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# Improve Technical Communication Using Scaffolding Method in Mechanical Engineering Courses

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## Abstract

One of the most effective and well documented ways, throughout literary sources, to educate and develop capable and independent professionals such as engineers combines lecture sessions with step-by-step synergistic activities (experiments and reports). Therefore, many engineering educators are seeking experiential learning techniques and implementations that are innovative to assist students understand, exercise, and communicate engineering concepts they learned. Although project-based learning allows students to be able to deduce and apply concepts effectively, students continue to struggle to communicate their work and results effectively from such experiential learning and other projects. Thus, to overcome the deficiencies in writing skills such as poor grammar and formatting, and effective literature review in reports, an instructional scaffolding plan has been developed and implemented in two junior level courses in parallel (Mechanical System Design and Thermal Fluid Laboratory course). The scaffold activities include incremental class activities and assignments as well as access to support resources. The scaffolding activities in the instructional plan will allow students to develop confidence from completing shorter and targeted assignments successfully earlier in the semester as they build their report for more complex and involve analysis and writing activities over the semester. The initially collected data for the two courses show above average performance based on student surveys before and after the scaffolding activities. This reflects an indirect assessment where students share their opinion of themselves. The collected data on direct assessment shows incremental improvement in performance of students based on relevant assignments completed in the courses. Additional assessments will be conducted in future offerings as well as other courses including Dynamics of Machinery, Measurement and Instrumentation, and System Dynamics and Control as part of an ongoing study. Although these are preliminary findings, such pedagogical technique has the potential to enhance the student learning experience and develop mindset to continue their life-long learning in their professional careers.


## Introduction

Engineering education has been an evolving process over time to meet the expectations and needs of multiple stakeholders including government, industry, and community [1]. This process has led to incorporation of project-based learning into engineering education, which has been found to be one of most impactful modes to develop and apply skills to help transform students into independent and proficient engineers [2, 3]. Therefore, most engineering educators seek experiential learning techniques to help students understand and exercise the engineering concepts they learned. Moreover, engineering instructors acknowledge the importance of strong communication skills including writing skills to showcase the student accomplishments through project-based learning. However, the task to foster effective communication practices among engineering students has been a challenge [4].

Students, pursuing engineering degrees, do not typically identify effective writing as an important aspect of professional communication within the engineering industry [4]. Thus,

several universities and colleges have introduced various assignments and projects that further emphasize technical communication skills into courses in their engineering curricula [1, 4, 5, 6, 7]. Furthermore, students struggle to implement concepts and skills learned from English and Communication courses into a technical report for Mechanical Engineering courses such as effective technical literature review. Research in engineering education has demonstrated both the importance of writing in the engineering workplace and the extent to which new graduates struggle with the generic and rhetorical features of a technical report [4, 5]. This has also been evident in our university and department where virtually all our students are transfer students coming from community colleges, which typically do not offer technical writing courses. To address this gap and to overcome the deficiencies of students' writing skills such as poor grammar and formatting, an instructional scaffolding has been found to be an effective approach for teaching writing skills to engineering students. The goal of the scaffolding approach is to encourage students to transfer and further develop prior writing instructions to a technical writing context in a step-by-step fashion over each course. This will lead students to produce professional and technical documentation effortlessly by the time of graduation.

In the sections that follow, the details of the scaffolded assignments and research methods for assessing those assignments will be described. It will be followed by presenting the preliminary results and discussion of the conducted assessment. The findings did not uncover significant differences in average grades and survey responses of student projects before and after each intervention. The conclusion drawn will highlight what has been learned about the scaffolding process and its potential for positive impact as well as suggest an improvement plan to make scaffolded instruction.

## Instructional Scaffolding

Scaffolding is as an educational tool utilized to minimize the difficulty of tasks within a project to then assist students to focus their effort and develop component skills [1, 8] Scaffolding involves breaking down large learning outcomes into smaller tasks that students complete in succession [1]. Scaffolding techniques also help engineering faculty integrate manageable writing assignments in their courses and provide timely feedback to students. 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 [9, 10, 11, 12]. Additionally, scaffolding has recently proven to be a successful tool in improving student learning in writing environments [13]. Scaffolding also allows for additional opportunities for students to receive feedback on their practice of component skills [1].

## Methodology

The philosophy behind this scaffolding approach was to encourage the students to improve their work without being penalized significantly in terms of point deductions. This reinforces the idea of learning from their mistakes by investing their time and effort efficiently.

An instructional scaffolding plan had been developed and implemented in two junior level courses, which were offered in parallel during the Spring 2021 semester. One of the courses was

a lecture-based course titled Mechanical System Design and the other was a laboratory-focused course titled Thermal Fluid Laboratory course. These courses were chosen to gage the students' communication skills based on what the transfer students learned from prior community college courses along with prior semester's engineering courses within the department. Moreover, the courses are taken by students prior to starting senior capstone design course in the following semester, which has communication component embedded.

The scaffolding activities in these courses included incremental writing assignments as well as access to support resources such as the Writing Center provided by the university.
After analysis of students' competence in communication skills from prior semesters, students were lacking in certain areas related to writing in engineering courses:

- Conducting literature review effectively using academic resources available
- Writing a clear introduction
- Writing objectives to wrap up the introduction effectively
- Meeting the requirements for citation and plagiarism consistently
- Writing results and discussion with appropriately formatted figures and tables
- Writing an abstract for a technical report

To help the students improve their writing skills in these areas, the course project, such as in Mechanical System Design course, was divided into three different assignments with specific focus on certain communication skills and parts of the project. Scaffolding 1 assignment was the first group assignment in a series of assignments designed to better prepare students to write their final technical project report. Students received feedback from the course instructor to improve on their work and build on it for the next assignment. The rubric and grading percentages were provided to the students with detailed instructions of what is being asked and how will the work be evaluated. This assignment focused on the formatting of the report as well as the technical aspect of the project ideation and designs. An example of a similar assignment from Thermal fluid Laboratory course to be submitted through the university's Learning Management System (LMS):

> Each team please submit lab report as an upload (pdf, docx or doc files). Follow report instructions and examples for formatting and grammar (check with Writing Center for grammar and spell check). Only 6 sections for the report will graded: Title Page, Table of Content, Introduction, Methodology, References and Appendices. The other sections are for completion for this report.

To satisfy the Scaffolding 2 assignment, students were expected to take the feedback from this assignment, revise their existing work and then build on. Furthermore, the previous work with corrections was sent again along new sections and segments of the project. This iterative process made sure that the students used the feedback and had multiple attempts to improve their work. An example of a Scaffolding 2 assignment from Thermal fluid Laboratory course to be submitted through the LMS:

> Each team please submit full technical report as a single upload (pdf, docx or doc files) in one attempt. Uncertainty analysis must be carried out as appropriate. Carry out data collection and analysis, including uncertainty/statistical analysis, if applicable. You only have 7 sections for the report that will be graded: Title Page, TOC, Introduction, Methodology, Results, References and Appendices. The other sections are for completion for this report.

Scaffolding 3 assignment was a near completion report and project submission including the abstract, results, and discussion sections by the student groups. By the end of this third iteration, the students had the opportunity to polish the report further before completing the work and final project submission. An example of the final report and assignment from Thermal fluid Laboratory course to be submitted through the LMS:

> Each team submit the full technical report including Abstract, Discussion and Conclusions with theoretical and simulation analysis/results (max 25 pages excluding appendices and TOC). You must also maintain less than 25% on Plagiarism Score. Review posted report guidelines after the project description in the file.

There are at least three-week intervals between each scaffolding assignment to allow sufficient time for the students to revise and implement the feedback while generating new content based on their progress. In the case where the students were not performing well after any of the assignments, the instructor will arrange a 1-on-1 meeting with the student group as an intervention and the students will get a walkthrough of the feedback and expectations.

The assignments were designed in such a way to provide maximum feedback while minimizing the impact on the students' project grades. The assignment grades typically counted as a normal homework or equivalently a smaller fraction of the overall grade compared to the final project grade. By the time students were ready to submit their final report, the grade, which, for example, was about 20% of overall grade, was preserved.

## Data Collection

To assess the effect of instructional scaffolding assignments on student performance, survey responses and grades for the two mechanical engineering courses were collected during Spring 2021 (remote instruction mode and hybrid laboratory mode due to Covid pandemic). For indirect assessment, the surveys asked student familiarity and confidence in relation to completing the certain areas listed earlier for a technical report. The surveys, created in Qualtrics, were voluntary and anonymous, and sent out electronically to all students in both courses before the first assignment and after the last assignment after being approved through the standard Institutional Review Board process. For direct assessment, the course grades were exported from the university's LMS into comma-separated value files and analyze in Microsoft Excel®. Student grade data were grouped and de-identified before conducting the analysis.

## Results and Discussion

The scaffolding assignments were implemented in the two mechanical engineering courses taught by multiple instructors over a single semester. Table 1 shows the direct assessment data from both mechanical engineering courses. The average percentage and standard deviation of the grades along with number of students for each course and each scaffolding assignment are shown. The average is also shown in terms of equivalent 5-point scale where 1 is unsatisfactory performance, 3 is average performance and 5 is excellent performance. Since this paper is work in progress, the preliminary results of the implementation are limited to comparison across the three assignments within each course.

Figure 1 shows the quantitative analysis, plotted as a boxplot, of the set of three scaffolding assignments for the Mechanical System Design course. A one-tailed two-sample t-test was performed on the data to conclude that the students' average grades from the first assignment to the second assignment did not observe significant improvement with a p-value of 0.9834. Similarly, the students' average grades from the second assignment to the third assignment also did not observe significant improvements with a p-value of 0.8780, even though the average grades are incrementally increasing for each successive assignment.

Table 1. Data of direct assessments for both engineering courses in Spring 2021.

| Course | Assignment | Average as Percentage | Standard deviation | Count | Average on a 5-pt Scale |
|---|---|---|---|---|---|
| **Mechanical System Design** | ***Scaffolding 1*** | 76.5% | 10.6 | 46 | 3.8 |
| | ***Scaffolding 2*** | 81.9% | 13.1 | 46 | 4.1 |
| | ***Scaffolding 3*** | 85.2% | 12.9 | 46 | 4.3 |
| **Thermal Fluid Laboratory** | ***Scaffolding 1*** | 86.3% | 3.1 | 61 | 4.3 |
| | ***Scaffolding 2*** | 83.8% | 4.8 | 61 | 4.2 |
| | ***Scaffolding 3*** | 85.1% | 8.0 | 61 | 4.2 |

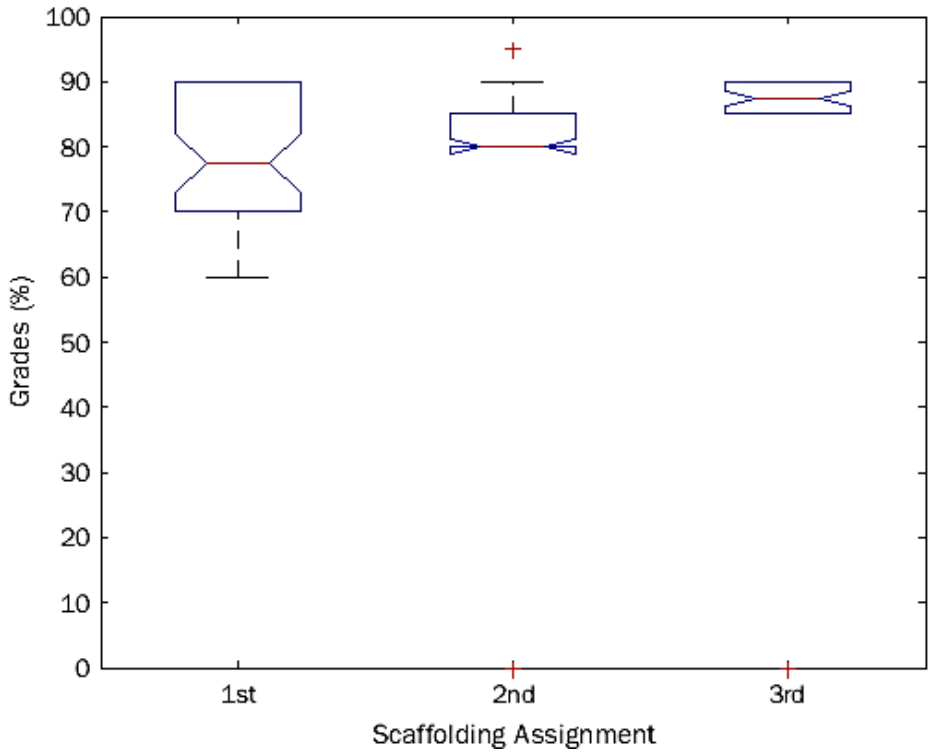

Figure 1. Boxplot of grades of scaffolding assignments for Mechanical System Design.

Figure 2 shows the boxplot of the set of three scaffolding assignments for the Thermal Fluid Laboratory course. It can be observed by employing the one-tailed two-sample t-test that there was no significant improvement, but rather a drop in performance, for the Thermal Fluid

Laboratory course from the first assignment to the second assignment with p-value of 0.0013. Moreover, it was observed that there was no significant improvement from the second assignment to the third assignment with a p-value of 0.8536, even though the average grade increased. The initially collected direct assessment (grades) data for the two courses does not show no significant improvement in student performances after the scaffolding activities. However, students performed above average (more than 70% or 3.5 out of 5) consistently to possibly indicate that the gradual approach to implement scaffolds through step-by-step concepts seems to help students gain further familiarity and confidence in their writing skills as well as be more aware of their issues related to writing.

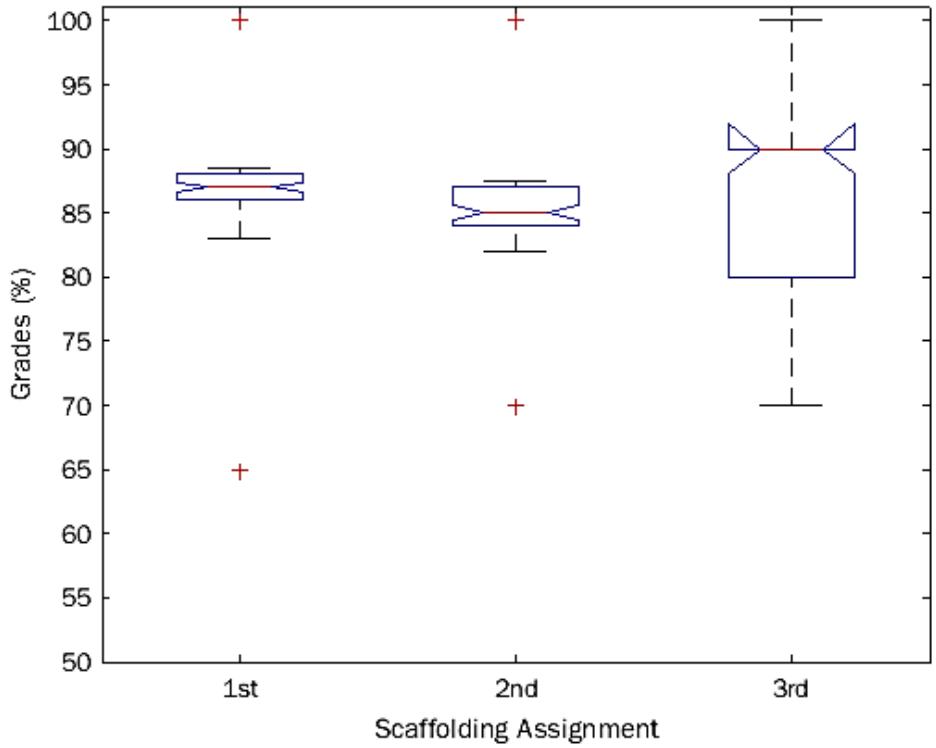


Figure 2. Boxplot of grades of scaffolding assignments for Thermal Fluid Laboratory.

Table 2 shows the indirect assessment (survey responses obtained using Likert scale) data from both mechanical engineering courses. After the scaffolding assignments were completed, the survey responses were collected to rate the students' confidence in their writing skills from 1 (strongly disagree) to 5 (strongly agree). Although the survey responses prior to the start of the scaffolding assignments were also collected, the number of respondents were less than 15% of the total students in each course, thus they were not considered to be statistically significant. Based on the student survey responses, the scaffolding assignments show agreeable rating by the students in helping them build confidence in their writing skills. Although the students on average agreed on certain areas of writing a technical report including conducting literature review, proper citation, avoiding plagiarism and writing an abstract, the students are still not very confident in writing objectives to wrap up the introduction especially in the Mechanical System Design course. The initially collected survey data for the two courses show consistently agreeable to strongly agreeable rating on average in student confidence after the completion of the scaffolding assignments.

Table 2. Data of student survey responses after completing scaffolding assignments in Spring 2021.

| Course | Survey Item | Average on Likert Scale | Average as Percentage | Standard deviation | Count |
|---|---|---|---|---|---|
| **Mechanical System Design** | ***Conducting literature review*** | 4.2 | 83.2% | 5.4 | 25 |
| | ***Writing a clear introduction*** | 4.2 | 83.2% | 5.8 | 25 |
| | ***Writing objectives to wrap up the introduction*** | 3.6 | 72.0% | 6.2 | 25 |
| | ***Meeting the requirements for citation and plagiarism*** | 4.0 | 80.8% | 5.0 | 25 |
| | ***Writing results and discussion with formatted figures & tables*** | 4.1 | 81.6% | 5.6 | 25 |
| | ***Writing an abstract*** | 4.0 | 80.8% | 6.2 | 25 |
| **Thermal Fluid Laboratory** | ***Conducting literature review*** | 4.4 | 87.0% | 3.9 | 20 |
| | ***Writing a clear introduction*** | 4.4 | 88.0% | 4.8 | 20 |
| | ***Writing objectives to wrap up the introduction*** | 4.2 | 84.0% | 4.6 | 20 |
| | ***Meeting the requirements for citation and plagiarism*** | 4.3 | 86.0% | 2.3 | 20 |
| | ***Writing results and discussion with formatted figures & tables*** | 4.5 | 90.0% | 3.4 | 20 |
| | ***Writing an abstract*** | 4.5 | 90.0% | 3.7 | 20 |

## Conclusion and Future Work

In Spring 2021 semester (remote instruction mode and hybrid laboratory mode due to Covid pandemic), a new approach was implemented in two mechanical engineering courses to help students practice and improve their technical communication skills in course and laboratory project reports. The changes were informed by an evidence-based practice to continue to develop the connections between engineering education research and implementation. The new assignment structure consisted of scaffolded assignments related to course project where students received feedback to have the opportunities to correct and revise their reports. This approach was to encourage student to implement the feedback they received prior to next scaffolding assignment. The data were collected from assignments given in the courses to investigate the impact on students' performance and learning skills. This set of data from survey responses reflects an indirect assessment where students share their opinion of themselves in a positive light. The collected data on direct assessment shows incremental improvement or unchanged in performance of students based on relevant assignments completed in the courses. Due to the limited dataset available, additional indirect and direct assessments will be conducted in future offerings of the same two courses as well as other courses including Dynamics of Machinery, Measurement and Instrumentation, and System Dynamics and Control. These assessments will be part of an ongoing study. Although these are preliminary findings, such pedagogical technique has shown the potential to enhance the student learning experience and develop the student mindset to facilitate their life-long learning journey throughout their professional careers.

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**Appendix – Sample Survey questions**

Sample of Survey created by both authors, sent to students by faculty moderators and had to be approved by IRB to be able to publish the data:

The purpose of this part of the survey is for YOU to assess your confidence in developing technical documentation

| | Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|---|
| Writing and Developing introduction and background sections | ○ | ○ | ○ | ○ | ○ |
| Develop and outline objectives clearly | ○ | ○ | ○ | ○ | ○ |
| Conduct literature review, and Meet the requirements for citation of references and plagiarism | ○ | ○ | ○ | ○ | ○ |
| Develop results and discussion with appropriate figures and tables | ○ | ○ | ○ | ○ | ○ |
| Appropriate design step with considerations of economic, environmental and societal contexts if appropriate | ○ | ○ | ○ | ○ | ○ |
| Meet formatting requirements | ○ | ○ | ○ | ○ | ○ |
| Meet spelling and grammar expectations (no mistakes) | ○ | ○ | ○ | ○ | ○ |