. Finally, (iii) authentic documents include familiarity with preprofessional documents; day-to-day operational writing; and informational and persuasive writing and communication. Examples of preprofessional documents include resumés, CVs, and cover letters. Operational documents include: letters; email; memoranda; reports; white papers; incident reports; and procedural and instructional writing. Finally, the third subcategory of (iii), informational and persuasive writing and communication, exposes students to: requests for proposals (RFPs); proposals; presentations and verbal briefs; as well as posters. Content categories (i) technical writing style and (ii) project management tools support students in the evaluation of and eventual execution of a selection of documents provided in (iii). At all stages of producing the four major course projects, students are prompted to apply their developing sense of technical style and preparation, while also leveraging the software applications that most suit the challenges they encounter.

The four major projects of this course culminate in the production of selected authentic documents: (i) professional portfolio; (ii) research report; (iii) technical manual evaluation; (iv) research presentation. These projects were selected for their utility and measurability with regard to ABET-approved student outcomes at The Citadel [10]. For those student outcomes most closely associated with the course objectives, "(f) an understanding of professional and ethical responsibility," and "(g) demonstrate the ability to communicate effectively," stand out as areas where this course contributes to curricular values. Specifically, (i) professional portfolio addresses both (f) and (g); (ii) research report clearly supports (f) and (g); (iii) technical manual evaluation supports (f); and (iv) research presentation allows for the measurement of (g).

Project-based learning

Project-based learning is an instructional design, anchored by a student-centered classroom, that requires students to collaboratively solve tasks, problems, and assignments with undefined processes coupled with clear end-result objectives. Students are invited to reflect on their chosen problem-solving approach, identifying strengths, weaknesses, and the boundaries of their knowledge [11]. Consistent with cognitive science findings, scaffolding knowledge and connecting existing and new information supports deep understanding, learning, and memory retrieval, particularly when reinforced by self-reflection. Additionally, studies in STEM-PBL, a novel repurposing of this instructional approach, show that among heterogeneous secondary-level STEM students, PBL approaches were associated with statistically significant performance gains among initially low-performing students and minorities, though the mechanisms behind this are not well understood [12].

Supported by findings in cognitive science, pedagogy research, as well as the broad calls within the engineering disciplines [7-8], PBL coursework in technical writing and communication supports new and continuing engineering student learning outcomes. That said, while technical communication skills can play a significant role in the career of an engineer, helping students develop these skills can be difficult [13]. As a near-term check of the persistence of learned technical writing and communication content, knowledge and skills from the sophomore level technical communications course were used in subsequent engineering courses. This curricular support is also in alignment with Kelley and Knowles' key practices that build the unique set of knowledge, skills, as well as unifying language to form common practices while investigating and solving problems [14]. These common practices include the task to communicate ideas, design decisions, justifications, explanations, and design rules of thumb [15].

Course impacts

Each engineering discipline at The Citadel has its own specific outcomes for graduates to communicate effectively Although there are differences in each engineering program, most follow a cognitive development model where basic fundamentals are learned and discussed in freshman and sophomore years, followed by more complex subjects which are reinforced by labs during sophomore and junior year. Finally, senior year often has short projects and a senior capstone or design project. Senior design courses provide excellent opportunities for students to practice technical writing.

The new technical writing and communications course is usually taught in the sophomore year. A mechanical engineering Measurements and Instrumentation course taken during the junior year has a fair number of lab exercises that required the students to write detailed lab reports. The results are shown below in Figure 1.

The solid bars represent the students who had the Technical Writing and Communications (TWC) course before the engineering course, and the striped bars were the students who took the basic English curriculum. The average GPA of the individuals who took TWC that semester is 3.048. The average GPA of the remaining students was 3.024 at the same time. The TWC students were basically the same performers as the non TWC students during the same semesters. However, the TWC students' lab reports averaged over three points higher. The TWC appears to make a positive impact on the engineering students to write and communicate their lab reports better.

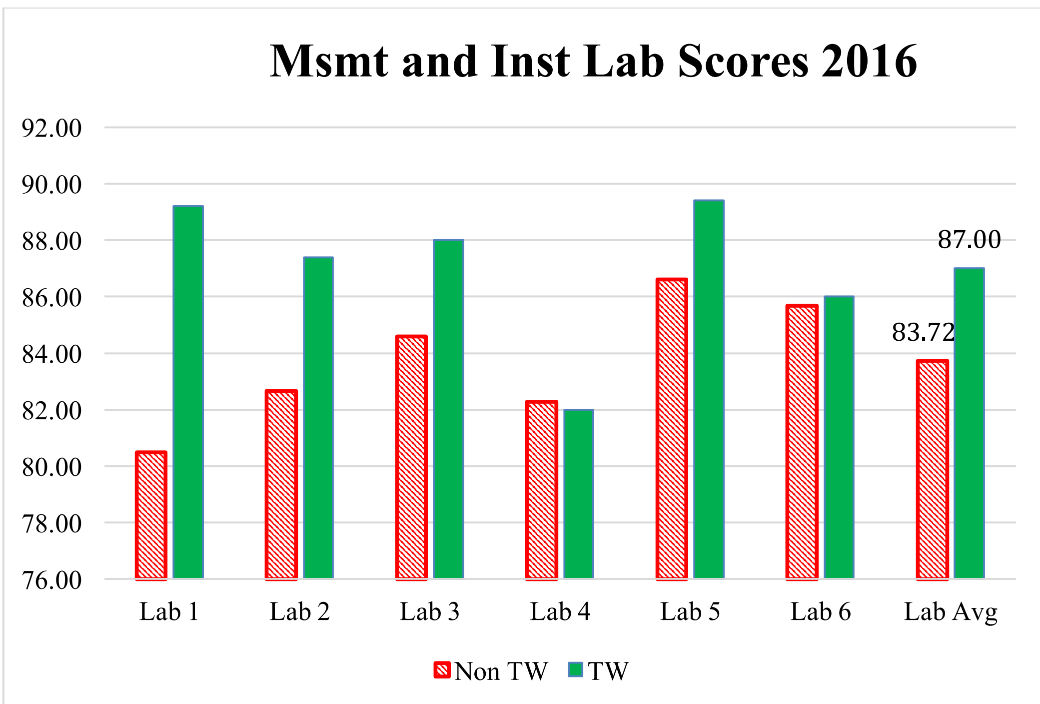

Figure 1: Lab scores (2016) for Measurements and Instrumentation

In another example, in Mechatronics, a project-based course that informs the approach used in the Technical Writing and Communication course, students followed a lab report format for each of their mini-projects. To increase student interest, creativity, and to promote the hands-on experience, open-ended labs were developed to foster problem-solving skills. Each team had different components and ideas for a real-world application. In addition to writing about their design decisions and addressing each area, students had to brief their project to the entire class. Even though the other students had the same baseline knowledge as they did on the technical material, they had no previous knowledge of the application. The team briefing the class had to be clear, succinct, and communicate their design and application to fellow engineers who had the opportunity to ask questions. The instructor graded them on their presentation, and a small number of their peers provided written comments back on their presentation skills. In addition to these demonstrations, teams submitted a lab report for grade. Instructors for the course have noted the overall improvement in writing quality and consistency over the last two years when the technical communications course became mandatory for engineering majors at The Citadel.

Senior design courses or capstone courses are another area where voluminous material can be present in a large two-semester project but benefit from a clear and concise written rendering. A considerable amount of effort has gone into elucidating the documents for technical writing assignments to students in the senior design sequence. By the time students reach their senior year, most can easily follow a format and address each area to some degree. However, there remains a tendency to include pages of raw data in the report—typically a result of students who struggle with prioritizing classes of information, or those trying to meet a minimum page requirement. When students are required to graphically portray this information and discuss the data (trend, consistency, etc.), they demonstrate a deeper and better understanding of the material. Senior design reports provide the engineering programs documented examples of students' reference management systems, technical reports, manuals, professional documents, and project documentation, creating and delivering oral presentations, and elevator pitches.

Initial competition outcomes of mechanical and electrical engineering students at The Citadel also indicate skill sets garnered in the technical writing and communication course may persist through year four of the curriculum. One of the requirements of the senior design mechanical and electrical engineer students at The Citadel is entering a "Shark Tank" contest sponsored by the School of Business. There is prize money and other benefits from this contest, designed to promote "Turning an idea into a business." Although there is always a strong field of contestants from Business students, engineers have entered each year as well. The technical writing and communication course at The Citadel is only two years old, but has already helped the engineer teams in this contest. Round 1 requires an executive summary on an idea or project that is judged by a panel recruited by the School of Business. In the current contest, five of nine teams were engineers who made it to the next round. In Round 2, students give an elevator pitch and answer questions from a panel of judges. Currently three of the five teams are engineers who will advance to the final contest. This locally sponsored contest allows engineering students to communicate with non-engineers while developing skills in writing reports, manuals, white papers, professional documents, and project documentation, creating and delivering oral presentations, and elevator pitches.

Survey instruments and results

Initial surveys of engineering students in the technical writing and communication course show that most students self-report struggling with technical writing prior to course instruction, identify key course content as useful during the course, and report increased success in comparison to their peers at career recruitment events requiring preprofessional preparation documents. Low-stakes, low-commitment, iterative, and non-compulsory surveys are a useful way of gathering qualitative and quantitative feedback on learner perceptions throughout a course.

The following survey instruments created for the technical writing and communication course reflect three moments—first, an introduction and diagnostic taken at the beginning of the semester, next, a snapshot of student self-reported preparedness and success taken mid-semester, and finally, a semester-end review.

These surveys were distributed using Google Forms, analyzed in MS Excel, and contain a majority of qualitative response types, as well as a few self-reported, quantitative response types. Qualitative data is rich, and can be modeled logistically for thematic content. Taken in sum, there are useful trends identified in the data regarding student perceptions and internship recruitment experiences. During the 'Introduction and Diagnostic' measure, taken over two semesters, slightly more than half of students surveyed (53%, n=107) report having some challenge with regard to writing and oral presentation. Some of these students specifically report difficulties with sentence structure and conveying ideas. This indicates that at course-outset, students were already aware of perceived weaknesses in the target area of study for the course. Additionally, most students had never held an engineering or STEM-specific internship, the acquisition of which requires some familiarity with the process of creating preprofessional documents (e.g., resumés, cover letters), as well as the personal presentation and networking opportunities typical of recruitment events. Figure 2 (n=107) shows that 71% of student-responders had never had a career-related internship work experience before, with 29% reporting having had an internship experience.

Figure 2. Reported Internship Work Experience

Approximately midway through the course, students were asked to apply components of their first project, the professional portfolio (containing, e.g., memo, letter, cover letter, resume, elevator pitch), to a Career Services internship and employment recruitment event. Results from this survey (n=87), shown in Figure 3, taken over three semesters, show students with self-reported high levels of preparedness for this event, at 71%. Students answering ‘no,’ indicating they were not prepared for the event were at 17%, and non-responders at 12%. Students who answered the question “Do you think you were well-prepared for [this event]?” were then prompted to explain why they were or were not prepared in a subsequent measure, with all students holding themselves accountable for their preparedness, or lack, respectively.

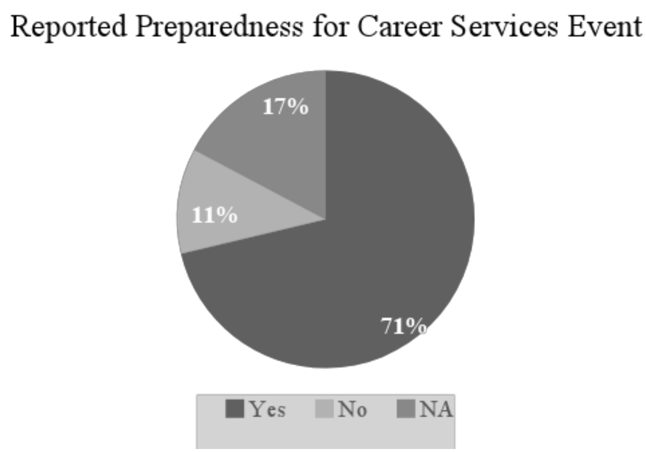

Figure 3. Reported Preparedness for Career Services Event

In a late-semester measure (n=87), taken over three semesters, students were asked “Were you offered an internship,” wherein they were expected to report on the results of their efforts at Career Services-facilitated recruitment events. This was a forced-choice response—students could respond ‘yes,’ ‘waiting for confirmation,’ ‘other (with explanation),’ or not respond. As Figure 4 shows, 41% of students had either procured an internship, or were in the process accepting one or possibly waiting for second-round interviews. Of the remaining 59%, it should be noted that not all of them wanted an internship, and indicated as such. For context, recall that this is a population for whom the vast majority has never held an engineering or STEM-specific internship before—and 41% are reporting some level of success at their first post-project event.

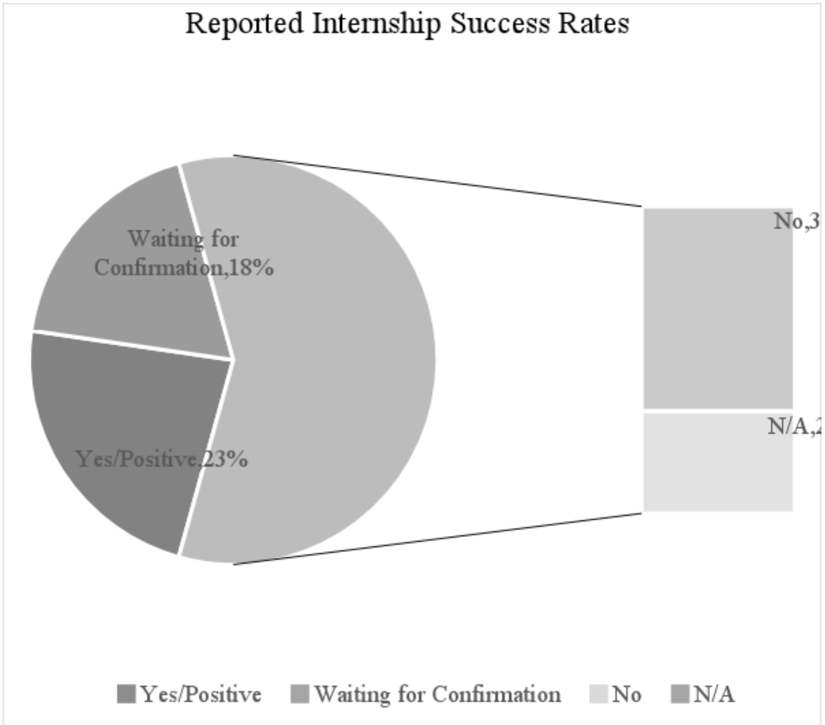

Figure 4. Reported Internship Success Rates

Discussion

When students were asked how useful the course was for them, the average was 4.15 on the on a 5-point Likert scale, showing a very positive reception of the course. In context, most engineering students at The Citadel rate humanities courses lower than their STEM courses. This is significant and demonstrates that they felt the course was valuable. This is reinforced by free text comments in reference to what they learned:

- "The writing and reviewing processes for technical writing."
- "Writing proper technical papers for different formatting and situation, and how to organize them."
- "The basics to constructing multiple types of technical documents."

The professional world requires people who can express their ideas effectively. Often engineering students underestimate their need to be able to write in a clear, concise, effective manner for different audiences of both non-experts and professionals. Future engineering professionals must develop stronger technical communication skills. By integrating a sophomore-level, project-based, technical communications course, and reinforcing the knowledge and skills throughout the engineering curriculum, faculty can work toward the goal of producing engineers who are prepared to meet current challenges in their disciplines, and who can communicate effectively to a variety of audiences.

References

[1] J. Donald, S. Lachapelle, T. Sasso, G. Gonzales-Morales, K. Augusto, and J. McIsaac, "On the place of the humanities and social sciences in the engineering curriculum: A Canadian perspective," *Glob. J. Eng. Educ.*, vol. 19, no. 1, pp. 6–18, 2017.

[2] R. Goldsmith and K. Willey, "'It's not my job to teach writing': Activity theory analysis of invisible writing practices in the engineering curriculum." *J. Acad. Lang. Learn.*, vol. 10, no. 1, pp. A118—A129, 2016.

[3] H. P. Sjursen, "The new alliance between engineering and humanities educators," *Glob. J. Engng. Educ*, vol. 11, no. 2, pp. 135—139, 2015.

[4] R. Goldsmith and K. Willey, "How can the development of writing practices in the engineering curriculum be enabled ?," *AAEE Conference*, 2016.

[5] K. M. Arnold, K. Thio, W. B. Reilly, M. A. McDaniel, and E. J. Marsh, "Understanding the Cognitive Processes Involved in Writing to Learn," *J. Exp. Psychol. Appl.*, vol. 23, no. 2, pp. 115–127, 2017.

[6] S. R. Goldberg, J. Rich, and A. Masnick, "The use of metacognitive writing-to-learn prompts in an engineering statics class to improve student understanding and performance," *121st ASSE Annu. Conf. Expo.*, 2014.

[7] American Society of Civil Engineers, "Achieving the Vision for Civil Engineering in 2025," ASCE, Reston, VA, August 2009.

[8] American Society of Mechanical Engineers, "Vision 2030: Creating the Future of Mechanical Engineering Education," ASME, New York, NY, September 2012.

[9] ABET, retrieved from http://www.abet.org.

[10] M. Bubacz, R. Rabb, J. Howison, K. Skenes, P. Bass, J. Geathers, and E. Book. "ABET Program Assessment (A.P.A.) for a New Engineering Program," *ASEE Zone II Conference, ASEE*, 2017.

[11] B. J. Barron, D. L. Schwartz, N. J. Vye, A. Moore, A. Petrosino, L. Zech., and J. D. Bransford. "Doing with understanding: Lessons from research on problem-and project-based learning," *J. of the Learning Sciences*, vol. 7, no. 3-4, 271-311, 1998.

[12] J. Norback and J. Hardin, "Integrating Workforce Communication into Senior Design," *Professional Communication, IEEE Transactions*, vol. 48, no. 4, pp. 413–426, 2005.

[13] S. Han, R. Capraro, and M. M. Capraro, "How Science, Technology, Engineering, and Mathematics (Stem) Project-Based Learning (Pbl) Affects High, Middle, and Low Achievers Differently: The Impact of Student Factors on Achievement," *Int. J. Sci. Math. Educ.,* vol. 13, no. 5, pp. 1089–1113, 2015.

[14] T. R. Kelley and J. G. Knowles, "A conceptual framework for integrated STEM education," *Int. J. STEM Educ.*, vol. 3, no. 1, p. 11, 2016.

[15] M. Borrego and C. Henderson, "Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies," *J. Eng. Educ.*, vol. 103, no. 2, pp. 220–252, 2014.