2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34409

Scaffolding Technical Writing Within a First-Year Engineering Lab Experience

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Scaffolding Technical Writing within a First-Year Engineering Lab Experience

Introduction

Although the education of engineers has been an ever-changing process that has developed over time based on the needs of society [1], in more recent years the call for engineering education reform has been stronger and echoed across multiple stakeholders. Government reports [2], industry leaders [3], [4], and scholars [5], [6] have all had a hand in bringing to light the changes that need to take place in how we educate the future generation of engineers and how we should study and inform those changes. One of the more popular routes that colleges and universities have taken to improve their engineering education practices over the past two decades is the addition of first-year engineering (FYE) programs.

By 2013, almost 60% of engineering programs had implemented a first-year engineering program [7]. The literature surrounding the purposes, practices used, and outcomes of these first-year engineering program is extensive. Engineering Education conferences and journals have numerous publications related to research on first-year engineering. Kajfez & Mohammadi-Aragh [8] present a literature review of first-year engineering research in four major journals. This article found that research indicates FYE programs are an environment in which research-based innovative classroom practices are commonly implemented in a way that enhances and improves student learning. While FYE courses are most commonly used to introduce students to engineering principles and teach engineering students design skills, programming, and mathematics [9], this paper will focus on teaching technical writing as a part of a FYE program and how the techniques used to teach technical writing were developed and grounded in research-based practices.

Background

Technical Communication in Engineering

The need for engineers to be proficient in the communication of technical content has been reiterated many times over in publications and calls for action from engineering industry leaders (e.g. [10],[11]) and engineering educators (e.g. [12], [13]). In fact, technical communication has been identified by many engineering and education professionals as a skill just as important as skills related to design [3], [14], and surveyed engineers have indicated that they spend a significant amount of their working time communicating their work in a variety of ways [15]. Although the results of a FYE program survey analyzed by Brannan & Wankat [9] noted that communication skills were not a common area of weakness observed in incoming engineering students compared to mathematics, science, or other general life skills, technical communication has been identified as a weakness of engineers leaving undergraduate programs and joining the workforce [11]. The misalignment of skill deficits related to communication between when students enter and leave engineering programs has led many engineering programs to take action. Many universities have introduced assignments and projects focused on technical communication skills into courses across engineering curricula (e.g. [16], [17], [18]). Many FYE programs have taken an active role in working to improve students' technical communication -

and more specifically technical writing skills - through either specific courses or lessons (e.g. [19]) or by integrating technical writing into an already established course or project (e.g. [20]).

Research-Based Teaching Practices

1. Scaffolding

Scaffolding as an educational tool is used to reduce the complexity of tasks and help students focus their practice and build component skills [21], [22]. Scaffolding involves breaking down large learning outcomes into smaller tasks that students complete in succession. These small tasks are meant to build and refine component skills necessary for the achievement of the large learning outcomes. Scaffolding has been shown to be successful in improving student learning at multiple education levels and across various subjects (e.g. [23], [24]). Additionally, scaffolding has recently proven to be a successful tool in improving student learning in writing environments [25]. Scaffolding also allows for additional opportunities for students to receive feedback on their practice of component skills.

2. Feedback

Feedback is an important learning tool that ranges from informal conversations with students about their work to their final course grade. In various contexts (e.g. education level, subjects), feedback has been shown to improve student learning by helping students improve their retention of the material, develop their content understanding, and interact more meaningfully with their instructor [26]. By providing feedback to their students, instructors can start a discussion about misconceptions or misunderstandings students hold. Students can correct any confusion they have using good feedback to direct their practice [22]. By using targeted feedback, students can adjust and correct their misconceptions, recognize their strengths and weaknesses, and set learning goals [27]. Despite feedback being important to student learning, research has shown it can be underutilized by students [28]. Correction opportunities are an additional learning tool used to encourage students to read and implement feedback provided to them.

3. Correction & Reflection Opportunities

Providing students with opportunities to practice skills and apply knowledge are important steps in helping students develop proficiency in a topic [22]. Dweck [29] also notes that learning from failure and using failure as an opportunity to identify shortcomings and improve is an important quality of growth mindset. The benefits of having students make corrections on assessments – specifically test corrections - have been well-researched. Research on college physics assessments found that not only did test corrections improve students' learning, but they also reduced student stress [30]. Libertini, Krul, and Turner [31] describe their use of test corrections with an additional reflection that has students provide details regarding their mistakes and corrective actions. They note that this exercise not only improved student learning in a college mathematics course but also helped students develop stronger study skills. This article aligns with additional research stating that the act of reflection on one's own learning has also been identified as an important tool that improves retention of material [32].

Course Context

The first-year engineering program at Ohio State, a large, midwestern, public university, is required for all incoming engineering students regardless of intended discipline. Each year approximately 2000 first-year students enroll in the program and take either the standard or honors version of the two-course sequence. In this paper the authors will focus on the honors version of the program, which has an annual enrollment of around 300 students.
Each class has approximately 36 students and a teaching team comprised of a faculty instructor, a graduate teaching associate, and undergraduate teaching assistants. The classrooms are arranged to encourage groupwork, with students seated at four-person tables with individual computers and a collaborative workspace [33]. These four-person groupings extend to the laboratory experience, where students rotate groups approximately weekly. The faculty instructors take primary responsibility for delivery of the classroom experience, while the graduate teaching associates develop and lead the laboratory component under the guidance of the instructors.

The first course in the honors sequence provides instruction in problem solving, computer programming, engineering design, and technical communication. The classroom portion of the course is presented studio-style in two-hour blocks three times a week. This coursework is supported by a weekly two-hour laboratory experience that includes an introduction to the various engineering disciplines available at the university, experimental design, data collection and analysis, and technical communication. The course is taught using an inverted classroom model [34] with both preparation and application assignments associated with each class and lab day.

In the laboratory component, these application (post-lab) assignments often take the form of partial or full laboratory reports. These reports have five primary sections: Introduction, Experimental Methodology, Results & Description, Discussion, and Summary & Conclusions. These five sections are often supplemented by one or more appendices. Students are provided with a guide to lab reports and memos, formatting guidelines, and other supporting documentation. These full laboratory reports are used to assess students' lab-related content knowledge but also assess their technical writing skills such as content placement, tense, person, spelling, grammar, formatting, conciseness, and clarity of their writing.
Though these laboratory experiences and their associated post-laboratory writing assignments have been effective at teaching students the intended technical content and laboratory report writing skills, they have often been identified as an area with opportunity for improvement. Students often report concerns regarding the workload associated with the laboratory component of the course, including feelings of being "overwhelmed" by writing full laboratory reports [35].

A New Assignment Structure: Scaffolding Post Lab Assignments

In summer 2020, instructional team members for ENGR 1281 proposed implementing new post lab assignments that utilized scaffolding as a tool facilitating student learning in technical writing for Autumn 2020. This change was proposed following the decision for the delivery of ENGR 1281 to be entirely virtual for the Autumn 2020 semester. Lab experiences that were typically hands-on were going to be re-imagined to achieve similar learning objectives through virtual experiences. Instructional team members saw this need for immediate and large-scale change as an opportunity to integrate evidence-based education practices into the lab portion of the course that aimed to aid in students' learning of technical writing practices. Table 1 compares Autumn 2019's lab schedule and associated technical writing post-lab assignments with Autumn 2020's lab schedule and associated technical writing post-lab assignments.

Table 1: Autumn 2019's lab & assignment schedule compared to Autumn 2020. Post-labs with technical writing focus that are part of the complete quantitative analysis for this paper are denoted with blue text. Post-lab Full Lab Reports used for comparisons through t-tests are denoted with red **.

Week	Autumn 2019		Autumn 2020	
	Lab Name	**Post-Lab**	**Lab Name**	**Post-Lab**
1	Lab 1: Marble Carrier	Worksheet	Lab 1: Intro to Lab	Worksheet
2	Lab 2: Spot Speed Study	Full Lab Report (individual) ** Full Lab Report Re-Write (individual) **	Lab 2: Spot Speed Study	Experimental Methodology
3	Lab 3: P&G Product Launch	Professional Letter	Lab 3: Circuits & Electronic Components	Worksheet
4	Lab 4: Analog Electronics	Worksheet	Lab 4: P&G Product Launch	Professional Email
5	Lab 5: Viscosity	Worksheet & Abstract	Lab 5: Viscosity	Results & Description
6	Lab 6: Motors Testing	Memo	Lab 6: Materials Testing	Worksheet
7	Lab 7: Data Acquisition	Full Lab Report (individual) **	Lab 7: Motors Testing	Discussion
8	*No Lab*		Lab 8: Humanitarian Relief	Discussion & Conclusions
9	Lab 8: Quality & Productivity	Full Lab Report (group) **	*No Lab*	
10	Lab 9: Materials Testing	Memo	Lab 9: Digital Signals & Logic	Worksheet
11	Lab 10: Toy Adaptation	Worksheet	Lab 10: Data Acquisition	Full Lab Report (partner) **
12	Lab 11: Aerodynamics & Propulsion	Full Lab Report (group)	*No Lab*	
13	Lab 12: Stoplight	Abstract	Lab 11: Aerodynamics	Full Lab Report (individual) **

Scaffolding was integrated into the students' laboratory experience through post-lab assignments. For each post-lab used to scaffold technical writing practice and develop students' technical writing skills (Labs 2, 5, 7, and 8), only one or two section(s) of a lab report was assigned. A new report section was introduced to students approximately every other week. The purpose of each section assigned was provided in each labs' preparation documents.

To provide students with continuity and multiple examples of the necessary content and information that belongs in each section of a lab report, all post-lab assignments were structured using lab report headings (Introduction, Experimental Methodology, Results & Description, Discussion, and Summary & Conclusions). Questions related to the experimental methodology used to collect data were asked under the “Experimental Methodology” heading. Similarly, questions asking students about the results of their data analysis would be found under the “Results” heading, and so on. When students were expected to write an entire section, that lab’s post-lab assignment would outline the purpose and necessary information for that section rather than listing individual question prompts. Appendix A provides the skeleton used to create each post-lab assignment.

After scaffolding technical writing throughout the bulk of the semester, the last two labs (Lab 10 and 11) asked students to write complete lab reports as their post-lab assignment, one as a partner lab report and the other as an individual lab report, as shown in Table 1.

A New Feedback Structure: Post Lab Assignment Correct & Return

Along with proposing the scaffolded assignment structure to provide students with more lower-stakes practice with technical writing prior to being asked to write a full lab report, the instructional team also wanted to provide students with opportunities and incentives to implement feedback they may receive on scaffolded technical writing assignments. The proposed plan for offering opportunities to implement feedback was to offer optional correction opportunities for students to earn points back that they missed on scaffolded technical writing portions of assignments.

For each scaffolded technical writing section (Labs 2, 5, 7, & 8) and full lab report (Labs 10 & 11), students could earn up to 5 points back on technical writing mistakes that resulted in point deductions by submitting a completed ‘Correct & Return’ worksheet. These worksheets asked students to include their original technical writing submission content, their corrected technical writing content, as well as a short reflection that addresses what mistakes were made, the steps taken to correct those mistakes, and how those mistakes could be prevented in future technical writing submissions. This structure employs evidence-based principles related to the importance of feedback to student learning [26] as well as the need for reflection upon one’s own learning for improved retention of content [32].

Students were given one week to asynchronously complete a lab’s procedures and post-lab assignment. Grading of the post-lab assignment was completed by undergraduate teaching assistants (UTAs) within the next week. Students were given one week after grades and feedback for the post-lab were released to complete and submit the ‘Correct & Return’ worksheet. The structure of this feedback cycle informed the lab and scaffolding schedule shown in Table 1, as the goal was to return feedback to students one week after the post-lab was submitted (two weeks after the lab being assigned), which provided enough time for students to use feedback from their most recent technical writing submission to inform their writing for the next scaffolded technical writing assignment on the schedule.

Limitations

The authors thought it particularly important to identify the limitations related to the conclusions that can be made from the data collected, analyzed, and presented throughout the remainder of the paper. The Autumn 2019 semester's labs were structured and conducted as weekly hands-on lab experiences with mandatory attendance. Autumn 2020's virtual lab experience had numerous changes beyond the implementation of scaffolded technical writing assignments and correction opportunities for those scaffolded assignments. Autumn 2020 labs were assigned as asynchronous experiences with optional attendance on the lab day to hear the lab content be elaborated on by Graduate Teaching Associates. All labs were conducted virtually with students running simulations or watching videos of the lab procedures being completed to collect data. In the case of some labs, lab content, timelines, and content-related expectations were adjusted or changed between Autumn 2019 and Autumn 2020 to better fit the virtual environment. Controlling for all the changes necessary when adjusting first-year engineering lab experiences from hands-on to virtual to confidently conclude that score changes were directly related to the new scaffolded approach to technical writing would be nearly impossible.

However, it's also important to note that reports over the past year regarding how students' learning has been (and may be in the future) impacted by virtual learning amidst the COVID-19 pandemic have pointed out that student learning experiences are likely being negatively impacted by the new virtual learning environment. Whether these impacts be emotional impacts due to isolation [38] or mental health struggles [39], or academic impacts due to higher workloads [40] and decreased motivation [41], college student learning is being negatively affected by the COVID-19 pandemic and the abrupt transition to virtual learning. Although the data collected and subsequent results related to the implementation of evidence-based practices in teaching technical writing cannot be evaluated *independent of the impact of the pandemic*, the fact that 1) students' scores showed significant improvement and 2) many students self-reported positive learning experiences *despite the impact of the pandemic* suggests anecdotal significance and positive impacts related to the evidence-based approaches implemented in Autumn 2020.

Data Collection

To evaluate the effect of scaffolding on student performance, as well as effort, the grades and survey responses for the first-year honors engineering students in 2019 (N = 392) and 2020 (N = 287) were collected. The surveys, which asked for student feedback on the lab and the amount of time the assignment took to complete, were conducted as part of regular instruction to monitor student attitudes and effort in order to direct and prioritize laboratory improvement efforts. The survey was required and graded for completion after each post-lab submission. This paper focuses on the question that asked, "How long did you spend on this post-experiment assignment?" Students self-reported the time, choosing from five ranges that together encompassed 0 minutes to 10+ hours in 2019 and 30 minutes to 8+ hours in 2020.
The laboratory grades and survey responses were exported from the university's Canvas-based learning management system into comma-separated value files and extracted using MATLAB. A given student's grade data were matched with survey data using student ID and then the grouped data were deidentified prior to analysis.

In addition to the quantitative data of student scores and survey responses, the program asked students to provide qualitative feedback in the form of an anonymous journal response [36]. This data was collected from all sections of ENGR 1281 in 2020. The journal prompt evaluated in this study read:

> "Now that ENGR 1281 labs are over for the semester, suggest one aspect of the Lab Report writing assignments and/or lab experience that you found particularly beneficial and that you would keep the same. Constructively suggest one change or improvement to the Lab Report writing assignments and experience."

The results were provided anonymously to the instructional team.

Data Analysis

Quantitative Data Analysis

A custom MATLAB script extracted the scores on the assignments for both 2019 and 2020 data, as well as the scores on the Correct & Return submissions from the 2020 data. To better understand student performance on the technical writing assignments, the scores were plotted using histograms. To make comparisons between years and assignments more consistent, the histogram bins were normalized by the percentage of responses they represented. These data sets were also plotted using box plots to show the spread of scores for each assignment and any outliers in the scores. T-tests were performed to test for an improvement in mean scores between different sets of assignments, including the first individual report, the final individual report, and the first group report for each year.

To better understand the time students spent on each technical writing assignment, counts for different ranges of time were determined and plotted on bar plots. The 2019 surveys asked students to select how long they spent on each technical writing assignment, including potential ranges of 0-2 hours, 3-5 hours, 5-7 hours, 8-10 hours, or more than 10 hours. Because the survey was setup where students could select multiple answers, any student that selected two answers was sorted into the longer of the time ranges to account for a worst-case scenario. The number of students who selected multiple answers accounted for less than 5% of the responses. To address the gaps in time and the potential for selecting multiple ranges, the 2020 surveys asked students to select a single value in the potential ranges of 0.5-2 hours, 2-4 hours, 4-6 hours, 6-8 hours, or more than 8 hours. Because some students filled out a survey more than once, we took the largest time range to account for the worse-case scenario again. The number of students who took the survey multiple times accounted for less than 2% of the total submissions for both years. Additionally, the total responses (normalized by the number of students) across all technical writing assignments were averaged for each year to give an estimate for the average time spent across technical writing assignments in the course.

Qualitative Data Analysis

Qualitative data went through two rounds of coding. The first round of coding utilized provisional coding [37] in which predetermined codes were developed based on the topics of interest and the prompt students were asked to answer that acted as the source of the qualitative data. Considering the three evidence-based practices that were emphasized in this semester's post-lab assignment structure were scaffolding, feedback, and correction opportunities, each of those served as a primary provisional code. These codes were assigned to passages of text if what the student was describing related to the evidence-based practice, and therefore the student did not have to use the specific language or title of the evidence-based practice in order for the code to be assigned. As an example, one participant mentioned that they "appreciated that we got to focus on writing one section of the reports at a time and taking it week by week". Although they did not specifically identify this as the evidenced-based practice of scaffolding, it was tagged with the scaffolding code, as scaffolding was clearly the practice the student was describing. Each of the codes had two secondary provisional codes: positive and negative. These secondary codes were derived from the prompt students were given, to comment on one beneficial aspect of the lab experience and one they would change. These secondary codes were simplified as "positive" and "negative". Continuing with the example provided above, this passage would have been additionally tagged with the "positive" secondary code. This first round of coding was quantized, and descriptive statistics of the quantized codes were used to communicate the presence and frequency that students specifically called out these evidence-based practices in open-ended questions regarding their Lab Report experiences.

The second round of coding more closely examined the journal responses, and more specifically each of the passages previously tagged with one of the provisional codes. This round of coding focused on theming the data within those responses related specifically to one of the provisional codes [37]. This form of analysis was used to allow for more detailed and descriptive results to emerge from the data that related to the students' self-reported benefits of the evidence-based practices used.

Results & Discussion

Quantitative Results & Discussion

Rather than analyze the results of each technical writing assignment, we decided to compare the results of specific cases between the two years. Specifically, this section analyzes the scores of the first individual report (including a rewrite opportunity in 2019), the final individual report, and the first group report for each year. Note that due to differences between the labs each year, the lab reports that are compared do not cover the same technical content, but have similar expectations for the technical writing assignments. Additionally, this section analyzes the time students spent on the technical writing assignments.

Scores on Lab Reports

Figure 1 shows the quantitative analysis of the first individual lab report students completed for each year. Both the histograms and box plots show vastly different results between the two years, where students who practiced technical writing by scaffolding sections through the course performed much better than those students who wrote a report earlier in the semester without using scaffolding to practice each section first. A one-tailed two-sample t-test was performed and concluded that the students' average score on the first individual report of 2020 was significantly higher than the average score on the first individual report of 2019.

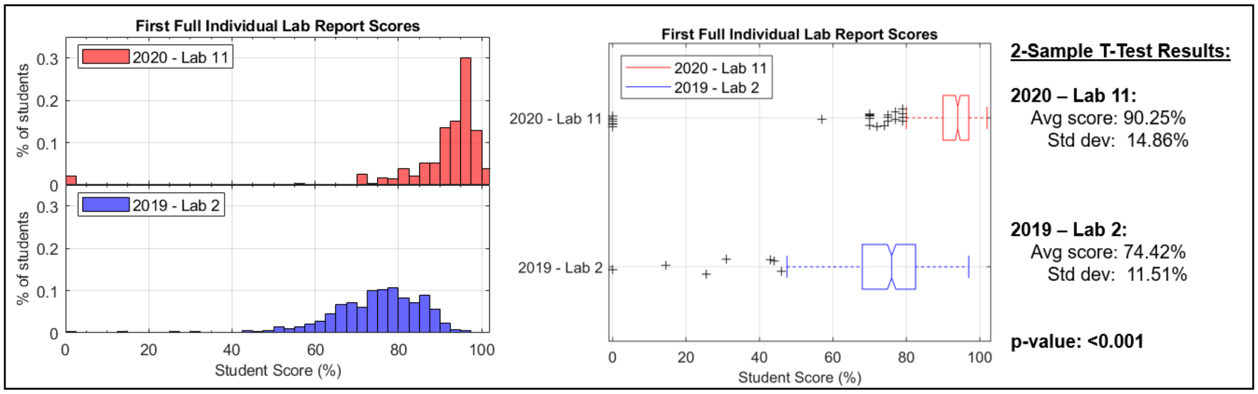

Figure 1: Quantitative analysis of the first full individual lab report scores.

While these results show a large difference in score between the two assignments, the 2020 students were able to practice each section of a lab report at least once before writing a complete lab report, while the 2019 students were asked to write a complete lab report without practicing each section. The 2019 students received feedback on their Lab 2 report and had the opportunity to make corrections and resubmit their report. Figure 2 shows the comparison between the 2020 Lab 11 report scores and the 2019 Lab 2 rewrite attempt. This comparison is representative of scores after students had been given feedback and the opportunity to make corrections on each lab report section. These results again show that that 2020 Lab 11 report scores were significantly higher than the 2019 Lab 2 rewrite scores.

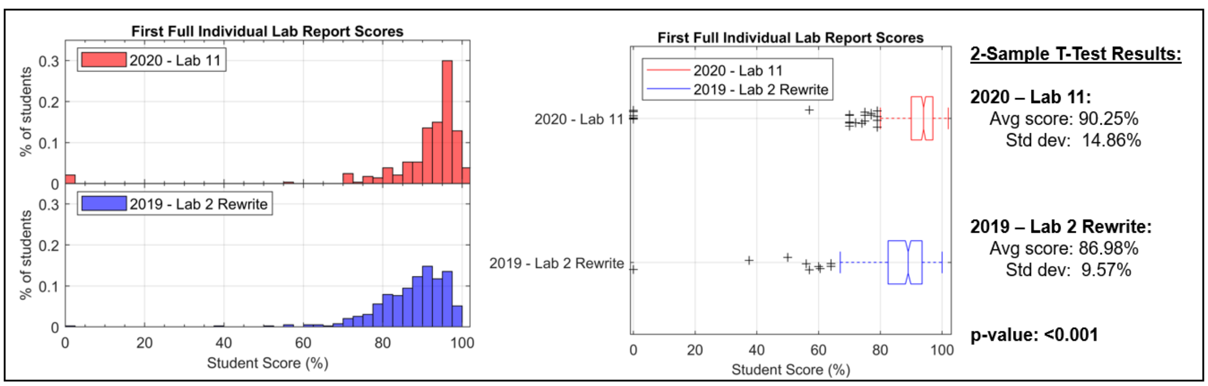

Figure 2: Quantitative analysis of the first full individual lab report scores (after a rewrite opportunity for the 2019 students).

To assess the students' technical writing skills at the end of each semester, Figure 3 shows the comparison between the last individual lab report of each year. As seen by the results, the 2020 Lab 11 scores were significantly higher than the 2019 Lab 7 scores, providing evidence that the 2020 students met the technical writing standards of the course better than the 2019 students. The 2020 students received a 2% bonus on each technical writing assignment that was turned in at least 24 hours early, but these grades were combined with their assignment scores, so it is difficult to determine the actual scores of the 2020 Lab 11 report. However, when the t-test was performed again while reducing all 2020 Lab 11 report scores by 0.5% (equivalent to a quarter of the students submitting the assignment 24 hours early, a generous estimate based on anecdotal observations), the t-test still provides significant results at an alpha value of 0.05.

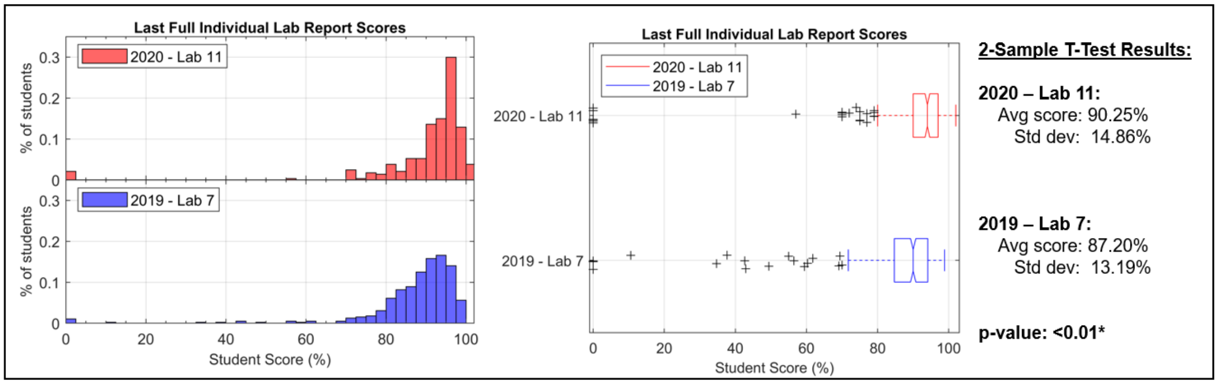

Figure 3: Quantitative analysis of the last full individual lab report scores.

To assess the students' technical writing skills when working in a group, the first group lab report of each year was compared, seen in Figure 4. It may be important to note that the 2019 students worked in groups of three or four, while the 2020 students worked in pairs. As seen from the figure, the 2020 Lab 10 scores and the 2019 Lab 8 scores did not vary significantly. These results suggest the 2020 students did not score significantly higher than the 2019 students, however the results also suggest that the 2020 did not score lower than the 2019 students despite writing fewer reports over the semester.

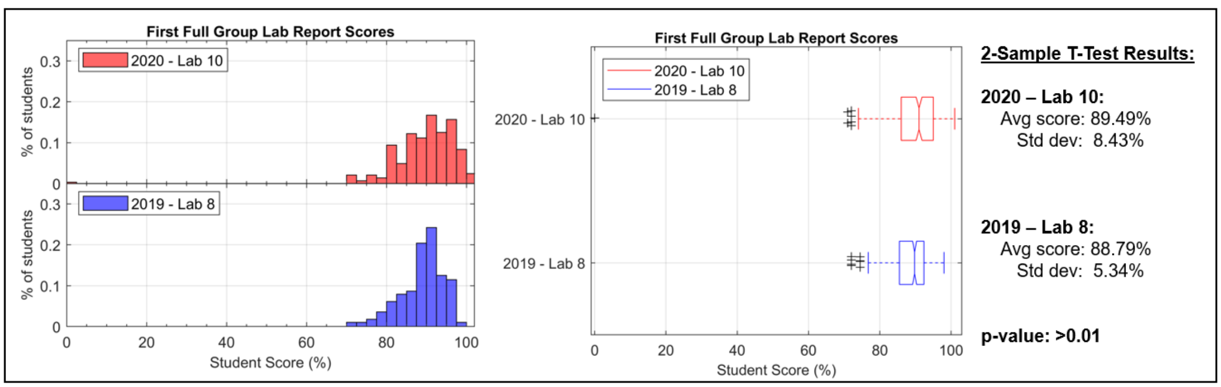

Figure 4: Quantitative analysis of the first full group lab report scores.

The results presented above suggest that by using scaffolding to introduce each section of a lab report, students may have improved on their technical writing skills better using scaffolding practices compared to writing multiple full lab reports. Looking at the first lab report, students performed significantly better in 2020 than 2019. This result is not surprising, as the 2020 students were able to practice and get feedback on each section at least once before writing a complete report, as opposed to the 2019 students who did not get the same opportunity. The 2019 students were provided feedback on their first report and allowed to make corrective changes and resubmit the report, allowing them the opportunity to practice each section and get feedback on the results, but still the scaffolded approach in 2020 led to better performance than in 2019. These results suggest that the scaffolding approach worked well because it allows for students to focus on one section at a time and potentially avoid being overwhelmed by feedback on an entire lab report. The results comparing the last individual lab report of each year also suggest that the scaffolded approach led to better mastery of technical writing skills by the end of the course.

Despite the 2019 students having additional opportunities to practice each section in their technical writing assignments through full lab reports, they did not appear to finish the course with as strong of technical writing skills as the 2020 students, who practiced writing each section fewer times but in a scaffolded manner. By implementing the scaffolding approach, we speculate that students achieved better mastery of the technical skills with fewer attempts.

Time Spent Practicing Technical Writing

To compare the time students spent working on their technical writing assignments, Figure 5 shows the combined average survey responses for the four reports in 2019 and the six technical writing assignments in 2020. While the ranges are not consistent between the two years, the 2019 survey results have a larger percentage of responses at the higher ranges. Additionally, it is worth noting that the two largest ranges for 2019 represent all times spent over 8 hours, containing almost 40% of responses while the 2020 data only contains approximately 5% of the responses over 8 hours.

To estimate the average time students spent on each technical writing assignment, the average survey responses were multiplied by their estimated time and summed across each category. The middle of each range was used for all ranges except the highest range, where 1 hour more than minimum of the range was used. Thus, the 2019 data used 1,4,6,8, and 11 hours for its estimates, while the 2020 data used 1,3,5,7, and 9 for its estimates. This calculation resulted in an estimated average time spent per technical writing assignment of 6.46 hours for 2019 and 4.34 hours for 2020.

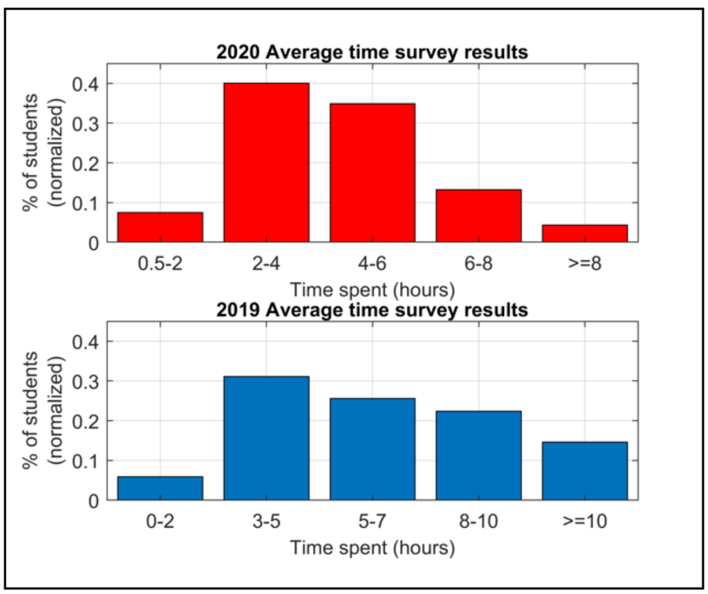

Figure 5: Comparison of time taken to complete lab report related assignments for both 2019 and 2020 students.

By analyzing the time taken to complete each assignment over the course of the semester, we showed that the 2020 students spent approximately 2 hours less on average for each assignment than the 2019 students. These results suggest that the scaffolding approach needed less time to practice technical writing skills but resulted in better performance. By implementing a schedule where students could practice specific technical writing sections and providing direct and targeted feedback about those sections, students were able to master these skills better than asking them to practice each section in each full lab report assigned. Because the 2020 analysis covered six assignments and the 2019 analysis covered four assignments, the total time spent on these assignments for each year was approximately equal. However, the 2019 data did not include the time spent working on the Lab 2 rewrite or other technical writing assignments (such as the Lab 6 and 9 memos, which are also significant technical writing assignments), suggesting that the 2019 approach resulted in more time spent by students with less mastery of technical writing. Considering the data in Figure 5, fewer students (~5%) spent more than 8 hours on technical writing assignments in 2020 than students in 2019 (~40%). This scaffolded approach reduced the number of students who spent large amounts of time on these writing assignments.

While we did not collect data on how long it spent UTAs to grade these technical writing assignments, the assignments were shorter as students wrote fewer sections over the course of the semester, likely resulting in less time needed to grade assignments. This time reduction in grading could help reduce the time needed to spend grading or allow UTAs the opportunity to spend that saved time providing better feedback for their students.

Qualitative Results & Discussion

The results of the first phase of provisional coding and subsequent quantizing provide a broad high-level overview of the frequency with which students identified the evidence-based practices implemented in the Autumn 2020 semester in the journals responses given. In total, 277 student responses were recorded, and a summary of the frequency of the primary provisional codes in the journal responses are shown below in Table 2.

Table 2: Summary of the frequency of provisional codes in the qualitative data.

Total Student Responses	**Responses Mentioning Scaffolding Structure**	**Responses Mentioning Feedback Provided**	**Responses Mentioning Correction Opportunities**
277	111	15	9

While many students (~40%) referred to the scaffolding process in their journal responses, far fewer mentioned the feedback they received on their technical writing (~5%) or the correction opportunities they were given (~3%). The secondary codes were used to identify whether students mentioned these evidence-based practices as the positive thing they would keep the same, or something they would suggest changing for future iterations of the course. Table 3 shows a summary of both the primary and secondary provisional codes.

Table 3: Summary of the frequency of primary and secondary provisional codes in the qualitative data.

Responses Mentioning Scaffolding Structure	111	Would Keep (Positive)	108
		Would Change (Negative)	3
Responses Mentioning Feedback Provided	15	Would Keep (Positive)	14
		Would Change (Negative)	1
Responses Mentioning Correction Opportunities	9	Would Keep (Positive)	6
		Would Change (Negative)	3

Most students (~97%) who identified the scaffolding approach to technical writing in their journal response identified it as a positive experience that should be kept the same for future iterations of the course. Most students (93%) who spoke to feedback included it in their description of what they would keep the same in the course. Comparatively, responses that mentioned the correction opportunities were not as overwhelmingly positive (66%). It should be noted that the ‘Would Change (Negative)’ secondary code does not code for negative student experiences, but instead identifies instances in which students identified that evidence-based practice as one that they would make a change to in future iterations of the course (e.g. changing the due date for Correct & Return assignments).

The second phase of coding more closely examined the student responses initially identified by the provisional codes to further explore students’ perceptions of the evidence-based practice and *why* students were identifying them as practices that should be kept in the curriculum. The passages originally tagged with provisional codes were re-coded using thematic analysis to identifying commonalities and reoccurring ideas and perceptions expressed by students. Due to the high number of students’ journal responses tagged with the scaffolding provisional code compared to the feedback and correction opportunities provisional code, the thematic analysis of the positive perceptions of scaffolding resulted in numerous themes with more frequency. The themes related to scaffolding are summarized in Figure 6. A complete list of the themes developed from the second phase of coding and their descriptions can be found in Appendix B.

Figure 6: Word cloud that visually represents the themes that emerged form students self-reported perceptions of the scaffolding structure of technical writing assignments.

Figure 6 represents the themes in a word cloud. Codes used to inform each broader theme were counted. The word cloud was created by associating the number of times that theme was present in the qualitative data with the theme. The larger the word in the word cloud, the more that theme was referenced in the qualitative data by students. Size of the word in the word cloud roughly resembles the salience of the theme amongst students.

The results from the qualitative data show that students overwhelmingly considered the scaffolded approach beneficial to their learning of technical writing. When asked to comment about one aspect of the lab report process that would beneficial, 39% of students specifically called out the scaffolded approach. While feedback and correction opportunities were also mentioned with an overwhelming positive response, the benefits of scaffolding were apparent to many of our students. The results suggest that the 2020 students not only performed better on the technical writing assignments in less time compared to the 2019 students, but also that believed the approach used was beneficial to their learning.

Conclusion

In the Autumn 2020 semester, a new structure was implemented regarding how students enrolled in the FYE course ENGR 1281 at Ohio State would be expected to complete post-lab assignments and practice technical writing. Changes were directly informed by three primary evidence-based practices in an effort to continue to strengthen the connections between engineering education research and practice. The new assignment structure built *scaffolded* technical writing practice into the post-lab schedule with additional *correction opportunities* that were meant to encourage student to implement the *feedback* they received prior to another technical writing assignment. Both qualitative and quantitative data were collected from assignments given in the course upon the completion of the semester to investigate the impact on students' performance and learning experiences. Quantitative data analysis determined that students demonstrated statistically significant improvement across technical writing scores for various assignments, as well as decreased time spent per technical writing assignment. These results indicate, but cannot indisputably conclude, that scaffolding improved student learning and served as a more efficient learning tool. Qualitative data revealed that many students had positive experiences with the scaffolded assignment structure, stating that it focused their practice at a moderate pace, improved their learning, and did not result in stressful or overwhelming emotions related to learning technical writing. While the evidence-based practices evaluated in this paper could not be evaluated in isolation due to the transition to the virtual delivery of the ENGR 1281 course in Autumn 2020, the results presented in this paper serve as evidence that scaffolding approaches may improve both achievement of student learning outcome and student learning experiences and perceptions of a course. Future work will likely include comparing future implementations of scaffolding in in-person course delivery to past in-person course delivery assignments in an attempt to control for the changes that the virtual environment may have caused.

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Appendix A – Skeleton Post Lab

Lab Name

Engineering 1281.01H

Autumn 2020

Student Name Here

Date of Experiment Data Collection: mm/dd/yy

Date Submission is Due: mm/dd/yy

1. Introduction

Introduction to this lab and material here

2. Experimental Methodology

Here is the text for the body of the Experimental Methodology section. This will be written by you in full and complete sentences. Refer to the Spot Speed Write Up, Spot Speed Presentation, and ETC guide for advice on writing a strong experimental methodology section.

3. Results and Description

If they are writing the results and description, use text similar to Experimental Procedures. If not, type up some sentences that make the results flow, but leave fill in the blank questions, or place holder tables / images that would typically go in results that they will need to add as part of completing this assignment.

4. Discussion

If they are writing discussion, use text similar to Experimental Procedures. If not, add short answer discussion questions here that evaluate if the lab learning objectives have been completed. Also, see discussion questions in previous year's write ups for ideas for questions here.

5. Summary and Conclusions

Ask students to summarize the experiment in a few sentences here at the end of each lab, maybe consider giving feedback to student about it, but not “grading” it until the two full lab reports.

Appendix B – Themes resulting from qualitative analysis

Table B1: Themes resulting from phase 2 of qualitative analysis.

Evidence-Based Practice	**Theme**	**Theme Description**
Scaffolding Structure	Purpose	Better understanding of the expectations and purpose of technical writing
	Pace	Spread over the semester and 'eased in' learning technical writing
	Less Negativity	Less feeling stressed, overwhelmed, unhappy due to technical writing assignments
	Learning	Improved learning and retention of knowledge related to technical writing
	Focused	Focus learning on specific content
	Practice	Opportunities for technical writing practice and skill development/improvement
	Efficiency	Workload/time spent working were managed well
	Feedback	More opportunities to receive and implement feedback
	Confidence	Feeling better prepared and confident when completing final technical writing assignment
Feedback	Quality	Feedback was detailed, specific, and actionable
	Learning	Improved learning and retention of knowledge related to technical writing
Correction Opportunities	Improvement	Opportunities to demonstration improvement in technical writing
	Learning	Improved learning and retention of knowledge related to technical writing