2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #36849

Cultivating technical writing skills through a scaffold peer review-approach of lab reports in a junior-level laboratory course

Dr. Yan Wu, University of Wisconsin - Platteville

Yan Wu graduated from Tsinghua University, Beijing, China, in 1996 with a bachelorâ€™s degree in Precision Instruments and a minor in Electronics and Computer Technology. She received her M.S. degree in Mechanical Engineering from the University of Alaba

Cultivating technical writing skills through a scaffold peer review of lab reports in a junior level laboratory course

Abstract

Communication skills is always on the top of list of the largest gaps between the career readiness of new college graduates and employer rated importance across all disciplinaries of higher education including engineering. Unfortunately, many students enter engineering programs with the wrong notion that engineering profession requires much math and science but little literacy. On the other hand, few engineering programs can afford a separate course dedicated to technical writing within the already tight credit budget.

The content of the lab reports is generally more directly controlled by engineering faculty teaching the course. Lab reports thus serve as a good tool to sharpen writing skills. Practically, however, providing consistent, quality feedback on lab reports is a time-intensive endeavor for the instructors. One potential solution is to leverage peer feedback. In addition to the obvious benefit of reducing the grading load of the instructor, this approach increases the students' self-awareness of the standards and facilitates internalization of expert judgment abilities about report writing. The challenge of this approach is that without clear structure and guidance, the peer review process will result in students not performing a meaningful review of their peers' work.

In this paper, I report my investigation of the effectiveness of a 'scaffold peer review' approach in lab report assignments and grading. The goal of the approach is to cultivate students' technical writing skills with significant buy-in from both the students' side and the instructor's side. The key elements of this approach are scaffolding report assignments with component writing, guided peer review, and revision. The scaffolding part of this approach aims at building up students' writing skill one component at a time towards a full-length report. For each report, students need to review another student's writing and answering a peer review questionnaire. The 'peer review questionnaire' serves as the primary guiding tool for peer-review. By answering a series of questions in the questionnaire, students present the evidence for their rating of others and give suggestions for improvement. They also give an initial grade to their reviewed writing according to a detailed rubric. After the peer review, each student has a chance to revise their own report. By focusing on only part of the full-length report, the grading burden is also reduced.

Direct and indirect assessments of students' technical writing skills were carried out in three semesters of the implementation of the 'scaffold peer review' approach in a junior level laboratory course. Results of the assessments show significant improvement of the technical writing skills of students. Students' reflection on about this approach and their perception about technical writing in general also confirmed the positive impact of this approach. Although the implementation is within the Engineering Physics program, the structure of this approach is readily applicable to a wide range of engineering disciplinaries with laboratory courses.

Introduction

Each year the National Association of Colleges and Employers (NACE) releases its survey data on the proficiency of various skill sets of new college graduates compared to employer's expectations. Communication skills are consistently among the top competency gaps between the career readiness of recent college graduates and employer-rated importance across all disciplines, including engineering [1]. Many studies in the literature [2,3] also pointed out that effective communicative skills, and more specifically, technical writing skills are vitally important for an engineering career with evermore collaboration demands in the global arena. A considerable part of an engineer's job is to figure out how to concisely communicate complex concepts and details to other people with technical writing. The types of writing include proposals, inspection reports, design documentation, progress reports, specifications, instruction manuals, online help files, emails, blogs, and more. A recent study [4] showed that students' abilities in technical writing were perceived to be below the standards by industry professionals, and engineering educators are requested to address this major competency gap urgently.

However, teaching technical writing faces several unique challenges in engineering education. Many students enter engineering programs with the wrong notion that the engineering profession requires much math and science but little literacy. After all, this misunderstanding is not totally unfounded because most engineering curricula center around courses with assessments heavily emphasizing numbers instead of words [3]. On the other hand, engineering faculty are reluctant to teach writing in their courses because they regard themselves as experts in engineering subjects rather than writing specialists. In addition, writing assignments are generally more time-consuming to grade than number-based assignments. Few engineering programs can afford a separate course dedicated to technical writing within the already tight credit budget.

The content of the lab reports is generally more directly controlled by the engineering faculty teaching the course and is also aligned well with students' learning interests. Lab reports in engineering courses can serve as an excellent tool to sharpen writing skills because students can both "write to learn" and "learn to write" with lab report assignments [5,6,7]. Two of the seven learning outcomes explicitly specified by Accreditation Board for Engineering and Technology (ABET) can be directly assessed using a lab report: ABET#2 an ability to develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions; ABET#6 an ability to communicate effectively with a range of audiences. Teaching technical writing through lab reports helps students synthesize and organize their thoughts to retain better information learned in the course. Practically, however, providing consistent, quality feedback on lab reports is a time-intensive endeavor. Many of the instructors are also discouraged by the lack of progress in students' writing despite their diligent efforts to give feedback. Many students move on from one lab report to the next without much heed of the feedback or motivation to improve their writing.

Allowing group reports can reduce the grading load but does not guarantee that every student in the group gains the same level of practice. In my experience, group reports often lose effectiveness in teaching writing skills. Students usually took a 'divide and conquer' approach for group reports and failed to gain an appreciation for the importance of cohesion within the document. One potential solution is collecting individual reports and leveraging peer feedback [8,9]. In addition to the obvious benefit of reducing the grading load of the instructor, this approach increases the students' self-awareness of the standards. It facilitates the internalization of expert judgment abilities in report assessment and writing [8]. The challenge of this approach is that without clear structure and guidance, students tend to reduce the peer review to minor edits, gravitating toward linguistic mistakes and overlooking rhetorical and organizational aspects of writing [10].

In this paper, I report my investigation of the effectiveness of a 'scaffold peer review' approach in lab report assignments and grading. This pedagogy method aims to cultivate students' technical writing skills with significant buy-in from both the students and the faculty. The three key elements of this approach are scaffolding report assignments with component writing, guided peer review, and revision. Scaffolding has been successfully implemented in general writing classes for many years [11]. Recently, several groups have recognized its value in teaching college-level technical writing and found initial success in teaching lab report writing [12,13]. For students with little practice in technical writing, it can be a daunting task to write a full-length lab report with all the compositional components, including introduction, materials and methods, results and discussion, and conclusion. Instead of writing a full-length lab report every time, students submit reports focusing on one or two individual components progressively throughout the semester. One concern of scaffolding is whether an instructor can consistently assess students' lab-related subject knowledge, usually in sections such as results and discussion, without a full-length report. Practical remedies to circumvent this obstacle include using alternative assessments like lab 'worksheet' [13] and making the results section mandatory but with lenient grading at the beginning of a semester [12]. With the scaffolding approach, students can build writing skills one component at a time until they are comfortable with each component and ready for a full-length report. In 'guided peer review,' students give feedback to others by answering a peer review questionnaire [10]. They also provide an initial grade for their reviewed writing according to a detailed rubric. With a grading rubric, students diagnose improvement areas and learn to evaluate writing [14]. With the guidance of the questionnaire, students present the evidence for their rating of others and give suggestions for improvement. After the peer review, each student has a chance to revise their report, and the final grade is only based on their revision for each lab report. The benefits of revision in writing have been well-researched [5], yet it is hard to implement with full-length report assignments due to the amount of work needed from students and instructors. Students are less stressed when focusing on only part of the full-length report to revise. Even though the instructor needs to grade the peer review and the revision, the grading process is much more streamlined due to two factors: First, the peer review is guided, meaning the students answer the same set of questions and make comments on the same specific items in the review. Secondly, both the rubric and peer review questionnaire already provide concrete feedback on which area to improve in the revision submission, and the revised report usually does not need a lot of correction from the instructor's side.

I implemented the 'scaffold peer review' approach in a junior-level lab-intensive course in 2019 and got positive results. After the initial success, I researched and devised several tools to assess the effectiveness of this approach in three semesters of the same course. Results of the assessments show significant improvement in students' technical writing skills. Students' reflections on this approach and their perception of technical writing in general also confirmed the positive impact of this approach. In this paper, I present the details of my implementation and findings of this approach.

Methods

<u>Implementation of the "scaffold peer review"</u>

EP3910 (Advanced instrumentation) is a one-credit laboratory course that consists of three modules on non-destructive surface characterization techniques commonly used to evaluate materials properties or perform failure analysis. The three modules are electron probe, scanning probe, and optical methods. Each module runs for three to four weeks, typically beginning with a two-hour lecture introducing the operation principles of the instrumentation in the module, followed by three experiments, each last two hours per week. The course culminates with a final project that lasts three weeks, a total of six lab hours. The course is required for all Engineering Physics majors during their junior year. The enrollment is capped at six students per semester so that students can get hands-on experience with highly sophisticated instruments such as scanning electron microscope (SEM) and atomic force microscope (AFM). We offer multiple lab sections so that for each section, there are usually only two students using the instrument at the same time. Students in the same section can share the data from their experiments but must complete all their assignments, including pre-lab, post-lab, and lab reports, individually and independently. By the time the students take this course, they have finished General Chemistry and the two-semester sequence of General Physics. All of which introduce to them basic laboratory practice and some lab report writing. They also have taken two semesters of college writing courses as part of their general education requirement for graduation.

Figure 1 illustrates the implementation of the "scaffold peer review" in the timeline of the EP3910 (Advanced instrumentation). The open circles in the timeline represent the actual lab experiments. The solid dots represent formal lab report assignments with the "scaffold peer review" process. The semester starts with an in-class activity called 'Dissecting a Paper,' where I introduce the essential components of a technical paper. Students are divided into small groups. Each group is assigned to read only one or two sections of the same paper with the section headings: introduction, methods, results, discussion, and conclusion. They need to answer several questions about their specific section's content and learn its communication goals. After the individual group research, the class reconvenes, and each group reports their findings so that the entire class can put together the essence of the paper, like putting together a zig-jaw puzzle. After this activity, I present a detailed guideline for lab report writing, explaining what to write in each section.

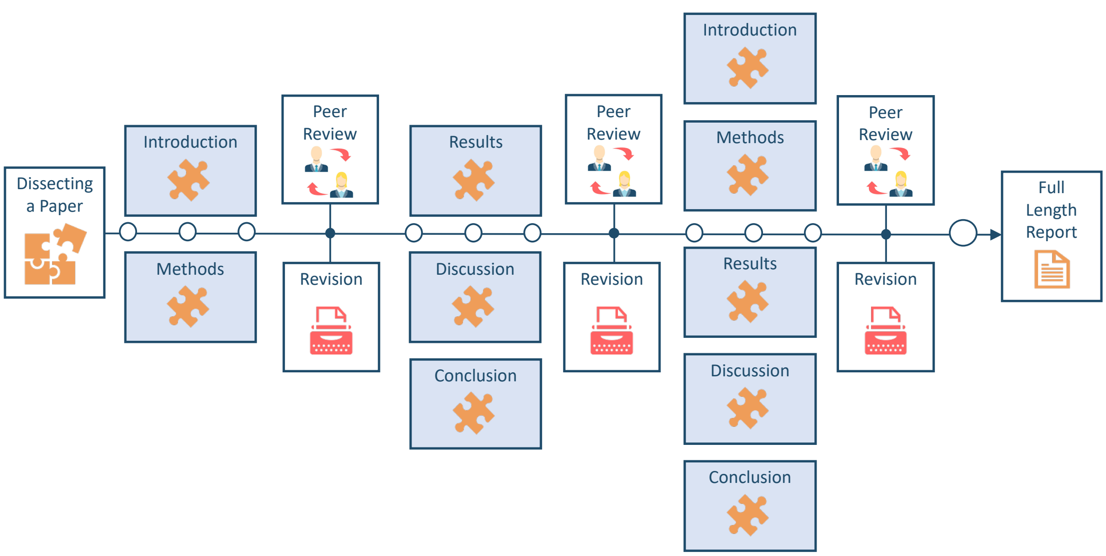

Figure 1 The scaffolding of writing assignments with component submission in the timeline of the course. Open circles represent labs, and solid dots are formal lab reports. Peer review and

revision are done after the draft report submission. The final project (big open circle) requires a full-length report without peer review or revision.

All labs require the completion of prelab reading and pre-lab quiz on Canvas before starting. The pre-labs and homework assignments take up 15% of the course grade. After each lab, students turn in a post-lab log sheet, which is more like a 'structured lab notebook' with required data analysis and interpretation but not to be graded for writing quality. I use the post-lab log sheet as an assessment tool for the content knowledge of the lab, and the log sheets are worth 20% of the course grade. Students do not need to write a formal lab report for each lab. A formal lab report is assigned for each module of the course, each worth 15% of the final grade. Each module usually consists of three experiments/labs. Students can choose any one of the three labs to write the formal lab report. I require students to deliberate only on the components being focused while giving completion credits for the sections that are not being focused. For example, Report#1 focuses on two compositional components: Introduction and Methods; Report#2 on Results, Discussion, and Conclusion; Report#3 is a full report.

I give each report assignment a grading rubric and a peer review questionnaire. The peer review is single-blind, meaning the reviewer is anonymous. The reviewer needs to answer a series of questions in the 'peer review questionnaire' about their review assignment. The questions in the questionnaire are detailed in Appendix A. Appendix A includes all the questions for a complete (full-length) report. For Report#1 and Report#2, only questions from the relevant sections in Appendix A are asked. In addition to the peer review questionnaire, students also give an initial grade of the report according to the rubric in Appendix B. The 'peer-review questionnaire' serves as the primary guiding tool for the peer-review process. The questions are inspired mainly by the work done by Smith [10] but tailored to the course content and to the Engineering Physics students. The questions link the abstract and subjective standard, such as 'the objective of the lab is clearly identified' to executable objective evaluation action like 'paraphrase the objectives as stated in the report.' After the peer review, students can revise their draft reports in response to the peer review feedback. The final grade of the report is based on the revision submission. I also give part of the grade to evaluate each student's peer review effort.

As shown in Figure 1, the course ends with a final project involving multiple techniques to analyze and evaluate the structure, composition, or behavior of a given sample. For the final project, students can propose their own ideas or choose from a list of ideas I provided. The final project lasts for three weeks, and the report is a formal full-length report worth 20% of their course grade. There is no peer review or revision for the final project report.

Assessments

Both direct and indirect assessments were carried out to evaluate the effectiveness of the 'scaffold peer review' approach in cultivating technical writing skills. The direct assessments were based on the lab report grading according to the rubric in Appendix B. A rubric provides an objective measure of the writing quality with clearly defined criteria. It offers students certainties concerning grading and promotes the efficiency of the instructor's evaluation process [14]. For the scaffold assignments, the components being focused on in the reports are given detailed criteria, with a four-point EMRN grading scale, where E stands for exemplary (4 points), M stands for meet expectations (3 points), R stands for revision needed (1 point), and N stands for not assessable (zero point). For the components that are not the focus of the report, only Pass /Fail grades are given, with Pass (2 points) meaning some writings fit the communication goal of the section and

Fail (0 points) meaning no relevant writing is provided. For Report#1, the EMRN grading scale is used for the Introduction and Methods, and the rest of the report is graded using Pass/Fail. For Report#2, the EMRN grading scale is used for Results, Discussion, and Conclusion. The rest of the report is graded using Pass/Fail. Report#3 requires all components of a formal report; thus, all components are graded using the EMRN grading scale. The students and the instructor use the same grading rubric to independently give feedback on the draft submission. Only the peer reviewer's grading is released to the students. The instructor's grading of the draft is not counted toward the final grade of the report and is used only for assessment purposes. After the peer review, the instructor gives a final grade of the report using the grading rubric and evaluates the "responsiveness" and "peer review quality." The instructor's grades on the draft and revision of the writing of the report (excluding the points of the evaluation of peer review efforts) were collected as data for quantitative analysis of writing quality. The assumption was made that by adhering to the rubric, an objective assessment of writing quality could be achieved.

At the end of the semester, students need to complete a survey to assess their understanding of report writing and their experience of the peer review process. Students' responses to this survey are indirect assessments. The survey asks students to reflect on their learning about technical writing in three aspects:

1. Their ability to write a good report.
2. Their ability to assess/evaluate the writing quality of lab reports by others.
3. Their experience in the peer review process.

The completion of this survey was counted as part of homework grades for the course, but their answers to the survey questions were not graded. The survey consists of two free-response questions and nine qualitative questions on a 5-point Likert scale, with responses ranging from "strongly agree" to "strongly disagree." The two free response questions are (1) "Have you ever had any concerns about the peer review process? What are they?" (2) "Do you have any comments/suggestions on how technical writing is taught in this course, or Engineering Physics curriculum, or in your college courses in general?" With the approval from Institutional Review Board at my university, direct and indirect assessment data were collected with the informed consent of students enrolled in the course.

Results and Discussion

Data of direct assessment based on the rubric in Appendix B were collected for three semesters of running EP3910 for a total of 15 students who took the course. The average point grades are divided by the maximum possible points per assignment to get the normalized grades. Figure 2 shows the average (mean value) of the normalized grades for this course's four formal lab reports. Students conducted peer review for Report#1, Report#2, and Report#3, and there are grades for draft and revision submissions for each of these reports. There was no peer review or revision submission for the final project report (report #4 in Figure 2). The error bars in Figure 2 are the standard deviation of the mean (SDOM) value of the normalized grades. Figure 2 shows the revised reports have significant improvement in writing quality.

This conclusion is further confirmed by comparing the revision grades with the draft grades using the one-tailed two-sample t-test. Table 1 shows the results of the t-test for a 95% confidence level for a sample size of 15 students for each formal report. The t-test for each report shows a statistically significantly higher average score for the revised final submission than the draft submission. The results of the t-test are hardly surprising: once students have clear feedback and know the area to improve, their writing will be better with revision. The more convincing evidence of the effectiveness of the scaffold peer review approach is the high writing quality of the final project report. The final project report is a report without peer review and revision opportunities, yet with a semester-long learning of technical writing, the students retained their writing skills and learned how to evaluate the writing quality of their own work. Students achieved an average grade of 93.5% with 2.0% of SDOM for the final report, and the average is at the same level compared to the revision grade for the previous three reports, as shown in Figure 2.

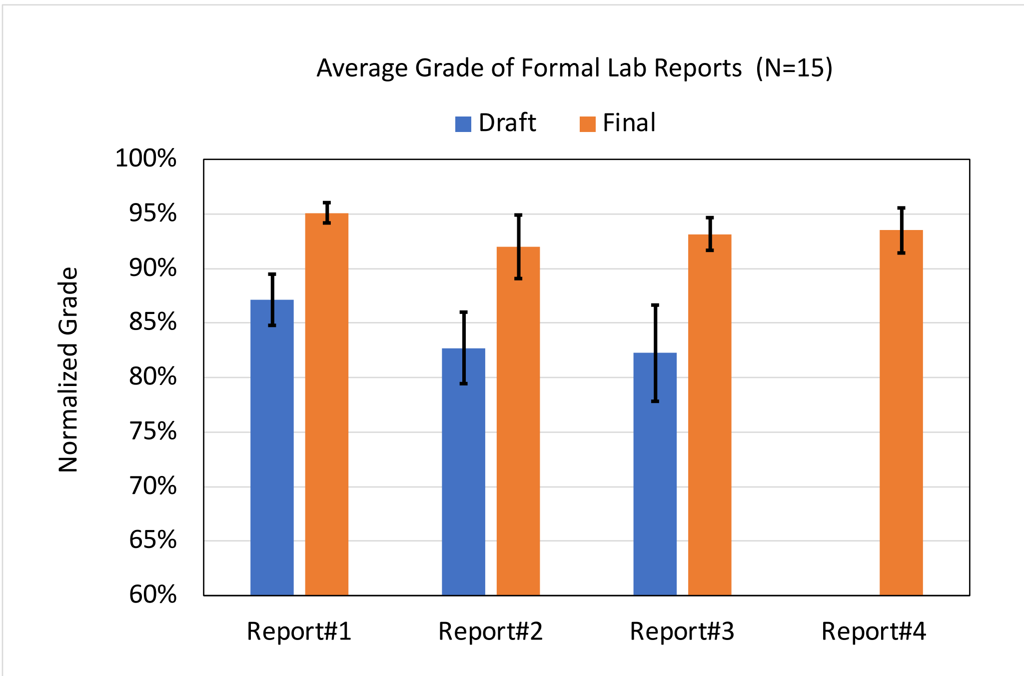

Figure 2 Average (mean value) of the normalized grade for the four formal lab reports in the course for three semesters and a total 15 students enrolled in the course. The error bars are the standard deviation of the mean (SDOM) value of the normalized grade. There are grades for draft submission and revision submission after peer review for Report#1, Report#2, and Report#3. Report#4 is the final project report with no peer review.

Table 2 Results of the one-tailed two-sample t-test for a 95% confidence level for a sample size of 15 students for each formal report that requires revision.

	Draft grade		Final grade		p value	Is the improvement significant?
	mean	SDOM	mean	SDOM		
Report#1	87.1%	2.3%	95.1%	1.0%	0.003<0.05	Yes
Report#2	82.7%	3.3%	92.0%	2.9%	0.022<0.05	Yes
Report#3	82.3%	4.4%	93.2%	1.5%	0.016<0.05	Yes

The results of the reflection survey can be grouped into three categories: (1) students' perception of their ability to write in Figure 3; (2) students' perception of their ability to critique other's writing in Figure 4; (3) students' experience of the peer review process in Figure 5. The average rating based a 5-point Likert scale are shown. The responses range from 5 to 1, where 5 means "strongly agree" and 1 means "strongly disagree. The error bars represent the standard deviation of the average rating. Figure 3 and Figure 4 show that students had an overall positive experience in learning how to write a good lab report and how to evaluate reports by others. When asked whether they need more practice in writing or evaluating lab reports, the average response rates are neutral. The average neutral response could be interpreted that they are moderately satisfied with their ability to write and their ability to critique other's writing. Regarding to the peer review, students unanimously agree that it is a useful experience as indicated in Figure 5. Most of them found that it was easy for them to evaluate other's report using the peer review questionnaires and the grading rubrics. They also found that the feedbacks from their peers are in general helpful.

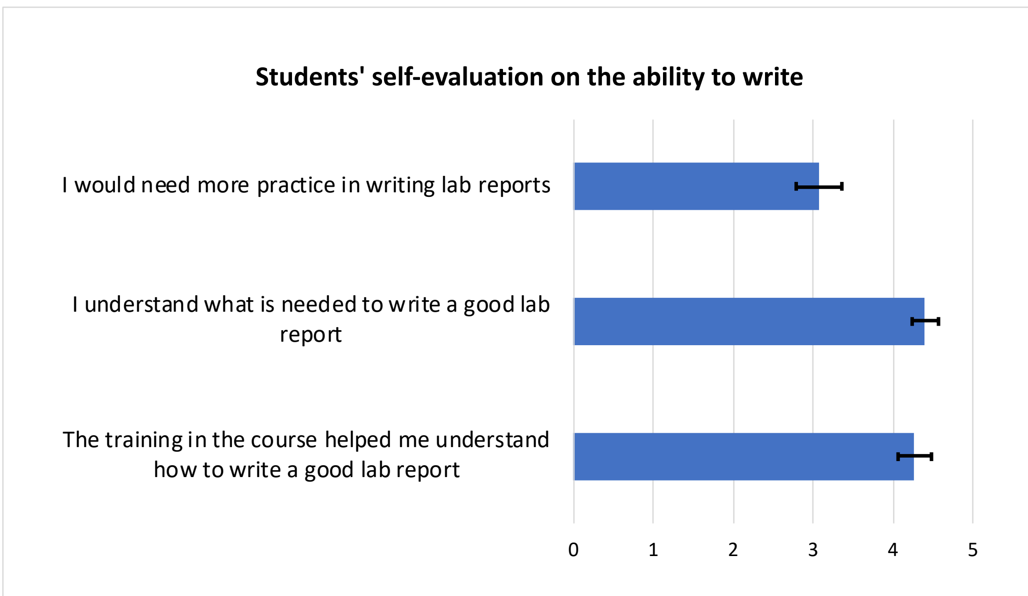

Figure 3 Average rating from students' self-evaluation of the ability to write a lab report. The rating is based a 5-point Likert scale with responses ranging from 5= "strongly agree" to 1= "strongly disagree." The error bars represent the standard deviation of the average rating.

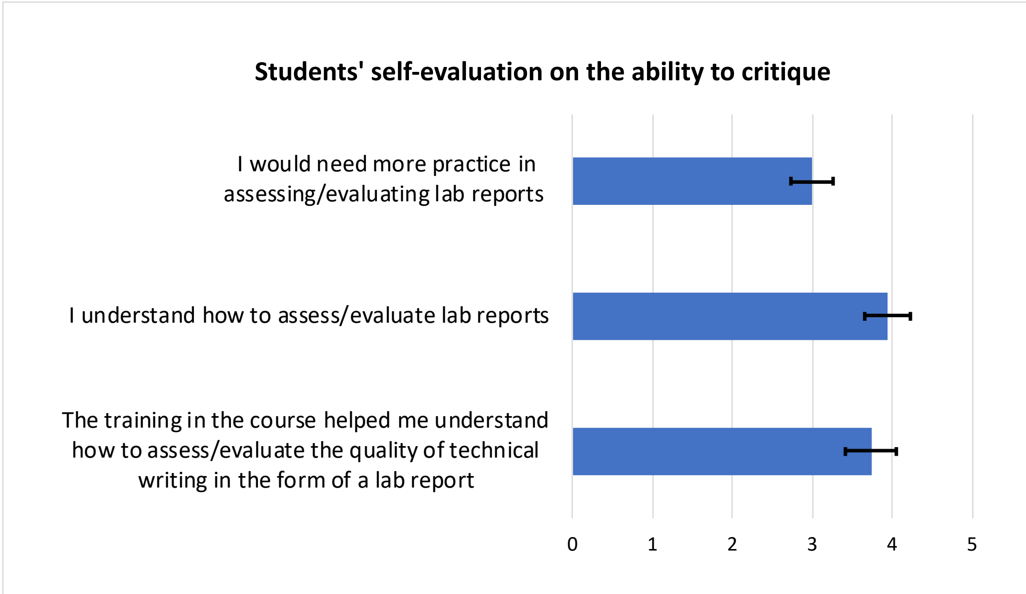

Figure 4 Average rating from students' self-evaluation of the ability to critique others' lab reports. The rating is based a 5-point Likert scale with responses ranging from 5= "strongly agree" to 1= "strongly disagree." The error bars represent the standard deviation of the average rating.

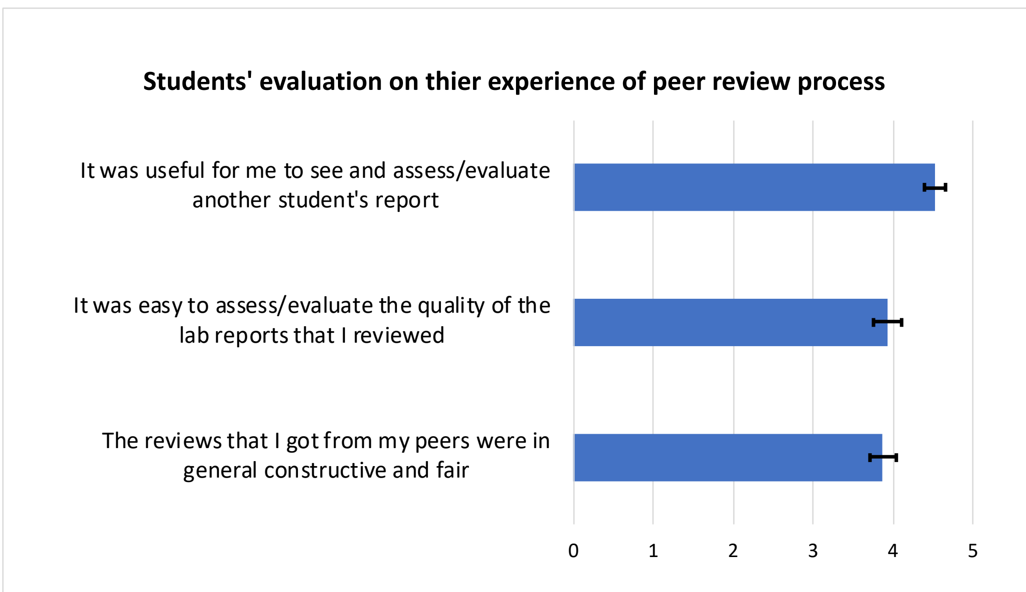

Figure 5 Average rating from students' self-evaluation of their experience of the peer review process. The rating is based a 5-point Likert scale with responses ranging from 5= "strongly agree" to 1= "strongly disagree." The error bars represent the standard deviation of the average rating.

The answers to the free-response questions generally confirmed the positive experience demonstrated by the Likert scale ratings in Figure 3 to Figure 5. Sample comments from students attesting to the positive peer review experience are:

- “I enjoyed the peer review process that this course offered for every report because having a second set of eyes read over your writing helped catch many mistakes that I had overlooked. Also, reading others' reports helped me understand how I could improve the clarity of my own writing.”
- “When it comes to the peer review process, I like the anonymous review, but I wish there was an option to communicate more with our peer reviewers so that they can elaborate more on what we might need to change if we have questions or need something cleared up.”

Students also reflected on how technical writing is taught in the course, the Engineering Physics curriculum, and their college careers. Sample comments are listed below:

- “I like how the lab reports are done in this class. Maybe we should have a day in class to talk about how to write a good lab report and going through examples and such. There are good examples given on the canvas page, but I think having an instructor giving some advice on it would be nice”
- “I think the process of having us focus on one or two sections at a time and slowly building up to a whole paper is a great idea. I think it really helped me perfect the different sections and write overall better papers.”
- “I enjoyed the way this course handled reports (by building up the pieces gradually rather than writing three reports that would be graded fully). I felt that this helped me understand the purpose of each section in a report better.”
- “I think how it was done in this class (and EP lab the first time) with the peer review questionnaire was super helpful because it was clear on what needed to be in the report and what doesn't. The only thing that was weird to me was that there was no specific format to follow like how the EE departments has the formal, informal and IEEE.”
- “I think that the technical writing taught in the Engineering Physics curriculum has prepared me for writing a variety of technical and research papers throughout my college career.”

The comments from students confirmed the positive impact of the scaffolding assignments on students’ learning experiences. They also gave constructive feedback on how to improve the teaching of technical writing in their education. For example, to follow the suggestion of spending class time going over examples of good technical writing, I was able to implement the “Dissecting a Paper” activity in subsequent semesters of teaching the same course. I also clarified some questions regarding the function of specific writing formats set by professional organizations and whether they can impact the quality of technical writing.

Conclusions

Teaching technical writing skills is vital in engineering education yet facing many challenges. For a pedagogy approach aimed at improving writing skills to be successful, significant buy-in from instructors and students is necessary.

The ‘scaffold peer review’ approach allows the students to build their writing skills with a moderate learning curve and reduces the instructor’s grading load. Quantitative data analysis of direct assessments of the lab reports demonstrated statistically significant improvement in writing scores of the revision after the guided peer review. More importantly, the final report scores show the same writing quality as a revised submission without the peer review process, indicating the retention of writing skills after a semester-long training on writing and evaluating formal lab reports. Indirect assessment data from the reflection surveys revealed that students think the 'scaffold peer review process' helps build up their technical writing skills and improves their ability to critique others' writing. Many students had positive experiences with the scaffolded assignment structure, stating that it focused their practice at a moderate pace and improved their learning experience. Although the 'scaffold peer review' was implemented in the course EP3910 the Engineering Physics program at the University of Wisconsin-Platteville, the structure of the assignments, as shown in Figure 1, does not have any disciplinary-specific requirements. With minimum adaption, the 'scaffold peer review' approach can fit well in a junior-level laboratory course in a wide range of engineering programs.

The key to improving writing skills is practice. If the students can practice what they learned about writing from one course in a consistent way in other classes, they will probably retain their writing skills better. In the Engineering Physics Program, following EP3910, two additional courses with heavy lab components use the same grading rubrics for lab reports as in EP 3910. Although these two courses do not have the same 'scaffold peer review' process, students can at least practice writing with the same standards. In general, one course in an engineering program is not enough to fully address the competency gap of technical writing described in the introduction. Engineering educators must examine the approach to teaching writing at the curriculum level.

References

[1] National Association of Colleges and Employers, "COMPETENCIES: EMPLOYERS WEIGH IMPORTANCE VERSUS NEW GRAD PROFICIENCY", https://www.naceweb.org/career-readiness/competencies/competencies-employers-weigh-importance-versus-new-grad-proficiency/ (accessed Jan. 29, 2023)

[2] P. Sageev and C. J. Romanowski, "A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills," *Journal of Engineering Education*, vol. 90, no. 4, pp. 685–693, Oct. 2001, doi: 10.1002/j.2168-9830.2001.tb00660.x

[3] D. Rus, "Developing Technical Writing Skills to Engineering Students," *Procedia Technology*, vol. 19, pp. 1109–1114, 2015, doi: 10.1016/j.protcy.2015.02.158.

[4] R. Ng and A. Wong, "PERCEIVED IMPORTANCE AND LEVELS OF TECHNICAL ENGLISH COMMUNICATION SKILLS AMONG STAKEHOLDERS IN ENGINEERING FIELDS," *IJEAST*, vol. 5, no. 2, pp. 43–50, Jun. 2020, doi: 10.33564/IJEAST.2020.v05i02.008.

[5] C. Hubka *et al.*, "A Writing in the Disciplines Approach to Technical Report Writing in Chemical Engineering Laboratory Courses," in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida, Jun. 2019, p. 32019. doi: 10.18260/1-2--32019.

[6] S. Wu, S. Zha, J. Estis, and X. Li, "Advancing Engineering Students' Technical Writing Skills by Implementing Team-Based Learning Instructional Modules in an Existing Laboratory Curriculum," *Education Sciences*, vol. 12, no. 8, p. 520, Jul. 2022, doi: 10.3390/educsci12080520.

[7] K. Wright, P. E. Slaboch, and R. Jamshidi, "Technical writing improvements through engineering lab courses," *International Journal of Mechanical Engineering Education*, vol. 50, no. 1, pp. 120–134, Jan. 2022, doi: 10.1177/0306419020939621.

[8]C. L. Romulo, A. Raoufi, K. Largen, and J. Reid Schwebach, "Using Peer Review to Improve Lab Report Assignments," *The American Biology Teacher*, vol. 80, no. 4, pp. 301–304, Apr. 2018, doi: 10.1525/abt.2018.80.4.301.

[9] S. Ringleb, O. Ayala, and J. Kidd, "Implementing Peer-Review Activities for Engineering Writing Assignments," in *2017 ASEE Annual Conference & Exposition Proceedings*, Columbus, Ohio, Jun. 2017, p. 28483. doi: 10.18260/1-2--28483.

[10] N. Smith, "Guided Peer Review of Technical Writing for Large Laboratory Course," in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida, Jun. 2019, p. 32882. doi: 10.18260/1-2--32882.

[11] E. A. Price and M. J. Harkins, "Scaffolding Student Writing," *L & L*, vol. 13, no. 1, p. 14, May 2011, doi: 10.20360/G2C88P.

[12] L. J. Deiner, D. Newsome, and D. Samaroo, "Directed Self-Inquiry: A Scaffold for Teaching Laboratory Report Writing," *J. Chem. Educ.*, vol. 89, no. 12, pp. 1511–1514, Nov. 2012, doi: 10.1021/ed300169g

[13] C. Wallwey, T. Milburn, and B. Morin, "Scaffolding Technical Writing Within a First-Year Engineering Lab Experience," in *2021 ASEE Annual Conference & Exposition Proceedings*, Virtual Meeting, Jul. 2021, p. 34409.

[14]M. A. Cantera, M.-J. Arevalo, V. García-Marina, and M. Alves-Castro, "A Rubric to Assess and Improve Technical Writing in Undergraduate Engineering Courses," *Education Sciences*, vol. 11, no. 4, p. 146, Mar. 2021, doi: 10.3390/educsci11040146.

Appendix A: Peer Review Questionnaire for a Complete (full-length) Lab Report

1. Introduction

1.A Background

a. Could you find answers in the background section to help you understand the following?
    - The basic theory about the physical system. What were the theories and/or equations presented? Were any underlying assumptions mentioned?
    - The motivation/importance of the experiment

b. Describe any aspects of the background information that you think may be incorrect or confusing.

c. How would you rate the depth & breadth of the background information? e.g., was it too much? Not enough? Did it lack focus on concepts relevant to the experiment?

d. What information sources were cited?

1.B Objectives (what is the goal; why)

a. Paraphrase the objectives as stated in the report.
b. Is the technical challenge or constraints of the experiment described? Is it clearly explained?
c. Any suggestions to improve the clarity of the objectives?

2. Methods

a. What are the samples/specimens?
b. As a reader, are you clear on how to make/prepare the sample based on the description?
c. What are the measurement tools used?
d. For special tools, are the instrument's model and manufacturer provided?
e. Summarize the major procedural steps according to the description in this section.
f. Are the key operation conditions for the measurement tools clearly specified?
g. List any details you were looking for that you did not find in this section.
h. List any details included you think were not relevant.
i. Any suggestions to improve the clarity of this section?

3. Results and Discussion

Note: the presentation of the results (what I call A sub-section here) and the discussion/analysis of the results (what I call B sub-section here) can be intertwined. For example, if there are three results to present, the structure can be A1B1 A2B2 A3B3 instead of A1A2A2 B1B2B3. (Either way is acceptable.)

3. A Results

a. What are the results presented in the report?
    - Give captions of figures and titles of tables in the report.
    - For results that are not presented in figures or tables, list key data points or paraphrase the key observation here.
    - Give the figures or tables that you cannot find any words of description in the main text. No tables or figures should stand alone without descriptions in the main text.
b. Are the figures presented professionally?
    - Are the figures numbered with captions? (The figure number and the caption of a figure should be placed below the figure)
    - Are the captions descriptive? A caption is a brief description of the plot/image, e.g., "The curve demonstrates a divergence of LVDT behavior from the simple model at higher frequencies," NOT "X vs. Y."
    - Do the figures convey information clearly? For images, are they clear with discernable details? Are the axes, font size, and line width readable for plots?
    - If there are plots in the figures, what are the labels for X and Y axes? What are the units for physical quantities?
c. Are the tables presented professionally?
    - Are the tables numbered with titles? (The table number and the title of a table should be placed above the table)
    - A table title serves the same function as a figure caption (in fact, it can be referred to as a 'table caption.' Conventionally, a 'title' is above, and a

‘caption’ is below the main presentation item.) Are the table titles descriptive?
- Are the data in the table labeled with units? List any data in the table you cannot associate with physical quantities with units.

d. Do the descriptions of the results highlight the key features of the data (e.g., the relationship between variables, pattern or trend in observations)?
e. Are the data/results relevant to the objective of the experiment? Is there any ‘raw data dumping’?
f. Are there any results that should have been presented to address the objective of the experiment, but you cannot find?

3. B Analysis and Discussion

a. Are there any explanations or interpretations of the results/findings? (e.g., Why these relationships are significant/insignificant. What does the table/figure tell you?)
b. If there are theoretical predictions, describe the accuracy of the experimental results. Are the discrepancies addressed by the author?
c. Give any aspects of the results (e.g., unexpected results, interesting observations, etc.) that the author should address in more detail, i.e., any “elephants in the room” that may have been glossed over?
d. (Special for this course only) Are all the questions in the lab instruction answered in this section? List the questions that you cannot find an answer here.
e. Any suggestions to improve the quality of the Results & Discussion section?

4.Summary and Conclusion

a. What did the author do to achieve the goal/objective of the experiment in the introduction section?
b. How well was the goal/objective achieved? If applicable, what suggestions for future work or improvement of the experiment are provided by the author?
c. Summarize the meaning or importance of the key results in this report. (i.e., find the implications of the results.)
d. How easy was it for you to find the meaning/importance of the key results in this section?

Appendix B: Lab Report Grading Rubric

EMRN grading scale when compositional components are the focus of the report.				
Introduction **A. Background**	**4 pts** **Exemplary** The basic theory of the physical system and the significance of the experiment are clearly described.	**3 pts** **Meet expectations** The basic theory of the physical system and the significance of the experiment are described but in a somewhat unclear manner.	**1 pt** **Revision needed** The basic theory of the physical system is erroneous, or the significance of the experiment is described but missing some important information.	**0 pts** **Not assessable** No background information OR irrelevant information is provided.

Introduction B. Objective	**4 pts** **Exemplary** The objective of the lab is clearly identified and stated. Information on technical challenges or experimental constraints is clearly communicated.	**3 pts** **Meet expectations** The objective of the lab is identified but is stated in a somewhat unclear manner. Information on technical challenges or experimental constraints is provided.	**1 pt** **Revision needed** The objective of the lab is partially identified and is stated in a somewhat unclear manner.	**0 pts** **Not assessable** The objective of the lab is irrelevant OR is not stated.
Methods A. Materials	**4 pts** **Exemplary** All materials and setup used in the experiment are clearly and accurately described	**3 pts** **Meet expectations** Almost all materials and the setup used in the experiment are clearly and accurately described.	**1 pt** **Revision needed** Materials and the setup are described but missing some important information.	**0 pts** **Not assessable** Many materials are described inaccurately OR are not described at all.
Methods B. Procedure	**4 pts** **Exemplary** Major experimental steps are listed in a logical order. Key operation conditions are provided. The level of detail is appropriate.	**3 pts** **Meet expectations** Experimental steps are listed in a logical order. Operation conditions are provided. The descriptions provide too many details or miss some important details.	**1 pt** **Revision needed** Procedures are listed but are not in a logical order OR missing descriptions of key operation conditions to the level that the experiment is hard to be repeated based on the description.	**0 pts** **Not assessable** Little descriptions of the steps of the experiment OR no information on the operation condition of the instrument. The experiment can be not repeated based on the description.
Description of Results	**4 pts** **Exemplary** Descriptions of the results are accurate, complete, and relevant. Key features of the data are pointed out with words	**3 pts** **Meet expectations** Descriptions of the results are complete and relevant.	**1 pt** **Revision needed** Descriptions of the results are inaccurate OR missing important information OR irrelevant	**0 pts** **Not assessable** Results/data are presented with no description in the main text.
Data Presentation	**4 pts** **Exemplary** Professional-looking and accurate representation of the data in tables, figures, and words.	**3 pts** **Meet expectations** Accurate representation of the data in tables, figures, and words. Figures and tables are labeled and titled but need to be corrected in format.	**1 pt** **Revision needed** Accurate representation of the data in written form but could have improved the communication with tables or figures.	**0 pts** **Not assessable** Data are not shown OR are inaccurate.
Discussion	**4 pts** **Exemplary**	**3 pts** **Meet expectations**	**1 pt** **Revision needed**	**0 pts** **Not assessable**

	The explanations or interpretations of the results are accurate and clear. The trends /patterns /discrepancies in data are logically analyzed. Be able to answer questions in lab instructions accurately and completely.	Explanations and interpretations of the results are clear. Answers to the questions in lab instructions are mostly correct..	Explanations and interpretations of the results are confusing OR major mistakes in answering the questions in lab instructions.	No analysis or discussion of experimental results.
Conclusion	**4 pts** **Exemplary** The summary or conclusion clearly communicates what has been done and how it was done to achieve the objectives. The implications of the findings are stated. When applicable, suggestions for improvement and future work are provided.	**3 pts** **Meet expectations** The summary or conclusion communicates what has been done and how it was done to achieve the objectives. The implications of the findings are stated but in a somewhat unclear manner.	**1 pt** **Revision needed** It is hard to understand what has been done, how it was done, or what the findings mean in the conclusion/summary section.	**0 pts** **Not assessable** No summary or conclusion is provided.

Pass/Fail grading scale when compositional components are not the focus of the report

Introduction **A. Background**	**2 pts** **Pass** The basic theory of the physical system and the significance of the experiment are described.	**0 pts** **Fail** No background information OR irrelevant information is provided.
Introduction **B. Objective**	**2 pts** **Pass** The objective of the lab is identified.	**0 pts** **Fail** The objective of the lab is irrelevant OR is not stated.
Methods **A. Materials**	**2 pts** **Pass** All materials and setup used in the experiment are described.	**0 pts** **Fail** Missing significant information on materials and setups.
Methods **B. Procedure**	**2 pts** **Pass** Major experimental steps are listed. Key operation conditions are provided.	**0 pts** **Fail** Little descriptions of the steps of the experiment OR no information on the operation condition of the instrument. The experiment can be not repeated based on the description
Results	**2 pts**	**0 pts**

<table>
<tr><td></td><td colspan="2">Pass
Results of the experiment are provided</td><td>Fail
No results of the experiment</td></tr>
<tr><td>Discussion</td><td colspan="2">2 pts
Pass
Analysis and discussion of experimental results are provided.</td><td>0 pts
Fail
No analysis or discussion of experimental results</td></tr>
<tr><td>Conclusion</td><td colspan="2">2 pts
Pass
Summary and conclusion are provided regarding what was done and whether the objective of the experiment has been achieved.</td><td>0 pts
Fail
No summary or conclusion is provided.</td></tr>
<tr><td colspan="4">Grading reserved for the instructor</td></tr>
<tr><td>Responsiveness</td><td colspan="2">2 pts
Pass
Submitted report and peer view before the deadline</td><td>0 pts
Fail
Late submission in either report or peer review</td></tr>
<tr><td>Peer review quality</td><td>3 pts
Exemplary
The peer review questionnaire is completed with details and helpful comments. Grading is fairly done.</td><td>2 pts
Meet expectations
The peer review questionnaire is completed. Grading is done.</td><td>0 pts
Do not meet exceptions
Peer review questionnaire is not completed OR grading is not done.</td></tr>
</table>