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Undergraduate Engineering Students Find Meaningfulness in Statistics Technical Writing Project

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Abstract

Technical writing is a vital aspect of engineering education and practice. This study analyzed a technical writing project designed to teach basic statistical literacy and technical writing skills in an undergraduate engineering probability and statistics course. A proctored student survey was conducted at the end of the semester and subsequently analyzed to determine the project's meaningfulness and influencing factors to students. Meaningful writing can be experienced when an assignment goes beyond academic specifics and takes on an ongoing significance for a student in their future careers or passions. Over 87% of students indicated that they found the project meaningful, as it provided an opportunity to learn the course material ($p=0.018$). Students also indicated the project was applicable to their fields as well as increased confidence for future writing projects in their professional careers ($p=0.012$). These findings support technical writing as a meaningful dimension and productive learning experience for students in engineering pedagogy and in statistical literacy.

Keywords
Engineering Education, Term Project, Undergraduate Student Writers, Statistical Literacy

1. Introduction
Technical writing has one goal – to communicate sharply, clearly, and precisely [1]. The degree to which this can be done is a learned skill, both in writing mechanics as well as in technical expertise within the subject. To reach this goal requires technical expertise and skills in writing. Britton [1] defines technical writing by four general characteristics to differentiate it among other writing types: scientific and technical matters, a use of scientific vocabulary, dedication to accuracy and objectivity, and its complexity in terms of the overall subject and its subsequent description [1]. A crucial feature of technical writing is its logical sequence of explaining scientific, mathematical, or engineering topics so that explanations flow together as a whole and can be interpreted precisely by the reader [1].

Much research exists on the teaching of technical writing [2-13]. Rus (2016) encouraged instructors to integrate content-based instruction while teaching basic writing skills [12]. She stated this approach of unifying writing skills with specific technical subjects reinforces both skills. This method is a more natural experience of acquiring language structures which likely to increase students' motivation for learning [12]. It teaches students to be active contributors to their learning process [10]. Wallman (1993) defined statistical literacy as "the ability to understand and critically evaluate statistical results that permeate our daily lives -- coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions" [14]. Being statistically literate enables one to converse about one's individual understanding, reactions, and conclusions about the data being analyzed [13]. Understanding the purpose, logic, and process of statistical investigations helps develop statistical literacy and the ability to derive statistical dispositions through reasoning [7].

Tishkovskaya and Lancaster (2012) also discuss an active learning pedagogy technique of Enquiry-Based Learning (EBL) [13]. They describe EBL as empowering to students as it is adjusted to how they could learn best [13]. EBL enables students to draw from their existing knowledge and take the responsibility for learning more based on the needs of the project [11]. A type of nurturing and enjoyable learning experience results from this kind of supportive environment [2, 13]. It is the type of academic experience that Eodice, Geller and Lerner (2017) would describe as potentially meaningful to students [3, 4]. These authors have done extensive studies across disciplines in what makes a project a meaningful writing assignment for students [3, 4, 15]. Meaningful writing occurs when "students are invited to tap into the power of personal connection; immerse themselves in what they are thinking, writing, and researching; experience what they are writing as applicable and relevant to the real world; and imagine their future selves" [3].

Eodice et al. found that meaningful writing was practiced when the students knew they were not only writing for the instructor or to simply complete the assignment, but for larger contexts of people or for their own personal edification [3, 15]. Meaningfulness cannot be required of students or found in assignments, but rather it is found in taking advantage of educational opportunities so that the project becomes connected with a student's own goals and interests [3]. Based on these pedagogical models [3, 4, 6, 9, 12], this study analyzed a project assigned in a junior level statistics course at a land grant public university. Learning outcomes included statistical literacy and competency. In line with other pedagogical resources [12, 13], this course included an advanced technical writing project incorporated within the curriculum. This term project's purpose was to combine the specific skill of statistical literacy with technical writing. The project was a semester long, iterative, report requiring students to explain, evaluate and decide how to apply statistical analyses to draw conclusions, and in short, to exercise their learned statistical literacy and improve their technical writing prowess. The secondary objective of the project and the broad goal, compared to that of only teaching written communication techniques and technical writing mechanics, was to edify the undergraduate engineers' ability to deliver a professional, clear, concise, and evidence-based written narrative. It was expected that upon successful completion of the project, students would better understand and be more confident in basic statistics through logical conclusions based on gathered data, interpretation, and communication of their findings. The outcome of this project was to create an opportunity for a meaningful technical writing assignment that also increased statistical literacy. It was hypothesized that because students had limited technical writing experience, this project would be meaningful in that they were given autonomy in the project to identify and cultivate its utility by group for themselves.

2. Methodology

This study was approved by the Institutional Review Board (Protocol #CV112619-EX. To mitigate coercion the lead author (CH) gathered all student feedback separate from class instruction without the instructor (BM) present. The writing center (MM and AY) and engineering education center (BL) provided consultant sessions and feedback on interim and final products separate from the instructor (BM) as well as guidance on the student surveys. There were 45 total students enrolled in the Fall semester-based course. A total of 39 proctored surveys were conducted for a response rate of 86.7%. Participants were aged 18-21 years, English speaking males, and junior-level Industrial and Management System Engineering majors (Table 1).

Table 1: Participant Characteristics

Characteristic	Student Relative Frequency (%) (n=39)
18-21 Years Old	69.2%
Male	79.5%
English Speaking[1]	89.7%
Industrial Engineering Major[2]	71.8%
Junior Class[3]	79.5%
Enrolled in Honors College	20.5%
Without Professional Internship Experience	84.6%
16+ Credit Hours	51.3%
At or above a 3.0 GPA	69.2%

1 – Non-native English speakers indicated Arabic as their primary language. 2 – Other majors included Financial Engineers, Mathematics and a dual major. 3 – Enrollment also included sophomores and senior-level students.

2.1 Semester-Based Project Assignment Details

The full details of the technical writing project were given to the students on week 4 of 16 of a following the first examination to ensure a basic understanding of statistics and data analytics skills. Given the diversity of the class, students were informed that they could choose their own groups of 3-4 peers based on the minimal criteria that they must partner with individuals who are unlike themselves (i.e., at least one team member should be a different major). The groups then submitted a 1-page proposal of the chosen topic and a publicly accessible dataset chosen for analysis. Periodically throughout the remaining part of the semester, three in-class writing days were held. These sessions included having three of the university's writing center tutors, as well as the instructor, the teacher's assistant (TA), and two graduate students available for small group instruction and discussion. Writing Center tutors assisted with writing, English narrative, grammar, structure, and genre specific requirements. Technical topics for statistical analyses were answered by the instructor, TA or graduate students. Groups were required to visit the writing center once outside of these in-class days before final submission. During these appointments, students could submit the entire draft paper for review by engineering and non-engineering tutors alike. The tutor could then meet with the group to discuss suggested revisions.

2.2 Survey Instruments

A proctored survey was given to students in which they indicated their experience of the project. All participants provided written informed consent prior to participating, and all data were deidentified. Many of the questions were adapted from the survey Eodice, Michele, et al. (2017) conducted [3], except no open-ended prompts were given. The survey's core centralized around questions about a student's previous experience (academic or career), how they would describe this project, and what was or wasn't enjoyed about the project. Students were also asked to provide information in several demographic fields such as major, gender, language proficiency, age range, grade point average, and academic involvement (i.e., honors college participation and credit hour enrollment). On the last day of class in the Fall semester, students were invited to participate in the survey. The instructor was not present. The intention of the research was first explained to the students through similar means as Eodice, Geller and Lerner (2019) by explaining to students that this "survey is part of a research study whose purpose is to gain an understanding of the elements that college students believe make writing tasks meaningful" [3]. In addition, it was explained that their participation would contribute to the knowledge of the writing among undergraduate students. The word "meaningful" was also described as it applied to the Eodice, Michele, et al. (2017) study in their emic approach to defining it [3]. The students were given a paper copy of the survey at their individual desks and at least 20 minutes to complete the survey under proctored supervision. The proctor was present the entire time and ensured all electronics were put away and silenced. The proctor also responded promptly to any questions giving no insinuations (verbal or nonverbal) regarding participant's answers.

2.3 Statistical Analyses

While the analysis was situated around whether students found the project meaningful, recurrent patterns in the data were first labeled and a list of codes was developed (Table 2). All dichotomous questions were coded with a "yes" indicating a high value and "no" being a low value. Additional questions were asked to determine the type and quantity of students' previous writing experiences (i.e., lab reports, memos, etc.). These responses were coded according to a high dose group (those responses that indicated 6 or more writing assignments of the same type) and low dose group (those responses that indicated under 6 writing assignments of the same type). Four Likert-scale questions were also asked in the survey. For coding analysis purposes, "definitely yes" and "probably yes" were combined (high dose) and likewise, "probably not" and "definitely not" were also combined (low dose).

Table 2: Study Variables included in Survey Instrument

Survey Question	Collected Variables (Type)
Participant Characteristics included age, gender, major, year of study, English speaker, honors college, credit hours and grade point average.	Categorical and Continuous
Have you worked at a professional internship, job, etc., in your field of study yet?	Dichotomous
Have you had a writing assignment previously like this term project?	Dichotomous
Which choices most closely describe why you may have found this project meaningful or did not find meaningful?	Multiple Choice
Did you enjoy having freedom to choose your topic?	Dichotomous
Did you enjoy writing in a group?	Dichotomous
Are there ways in which this writing project might contribute to the kinds of writing you hope to do in the future?	Dichotomous
Describe the process you used to write	Check Any
Describe the kind of writing you did	Check Any
Do you feel like this project was connected to the course?	Dichotomous
Do you think you will write in your professional career?	Dichotomous
Do you feel more confident in writing a professional paper after the completion of the project?	Dichotomous
Did you or your group utilize the writing center during the project outside of in-class workdays?	Dichotomous
Did you or your group see your instructor specifically about the project outside of class?	Dichotomous

Minitab® Statistical Software (Version 2020, Minitab, LLC, State College, PA) was used for all statistical calculations. To determine significant findings, Chi-square tests were used to compare categorically coded Likert and Dichotomous questions. An alpha value of 0.05 was used. Binary Logistic regression was used to determine if the dichotomous questions and participant characteristics related to students' inclination to indicate that the project was or was not meaningful. Whether a student indicated the project as meaningful was used as the response variable The meaningful responses were assigned as the event. Using the initial pool of 18 variables (all participant characteristics and

dichotomous questions), *a priori* analysis was conducted to determine potential covariates of meaningfulness. Year, English Speaking and Gender were excluded in this pool of covariates because of the overwhelming representation junior level males who were English speaking. Most students did not have previous internship experience and had above a 3.0 GPA. These variables were excluded from the pool of covariates. The categorical predictors chosen were dichotomous questions as well as Major, Age, Credit Hours, and Honors College participation.

3. Results

Out of 45 total students in the class, there were 39 responses (86.7% response rate). The findings indicate that the junior-level students were more likely to fall within the 18-21 years old age interval (p=0.006) (Table 3). The results also indicated that students with English as their second language were older than 22 years old (p=0.006). Almost all students in the honors college were within the 18-21 years old age bracket (p=0.042). Students in this age bracket were also much more likely to report that they had above a 3.0 GPA (p=0.023).

Table 3: Descriptive Analysis of Participant Characteristics and Outcome Measures

Variables	Statistical Significance (P-Value)	
Year vs. Age	0.006[a]	
Age vs. English Speaking	0.006[a]	
Age vs. Honors College	0.042[a]	
Age vs. GPA	0.023[a]	
Age vs. Similar Past Writing[1]	χ^2 (1) = 3.754	0.053[b]
Gender vs. Seeing Instructor[2]	0.035[a]	
Credit Hours vs. Meaningful[3]	0.127[a]	
Major vs. Technical drawing	0.017[a]	
Meaningful[3] vs. Project Connectedness[4]	χ^2 (1) = 5.577	0.018
Similar Past Writing[1] vs. Future Writing[5]	χ^2 (1) = 4.022	0.045
Confidence[6] vs. Future Writing[5]	χ^2 (1) = 6.364	0.012

a - Chi square Pearson tests were used except instances where counts less than 5 were occurring and p-values resulting from Fisher's exact test are reported. b - p -value is marginally significant. Subscript values: 1 = Have you had a writing assignment like this in the past?; 2= Did you or your group see your instructor outside of class for this project?; 3= Did you find the project meaningful?; 4= Do you feel like this project was connected to the course?; 5= Are there ways in which this type of writing might contribute to your future?; 6= Do you feel more confident in writing after this project?

In comparing the participant characteristics and the dichotomously coded questions on the survey, several associations were found. All females who took the survey indicated that they saw their instructor outside of class (p=0.035). Those with 16+ credit hours also indicated that they found the project meaningful (p=0.07). Of the 19 students taking 15 credit hours or less, 17 indicated they found the project meaningful compared to the mere 2 who indicated they did not (p=0.07). Comparing age versus previous writing experience, there was marginal significance indicating that older students (ages 22-29 years old) had more writing experience (p=0.053). Non-Industrial Engineering majors all indicated they had done very few (0-5) technical drawings over their academic tenure. Among the Industrial Engineering majors, 37% indicated they had done 6+ technical drawings.

There were no statistically significant findings comparing the participant characteristics and the Likert questions (p>0.05). However, in comparing the Likert questions and the dichotomous questions, there were several important findings. Most participants (70%) found that the project was meaningful and that the project connected to the course (p=0.018). Most students indicated that this type of writing would contribute to future writings (p=0.045), 28 in total, but were evenly split as to if students had had this type of writing before. Almost 54% indicated they had had a writing assignment like this previously. Over half of the students indicated that they were more confident after the project in their writing and that this type of writing done in their future (p=0.012). In determining if the dichotomous questions related to whether a student was more inclined to say the project was meaningful, binary logistic regression was performed to model the data. The Deviance R squared value indicated that the model explained approximately 62.72% of the deviance in the response. Significance was found in if students saw their instructor outside of class (p=0.021). Moderate significance was found in if students enjoyed having freedom to choose their topic (p=0.085). The odds ratios indicated that students were 10,191 times more likely to say that the project was meaningful if they indicated they enjoyed having the freedom to choose their topic.

4. Conclusions

One of the most important findings of this study was that over 87% of students found the project meaningful. One question on the survey asked students to choose their top reason as to why they felt the project was meaningful. The

top two responses were that this project provided an opportunity to learn the course material as well as that the project was applicable to students' fields (Figure 1). This may have been why most students also found that the project was meaningful and that it connected to the course. Specifically, 82% of students felt that the project was connected to the course. This was a positive finding as the project was designed to give these opportunities. There was also success in 30% of students indicating that the project was meaningful because of the opportunity to learn the course content. This finding is similar to the pedagogical research Rus (2016) presented with the success of content-based instruction [12]. The way this project provided content-based instruction proved to be a worthwhile way to present technical content to students. This also joins the work of Hofer, Yu and Pintrich (1998) in the way that students became contributors to their learning processes throughout the project [10]. The deeper understanding of statistics students gained by drawing connections between data and the meaning of that data is akin to Enquiry-Based Learning [13]. The project required students to take the responsibility of diving deeper into their statistical findings to research and discover information in which their existing statistical knowledge base was deficient. Not only did students derive meaning from their statistical analyses, but students were held to the standard of presenting their findings ethically [16]. Data ethics was an important thing for students to learn as public servants and for their professional development. Over a quarter of the students found the project was applicable to their field, a finding that supports the preparation of students for careers, a goal of engineering education. This project helped students learn statistics but also broadened learning by becoming more aware of the connection between the classroom and their future careers. The project gave them the opportunity to gain experience to find real-world data, draw conclusions, and present that data ethically.

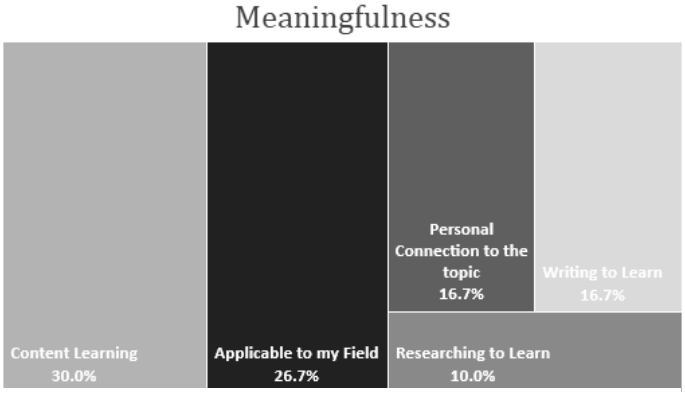

Figure 1: The choice(s) that most closely described why students found this project meaningful

At several points during in-class workdays, students were encouraged to step back from analyzing datasets and ensure they were reflecting on the main point they were trying to statistically evaluate. It was a common issue that groups become overwhelmed with a vast dataset. The instructor, TA and/or graduate students would then help the group refocus on what they were trying to evaluate through statistical analyses, which in turn helped the group summarize their findings. Several groups discussed their writing processes and there was active dialog between writing center tutors present on in-class workdays. In these discussions, students had to explain the meaning of their findings to someone unfamiliar with their specific process (i.e., non-technical audience). Almost 90% of the students in the class took advantage of utilizing the writing center throughout the writing process. This was a great exercise for students' professional careers and an asset of technical writing communication [1]. The interactions observed during in-class workdays showed evidence of how students were actively learning how to work in diverse groups with their peers and non-technical patrons. Almost 60% of students indicated they enjoyed writing in a group. While this was a requirement of the project, it did allow for active discussion with classmates. Garfield (1993) speaks highly of the opportunities to learn from one another in a group setting and this was seen in these discourses [6]. The three in-class workdays also provided opportunities for peer discussion and brainstorming. Due to the diversity represented within the classroom as well as internally in the groups, discussions were broad and well rounded. Having the freedom to choose project topics was appreciated by almost 70% of the survey participants, because of this diversity of major and background.

Eodice, Geller and Lerner (2017 and 2019) and Eodice et al. (2017) provided much of the inspiration tactics to make this project a meaningful writing project for students [3, 4, 15]. Students in this project were allowed to pick any topic they were interested in as a group, provided that they could find applicable data sets. Many groups selected topics they were passionate about or interested in over a range of topics from money to the environment. Students were encouraged to find something they were interested in researching and figure out how to find statistics, as well as understand and communicate back what they discovered. Some groups also became so engaged in their studies that they submitted their papers to undergraduate research publications. This point resonances back to the point that Eodice, Geller and Lerner (2019) made in which they found meaningful writing was done when the students knew they were not only writing for the instructor or to simply complete the assignment, but for larger contexts of people [4]. This assignment became connected with students' personal objectives and passions because of the freedom to choose their

topic. Nearly 72% of students indicated that they thought they would do similar types of writing in the future as professionals and over 87% predicted they would write in their careers. Eodice, M., Geller, A. E., & Lerner, N. (2017) state that "students find writing projects meaningful when they have opportunities to connect on a personal level, to find meaning beyond the specifics of the assignment itself, and to imagine future selves or future writing identities connected to their goals and interests" [3]. Because of this project's applicability to their future lives, due in part to the scope and personal nature of the topics, this may have also contributed to the overall meaningfulness of the project. Almost 60% of the class indicated they felt more confident in writing a professional paper after the completion of the project. This was also great positive feedback as the academic experience this project provided would enable and empower the students in and out of the classroom.

While the success of this project is encouraging, almost 56% of students indicated they had not had an assignment like this previously. In analyzing the types of writing that students indicated they had completed, non-Industrial Engineering majors all indicated they had done very few (0-5) technical drawings over their academic tenure. Among the Industrial Engineering majors, 63% indicated they had also done a few (0-5) technical drawings. While this discrepancy between majors is interesting and would relay future research, students have not had many opportunities to write across their programs. The types of writing that students indicated completed in their academic tenure. Clearly this project was not only meaningful to students, but also a rare occasion for them to learn technical writing in this format. Except for Laboratory Reports, students indicated they had completed 5 or less assignments within each of the categories. Given the overall pedagogical success of this project, other classes throughout the undergraduate curriculum would do well to consider integrating technical writing projects for students' erudition. Sample size was a limitation of this project. The revision process was a vital way for students to better their writing process. Further understanding student perceptions and progress via self-assessments would be beneficial. Students may have other motivations for choosing descriptive words for the project without reflecting directly on the project's meaningfulness when completing the survey. Thus, having Likert scale questions where students could describe their reactions to the words pertaining to meaningfulness, could give a clearer perception. Future work includes understanding the technical writing opportunities in undergraduate engineering degree paths.

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