2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33673

Educational Opportunities for Technical Writing in Engineering Education

Dr. Susan J. Ely, University of Southern Indiana

Dr. Ely began her academic career at the community college level, after having worked as an engineer in areas of manufacturing, distribution, logistics and supply chain. Her research interests in Supply Chain Management include optimization through resiliency, lean supply chain practices and effective instruction in supply chain for career development, professional development of educators and online practices.

Mr. Jotam E. Chen, University of Southern Indiana

Jotam Chen is currently pursuing a bachelor's degree of science in Industrial and Manufacturing Engineering with a minor in mathematics at the University of Southern Indiana. His expected graduation date is May 2022. He is the recipient of a full-ride scholarship, which has allowed him to study and engage in research abroad. In his studies, Jotam is focusing on engineering education and data science. Jotam has worked as an intern at the Panama Canal Authority and at the Toyota Motor Manufacturing Indiana. After undergraduate school, his plans are to pursue a Ph.D. in Industrial Engineering and work in research and academia.

Educational Opportunities for Technical Writing in Engineering Education

Introduction

Strong oral and written communication skills are imperative to assuring success in the workplace. Research suggests that oral and written communication skills are in high demand by employers regardless of degree field [1]. Additionally, the U.S. Department of Labor reported that oral and written communication skills along with critical thinking and teamwork skills are fundamental to every employee's ability to accomplish tasks in the workforce [2]. This being said, it becomes imperative for educational curriculums to include effective courses that stimulate oral and written communication skills among students. The implementation of effective technical wiring courses in various fields will assure the students' success when facing-real world writing situations.

For this research, engineering students enrolled in a Experimental Design and Technical Writing course at a small midwestern university were surveyed at the beginning and end of the semester to better understand student's perceived importance and value of technical writing. GoogleForms was used to survey students using a Likert-scale on their perceived skill as well as their perceived importance of technical writing for their engineering coursework and engineering career path. Data was analyzed by evaluating the pre and post survey pairs for student responses, using the Signed Wilcoxson analysis method. After a brief review of literature and an overview of the course evaluated, results from the surveys as well as relevant discussion are presented in the paper that follows.

Background and Relevant Literature

Technical writing skills are considered important for engineers, which can prove challenging for engineering students, as they tend be math-oriented problem solvers [3], [4]. Researchers have found that the ability to communicate effectively and analyze data affect tremendously on the engineer's overall performance [5]. Thus, future engineers require extensive skills and knowledge related to technical writing that can be applied to a variety of engineering settings. In one study, it was found that the writing completed in academic settings often varied greatly from the writing required of an engineer in the workplace [6]. In order for future engineers to produce efficient functional texts, they must acquire specific features of academic training in their undergraduate education that mirrors the demands of professional engineering career paths [7]. Research also proposes that students are lacking in projects that enhance their communication and teamwork skills [8]. This highlights the importance of the role of engineering educators as they are required to make careful selections of teaching material that both develops the student's general writing skills and provides students with relevant practical experience in project-based learning and opportunities to work and write together as a team.

The Technical Writing and Experimental Design course at the University of Southern Indiana is intended to help students develop the knowledge and skills needed to prepare them for the remainder of their collegiate courses and for their career. Development of this course occurred after receiving feedback from local employers that writing and communication skills of graduates were not at desired levels when entering the workforce [9]. Additionally, the University of Southern Indiana had recently modified how general education concepts would be reinforced in

program specific courses of study [10]. The establishment of embedded writing course objectives in engineering programs necessitated the creation of a technical writing class that would serve all engineering students, regardless of major, early in an engineering students' academic program to be reinforced at a higher level of competency during their senior year.

This course also enabled engineering faculty to integrate a core course for all engineering students meeting standards set by the engineering accrediting board, Accreditation Board of Engineering and Technology (ABET) [9]. Some of these learning outcomes are the ability to communicate effectively with a range of audiences, the capability of developing and conducting appropriate experimentation, and analyzing and interpreting data [11]. This course focuses on experiment-based technical writing assignments that enhance the students' communication and teamwork skills. Students learn to produce high-quality functional texts while also gaining technical understanding in various engineering concepts.

The Technical Writing and Experimental Design encourages students to be writers, readers, reviewers and experimenters by providing them feedback at multiple stages of the experimentation and writing process, as well as iterative writing through peer review and grading of multiple paper revisions. The course was created to follow a modular format, integrating a form of research or experimentation paired with an appropriate writing or technical communication element, to integrate both experimentation and documentation within a single module. Each module, learning objective, and relationship to engineering career expectation is described as follows:

- Essay: A formal research paper regarding ethical factors associated with large-scale engineering failures in history. This paper requires students to make use of online library resources with peer-reviewed scholarly works regarding events based in engineering failure, such as the Space Shuttle Challenger explosion, the lack of containment at Chernobyl, the issues associated with the Boeing 737 MAX, the failure of the New Orleans levees after Hurricane Katrina, and other engineering disasters. This module combines literary research, ethical analysis and writing essays about technical content. While not necessarily a technical form required by employers, both research abilities and a thorough understanding of engineering ethics are goals set by Accreditation Board of Engineering and Technology and are integrated into the course as specific learning objectives.

- Memo: Formal document that engineers use to make requests, give announcements, and communicate report findings. Business memos have been found to be one of the documents that engineering employers encourage to assess along industry and academic guidelines when students take technical writing courses [12]. In this course, students prepare an engineering memo describing the results of an experiment in probability modeling. In this module, students complete an experiment testing expected values from binomially distributed data against individual trials of an experiment. Students synthesize their data graphically and create a short (2 page) memo discussing the expected and actual values from their experiment.

- Technical report: Document that describes the process, progress, or results of technical research along with recommendations and conclusions of the research. Technical reports are considered one of the most important type of documents written by engineers [13, 14].

Engineers must have the ability to communicate solutions to problems not only graphically, but with comprehensive documentation and technical reports requires this skill [15]. To practice this form of documentation, a group technical report discussing a report that was conducted utilizing a formal engineering design of experiment process. Students are given an experimental objective and must first design their methodology, define all control, response, constant and nuisance factors, determine number or trials and replications and assign tasks to individual team members to successfully execute the experiment. Students then write a technical report as a group, documenting their results following a provided template (Executive Summary, Introduction, Methods and Materials, Presentation of Data, Analysis of Data, Conclusions and Recommendations. This assignment is submitted first in draft form, to provide opportunity for faculty revisions and recommendations prior to submitting a final assignment.

- Business proposals: Document that presents the solution to a problem and explains to detail process and requirements to execute the solution along with the constraints encountered to meet customer specifications. These types of documents are most likely to be read by executives in an organization. This being said, engineers need to have the ability to write such document in a way that would allow executives with no technical knowledge understand the content quickly and accurately [15]. The final module of the course includes the design and building of a prototype product based on given parameters and performance specifications. Students work individually to design, build and test their device. Students write a business proposal letter as if responding to an engineering design RFP (Request for Proposal). Students document the full design specifications, materials used in construction, method of construction, associated costs and results of testing in their final technical report. Students create a business proposal and deliver an oral presentation, as if presenting to a potential client.

By this variety of experimentation, types of design processes and forms of technical communication, students are exposed to technical writing styles found commonly in an engineering position in industry, rather than simply learning mechanics of writing that might be taught in an English-based technical writing course. By including sections on technical writing, statistical analysis, error propagation and other engineering concepts, students are encouraged to execute experiment-based activities and then write effectively about them through memos, executive summaries, business proposals, and technical reporting. Previous studies on technical writing for engineering students have documented outcomes assessments indicating that students in programs that experience a dynamic integration of communication and engineering education display significant improvements in writing and communication tasks [16]. Additionally, experiment-based learning has demonstrated to increase the engagement among students and improve the performance of students in critical components of technical documents such as the grammar, spelling, quality of writing, scientific integrity, and depth of analysis [17].

The course evaluated by this research is a 2-credit lecture and lab course, including 2-hours of laboratory exercises and 1 hour of lecture each week. Typically, the laboratory time includes an introduction to the method of experimentation, related physics and engineering concepts, key statistical principles required for data analysis and the establishment of the theoretical framework for each experiment. Students also identify key variables, constraints and potential sources for

error within their methodology during this lab time. Lecture periods are used to discuss technical writing best practices, key concepts in engineering writing, appropriate methods for presentation of data, grammar and common mistakes seen in technical writing. Lecture periods are also used for peer review, editing and proofreading documents and group discussion of experimental results. For this course, learning objectives include understanding experimental design, data analysis and technical communication. As such, over 50% of course time is spend on experiment design and execution, with the remainder of the course time focusing on the writing principles and practices mentioned above.

While research has documented that engineering faculty, engineering alumni and employers of engineers value technical writing skills, surveys of employers continually document a need for higher levels of competency in technical communication, both locally at USI and in surveys conducted of employers throughout the United States [2]. Additionally, students at USI frequently enroll in the Technical Writing course in their junior or senior year, rather than completing the course as a sophomore, as intended by their plan of study. Over the past 4 semesters, 77% of students are upperclassmen (junior or senior) and only 23% are sophomore status. All students take this course as it is required for all majors in engineering. However, students show hesitancy in enrolling for the course, as it is not a prerequisite of any other engineering course, other than a senior design course taken in the final semester prior to graduation. This raises the question as to how much value the students themselves see in a technical writing course. Do students understand the critical nature of the skill and how this course can benefit their studies and their careers as engineers in the workforce?

The University of Southern Indiana requires end-of-semester surveys of all courses to provide students with an opportunity to evaluate the course and the instructor, only one question of the survey relates the effectiveness of the course in teaching the content. There are no questions in this survey instrument pertaining to students perceived value of the course, both academically and as it relates to their career path. Therefore, to evaluate students perceived importance of this skill, additional data must be gathered.

In order to assess students' perceived improvement of knowledge and skills related to technical writing in engineering, and their perceived importance of technical writing as an engineering skill, an online survey was distributed to engineering students the beginning and end of the Engineering Design and Technical Writing Course. This anonymous Google Survey had students record their perceived skill as writers of technical engineering documents and their perceived importance of technical writing both to their education and their career. Additionally, the perceived skills in technical writing by students is compared to the grade they earned in the course, to determine if students adequately assessed their competency in various technical writing techniques.

Methodology

In order to quantitively measure the reinforcement of technical writing knowledge and skills of the students that experienced this experiment-based technical writing, all students enrolled in the Fall 2020 semester of ENGR 291 – Experimental Design and Technical Writing course were surveyed using Google Forms. Students were informed of the purpose of the survey and guaranteed

anonymity through the Google Forms. Each question used a 4-point survey, with responses varying based on the question posed. Students were surveyed at the beginning and the end of the semester to determine if there was a change in the student's perception of their own skill or the importance of the subject matter. Additionally, the average academic performance was compared to the average perceived skill to explore if students adequately assessed their competency in various technical writing techniques. A 4-point scale was utilized, as it corresponds to the 4-point grading scale used by the university for ease of comparison. The questions and their response scale are presented below.

1. How would you describe your ability to write technical engineering documents?
   Excellent (4)/ Good (3)/ Fair (2)/ Poor (1)
2. Do you feel comfortable writing technical engineering documents?
   A great deal (4)/ Somewhat (3)/ Very little (2)/ Not at all (1)
3. How important do you think technical writing is in engineering education?
   Critical (4)/ Important (3)/ Minor importance (2)/ Not important (1)
4. How important do you think technical writing will be for working in engineering professions?
   Critical (4)/ Important (3)/ Minor importance (2)/ Not important (1)

Of the 24 students enrolled in the course, 20 students completed the survey at the beginning of the semester and 16 students completed the survey at both the beginning of the semester and the end of the semester. While 16 students is a small sample size, it does represent a response rate of 66.67%. It is also important to note that due to the COVID-19 pandemic, in class instruction was eliminated for the last 4 weeks of the semester, which could impact rate of response for the second survey and potentially impact the students confidence at the end of the semester.

Data Analysis

Student names were removed from data prior to analysis. However, data was grouped into matched pairs to evaluate the change in response between the beginning and end of the semester. This "pre-post" analysis was to observe potential changes in student opinion due to the instruction provided within the course itself. In other words, did students change their opinion about the importance of technical writing after having completed a technical writing course?

Analysis of Likert-based data is typically considered to be categorical and not normally distributed [18]. Therefore, after descriptive statistics were computed for each group, the pre-post comparison was made using the Sign Test for Median of the difference of the pre-post response pairs, a methodology shown to be most effective when analyzing changes in responses using a pre-post methodology based on a Likert measurement scale [18]. For additional analysis of perceived skill with actual awarded grades, the mean average grade for each course section was compared to the section average of survey results for the question addressing perceived ability (question 1).

For the first question regarding engineering ability, students showed a slight increase in mean response (2.684 to 3.125), which did not reflect a statistically significant increase ($p = 0.063$). When comparing the perceived skill based on survey results and the awarded grades, students were

awarded grades slightly higher (3.2 compared to 2.904) but not statistically significant (p = 0.340). Therefore, over the course of the semester there was little change in perceived skill, but the students were shown to have a similar actual skill compared to their perceived skill, as based on awarded grades.

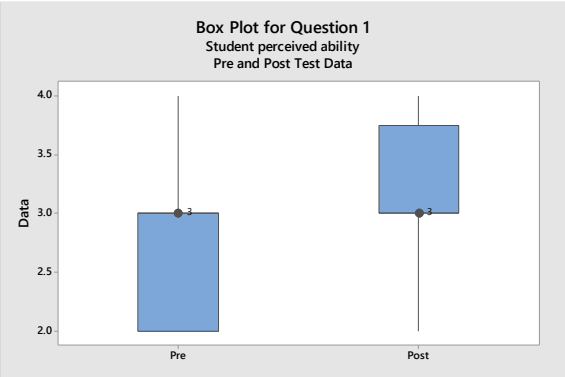
For the second question regarding their comfort with technical writing, there was an increase in the mean response (3.158 to 3.625) over the course of the semester, which was statistically significant (p = 0.031). This would indicate that students do increase in comfort with the additional practice over the course of the semester.

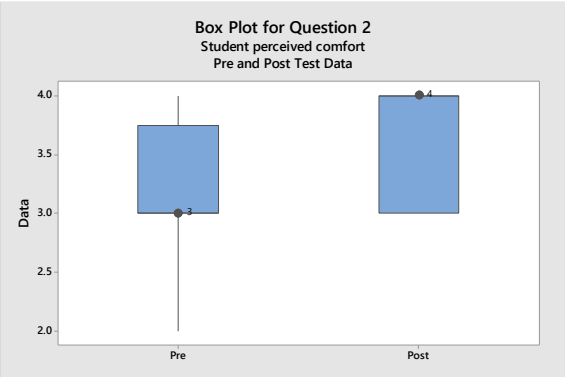
For the third question, regarding importance of technical writing for engineering education, there was no change at all in mean (3.632 and 3.688) over the course of the semester. This is also true for the fourth question, which addresses the perceived importance of technical writing for engineering careers (3.579 and 3.625). For both questions the p-value was reported as p = 1.0, demonstrating no difference between responses at the beginning of the semester compared to the end of the semester.

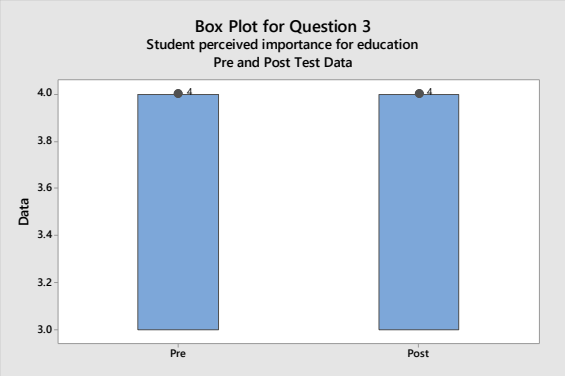
The data for the results are consolidated in the table below.

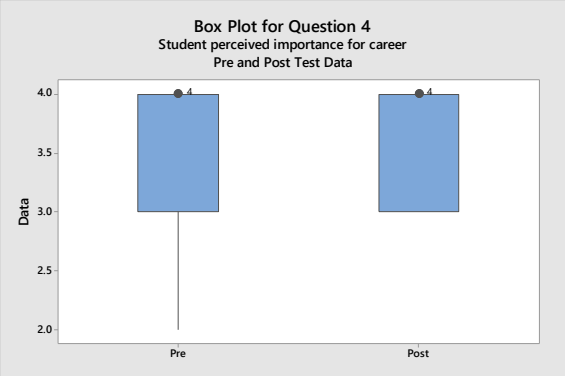
Question #	Mean (beginning of semester)	Mean (end of semester)	p-value	Final Grade / p-value
1	2.684	3.125	0.063	3.2/ 0.340
2	3.158	3.625	0.031	
3	3.632	3.688	1.000	
4	3.579	3.625	1.000	

Box plots comparing the medians of the pre and post survey results for each question are presented below.









Questions one, three and four had identical medians when comparing the student perceptions at the beginning of the course to the end of the course. While question 1 did show a statistically significant difference in the mean, these plots demonstrate that the median remained the same. For question 2, there is an increase in median from 3 to 4, supporting the increase in response as calculated by the Wilcoxson signed test.

Discussion

These results involved a small study (n=16) on single semester (Fall 2020) at a single institution. However, these results from this study differ from anecdotal experiences of faculty and the enrollment information from the last several semesters at this institution. Faculty advisors in the engineering department note a consistent delay in students wanting to enroll in the technical writing course, which was designed to be taken during the 2nd year of most engineering programs at the institution. The delay in enrollment would seem to suggest that students do not value the technical writing course as a mechanism of supporting their engineering education, despite a high rating of importance (3.6/4.0). Also, while students rate the skill as being important for their career (3.6/4.0), the students do not enroll in the course as sophomores (as intended by their plan of study) which could assist them in any co-op or internship experiences later in their college career. This delay of enrollment undermines the intent of the program of study for all engineering programs at the institution.

While students showed an increase in confidence over the course of the semester, that did not correspond with a perceived increase in skill. Students are statistically significantly more comfortable with their writing ability at the end of the semester, than there are confident in their skill ($p = 0.018$). As their perceived skill aligned with their final assigned grades, this reinforces the question on how much students desire to write well. While the students rate writing as important (mean of 3.6/4.0) they seem content to only achieve moderate results in the course (3.2/4.0). This would indicate that students may thinking writing is important, but not important enough to put forth the time and effort required to achieve excellence.

Further Research

The research intends to continue this study in future semesters to both increase the total sample size being studied and determine if the COVID-19 pandemic potentially impacted the results of this survey. It is also possible that an established survey on self-efficacy in technical writing for

engineering students has already been developed. Using a validated survey could provide more thorough and nuanced results than those obtained in this research.

It is also important to note that faculty advising practices may need to be adjusted, to further encourage sophomore students to enroll in the ENGR 291 Experimental Design and Technical Writing course as sophomores, rather than waiting until they are upperclassmen. While increasing a student's comfort with technical writing is a desirable outcome, increasing their technical communication skills is the primary objective. Faculty should reinforce the importance of the skill and the methods for obtaining those skills as part of their instruction in the course. It may be helpful to have alumni or employers speak to students throughout the course of the semester to better emphasize the need for cultivating skills as writers, in addition to their technical competencies.

Conclusion

While students state the importance of writing both for their time in academia and as professionals in engineering fields, delayed enrollment and average competency in technical communication skills would seem to contradict the stated importance. Additional research in this area could provide insight on how to best support students in this critical engineering skill set.

References

[1] J.A. Rios, et al., "Identifying critical 21st-century skills for workplace success: A content analysis of job advertisements." *Educational Researcher*, vol. 49, no. 2, pp. 80–89, 2002.

[2] United States. Bureau of Labor Statistics, Dept. of Labor. "Soft skills: The competitive edge." Web. March 2021. www.dol.gov/agencies/odep/publications/fact-sheets/soft-skills-the-competitive-edge.

[3] W. Schneiter, "Writing and undergraduate engineers – a continuing problem." *Proceedings of the ASEE Annual Conference and Exposition,* 2003.

[4] K. Sura and N. Romond, "An outcome-based assessment of engineering writing proficiency classes.", *Proceedings of the Industrial and Systems Engineering Research Conference,* 2017.

[5] C.Prusty, A.K. Dwivedy, and J. Khuntia, "Why and how do engineers communicate?", *IUP journal of soft skills*, vol.9, pp 45-50, 2015.

[6] S. Conrad and T. Pfeiffer, "Preliminary analysis of student and work-place writing in civil engineering." *Proceedings of the ASEE Annual Conference and Exposition,* 2011.

[7] D. Rus, "Developing technical writing skills to engineering students." *Procedia Technology*, vol. 19, pp. 1109–1114, 2015.

[8] K. Pate, J. Marx, and F. Breidi, "Design of a transparent hydraulic educational demonstrator utilizing electrically controlled valves." *Proceedings, 2018 IEEE Frontiers in Education Conference (FIE),* 2018.

[9] N. Smith, A.J. Hill and T. McDonald, “Design and implementation of a course in experimental design and technical writing.”, *Proceedings of the ASEE Annual Conference and Exposition,* 2018.

[10] University of Southern Indiana. University of Southern Indiana, “Factbook”, https://www.usi.edu/planning-research-and-assessment/usi-fact-book/student-dashboards/. (assessed February 13, 2021).

[11] ABET “Criteria for accrediting engineering programs 2018-2019.”, https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/ (assessed February 12, 2021).

[12] N. Amare and C. Brammer, “Perceptions of memo quality: A case study of engineering practitioners.” *Journal of Technical Writing and Communication,* vol. 35, no. 2, pp. 179-190, 2005.

[13] J.T. Emanuel, “The Executive Summary: A Key to Effective Communication.” *Technical Communication,* vol. 43, no. 1 pp. 78-82, 1996.

[14] H. Heike. *How to Write Technical Reports Understandable Structure, Good Design, Convincing Presentation*. New York: Springer, 2010.

[15] A. Wadood Khan, "The Engineers’ Guide to Technical Writing: Insights for Budding Engineers." *Advances in Language and Literary Studies*, vol. 10, no.4, pp. 80-87, 2019.

[16] J. D. Ford and L. A. Riley, “Integrating Communication and Engineering Education: A Look at Curricula, Courses, and Support Systems,” *Journal of Engineering Education,* vol. 92, pp.325-328, 2003.

[17] H. S. Saad, “Implementation and Assessment of New Techniques in Technical Writing”. *Proceedings of the ASEE Annual Conference and Exposition,* 2018.

[18] P.K. Roberson, S.J. Sherma, D.J. Mudfrom and T. M. Holmes, “Analysis of paired Likert data: how to evaluate change and preference questions”, *Family Medicine,* vol. 27, no. 10, pp. 671-675, November 1995.