Assessing Faculty Implementation of Laboratory Report Writing Instructional Modules

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Abstract

"An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions" [1] is a fundamental outcome of all engineering programs. Students conduct laboratory experiments in all areas of engineering and report on their findings. New faculty, however, have little experience or training in how to develop effective lab report assignments and instruct students on how to write laboratory reports. In an effort to improve both the teaching and learning of laboratory report writing, engineering educators from three distinct universities (one large public research university, one small public polytechnic university, and one private undergraduate university) developed a series of online laboratory report writing instructional modules. These modules were presented to laboratory instructors, half with less than four years of teaching experience—at a Community of Practice (CoP) retreat in the spring of 2022. Focus groups were conducted with the instructors to determine the potential benefits and shortcomings of the modules, after which the modules underwent significant revisions. Near the conclusion of the CoP retreat, participants reported feeling motivated to implement the newly revised modules to improve their laboratory report writing instruction. Follow-up focus groups were conducted in the following winter to determine if this motivation remained high throughout the summer and resulted in the development of new and improved laboratory assignments in the new academic year. The paper will briefly introduce the modules and present the results of these focus group meetings.

Introduction

Written communication is an important professional skill that is required for all successful engineers. ABET's Outcome 3 [1] requires that students must demonstrate "an ability to communicate effectively with a range of audiences." Employers often cite an engineer's ability to communicate as essential, and one study found that this ability was perceived to be the most important skill among government agencies [2]. Various studies, however, often reveal gaps between graduates' abilities and employers' expectations [3].

Often, engineering students' first exposure to engineering communication occurs when they write lab reports. Another fundamental ABET outcome is "An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions" [1]. These analyses, interpretations, and conclusions are usually communicated in a laboratory report.

Unfortunately, most faculty have little training or instruction in how to develop effective lab report assignments nor how to instruct students on how to write laboratory reports. This is especially problematic for new faculty who additionally have little or no experience designing, assigning, and grading laboratory reports. Some engineering programs, such as the Writing-Enriched Curriculum program at the University of Minnesota and Engineering Communication Program at Cornell, offer resources to support engineering faculty in writing pedagogies [4, 5]. Other US engineering programs, such as Stanford or Virginia Tech, host writing or technical

communication programs directly by communication experts [4]. However, not all engineering programs have such resources to support new faculty's professional development in writing pedagogy.

There have been a number of efforts to support engineering instructors' writing pedagogies. Buswell et al. [6] developed writing intervention tools, including rubrics, graded writing examples, and strategies for developing writing prompts, to assist engineering instructors. Kim and Olson [7] developed instructional materials to enhance students' writing transfer from general education writing to engineering lab report writing. A number of technical communication textbooks or websites are available for STEM instructors; however, many of those resources are not well aligned directly with the engineering lab report genre [8]. Or, novice engineering instructors may not have sufficient writing knowledge to implement the existing resources in their engineering lab courses.

To address these shortcomings and to help new and seasoned faculty improved their instruction on lab report writing as well as develop better lab writing assignments, this research developed a number of lab report writing modules for use by instructors. These modules were introduced to and refined by a group of engineering lab instructors during a Community of Practice (CoP) retreat.

A Community of Practice (CoP), a group of people who share a common interest in a specific topic and come together to fulfill both individual and group goals, is a popular approach in faculty professional development. In engineering education communities, there are a number CoP to cover a wide range of topics, such as electric circuits [9], infrastructure [10], and biomedical engineering [11]. The CoP approach has been successfully utilized to develop or update engineering course materials. A group of engineering instructors at the University of Illinois, Urbana-Champaign formed a CoP to reform the Introductory Dynamics course to enhance students' engaged learning, standardize course materials, and promote faculty's teaching efficiency [12]. It has been proven that the involvement of a CoP when developing pedagogical materials is critical.

This paper investigates how a CoP retreat impacts the participants' perspectives and practices in writing education, focusing on engineering lab report writing in introductory lab courses. We also aim to use the CoP to update a series of modules [13], which are designed to assist faculty in developing effective experiments, constructing appropriate and usable assessment instruments, and teaching effective lab report writing. The study also includes assessments of student preparation [14] and perspectives [15]. The portion of the larger study that this paper presents is the introduction of the modules to new and seasoned instructors at the CoP retreat and the resulting implementation of the modules by those instructors.

Modules

The instructional modules, and their development, are presented by Riley, Kim, Lulay, and Lynch [13]. A brief summary of the modules is quoted from that paper here.

Based on the report writing outcomes and investigations of student report writing performance at the three participating institutions, the authors prepared scaffolded learning modules organized around (1) fundamental concepts needed to submit a successful first report, (2) intermediate concepts intended to support more rigorous consideration of data sources, methods of analysis, and conclusions, and (3) advanced concepts in error and logical appeals. A preface was developed to orient users and support instructors with guidance around [assignment] design and the use of effective rubrics. The organization and titles of the modules are provided here:

- Preface
  - Introduction to Modules for Engineering Lab Instructors
  - Assignment Design
  - Assignment Rubric Design
- Fundamental
  - F1 - Audiences of Engineering Lab Reports
  - F2 - Lab Report Organization
  - F3 - Lab Report Conventions
  - F4 - Data Analysis 1: Simple Statistics
  - F5 - Data Presentation
- Intermediate
  - I1 - Lab Data as a Primary Source
  - I2 - Summary/Conclusion Writing
  - I3 - Data Analysis 2: Trendlines
  - I4 - Referencing
- Advanced
  - A1 - Logical Appeals (Claim-Evidence-Warrant)
  - A2 - Data Analysis 3: Error
  - A3 - Data Analysis 4: Propagation of Error

The modules are meant to be very concise, simple, and easy-to-use aids for helping engineering students improve their engineering laboratory report writing skills, specifically preparing and presenting the results of engineering experiments. The collection of modules was designed and structured with scaffolding in mind. Early concepts in writing lab reports are covered in the fundamental section for students new to lab report writing. More experienced students might skip these sections and be directed to topics in the intermediate or advanced sections. Module content could be used for just-in-time instruction when student questions or early performance indicates the need, or a module could be incorporated as a whole lesson with progressive instruction in lab report conduct and writing that could occur over the course of an academic term. The modules are independent, not sequential, so an instructor may use fundamental modules in one topic, and advanced modules in other topics.

The modules, as described above and used during the CoP meeting, were developed based on prior studies of student lab writing performance [13], writing instruction best practices [16], writing transfer theories that connect lab writing instruction to prior writing experience [7, 15], and other evidence-based instructional practices like scaffolding [17]; alignment of learning objectives, activities, and assessment [18]; effective feedback; and the use of rubrics [19]. Another paper [20] describes the revision of the modules by the CoP participants into an Instructor's Guide to Engineering Lab Writing and a Student's Guide to Engineering Lab Writing.

The Instructor's Guide is now arranged according to the process used during the CoP meeting described here: select writing and technical learning objectives based on a scaffolded approach that builds in subsequent labs, craft a contextualized assignment that provides specific guidance about the audience, conduct the lab and include writing instruction and guidance tied to the Student's Guide, provide a rubric (based on the learning objectives selected) for scoring the lab report, provide specific writing (as well as technical) feedback to the student, and repeat and build more advanced writing abilities in subsequent labs.

The Student's Guide is now arranged around the traditional laboratory report format (Introduction, Methods, Results, Discussion, Conclusion or IMRDC) in order of increasing cognitive difficulty, first addressing formatting conventions and arrangement, then specific section contents and methods of data analysis, and finally effective methods of interpretation, reasoning, and conclusion writing.

Participants

Eight faculty members from three distinct universities participated in this phase of the study. The universities included a rural, public, teaching-focused polytechnic university; an urban, private, teaching-focused university; and an urban, commuter, public, research university.

Eight participants from these three universities were invited to attend the CoP. Seven of the participants identified as male, the other female. Two participants were civil engineers, two were mechanical engineers, and the other four were electrical engineers. They all taught engineering laboratories and were interested in improving their lab assignments and the quality of the reports submitted by their students. Two participants were from Oregon Tech, one of which was first-year educator, the other was a veteran professor with years of experience. Another veteran instructor from University of Portland participated. The other five participants were from Washington State University Vancouver, three of which had less than four years of teaching experience, while the other two had more than 10 years. No other demographic data were collected, nor were the researchers trying to obtain a sample to represent all engineering faculty. Participants who were self-motivated to use the modules and provide feedback were selected to participate in this formative development project regardless of their backgrounds.

All of the participants had taught at least one lab in the previous year and all of the participants assigned written lab reports. The participants received funding to attend the Community of Practice retreat at Washington State University Vancouver.

Community of Practice

Community of Practice is a loaded term that means different things to different people. "Confusion exists in the broader educational…fields about the different uses and meanings implied by the concept 'community of practice'." [21] Some CoPs are formal or "engineered", while others occur naturally and are more informal. Tensions exist between formal and informal CoPs [22]. Some think that the use of the term must be paired with an explicit description of the process, contexts, and aspects of the CoP being discussed or implemented [21].

Communities of Practice were first introduced in 1991 by Lave and Wenger [23]. Initially, these were described as voluntary communities with no formal or prescriptive methods. "Communities of Practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis." [24] The theory evolved over time into more formal implementations such as instrumental approaches [21], organizational communities [25], and engineered formal CoP [22]. Because of this wide range in definitions and implementations of CoPs, it is important to define the CoP that was used in this study.

This community is on the less formal side of the spectrum. It is a group of professors who all teach engineering labs and have a strong interest in improving their students' writing skills and laboratory reports. The participants described above volunteered to participate and received funding to attend the first meeting of the CoP. This community plans to meet annually to share ideas and support each other's efforts to improve engineering writing.

The first meeting took place face-to-face on the campus of Washington State University Vancouver in June 2022. The meeting was a two and one half days workshop that included activities such as Assignment Design, Rubric Design, and Lab Instruction Demonstrations as well as reviewing and refining the modules [20]. Another face-to-face CoP meeting is scheduled for June 2023, with additional participants invited. The entire group has not yet met again, though plans to have regular meetings online have been discussed. On the individual campuses, a mentor-mentee relationship had developed because of the CoP meeting and the new faculty participants have informal meetings with the seasoned faculty to continue the discussions of implementing the writing modules.

Focus Groups

"A focus group is a semistructured group interview that deals with a specific topic or experience…used extensively…as a means of evaluating products and services." [26] The products and services being evaluated in this research were the writing modules and the community of practice workshop. The purpose was purely formative with the intention of gathering data that would assist the researches in improving both the modules and the workshop.

An outside consultant with experience in human subjects research was contracted to facilitate the focus groups with the participants. This focus group first met during the CoP workshop in June 2022 and then again via video conferencing in January 2023. All eight of the participants attended both of the focus groups.

The first focus group met in person for one hour and included discussions about what constitutes good writing, learning goals associated with lab reports, how students learn to write lab reports, the nature and effects of feedback on reports, and ideas for current and future modules. Questions used to initiate the conversations included:

- What constituted good writing?
- What learning goals do written lab reports help to accomplish?
- How do your students learn to write lab reports?
- What writing abilities are you hoping to develop?
- What tools or modules could help you develop better lab-writing assignments.

The follow-up focus group took place six months later via videoconferencing for an hour and the discussions included changes to laboratory writing approaches as a result of being in the CoP as well as the use and effectiveness of the refined modules. Questions used to initiate the conversations included:

- In what ways did your lab-writing assignments change as a result of attending the CoP?
- Describe any ways that writing/assigning/grading of labs improved.
- Have you used or asked your students to use any of the modules discussed at the CoP/?
- What modules did you find effective and why?
- What modules still need improvement and why?

Both sessions were recorded with the permission of the participants. The external consultant used an open-ended coding scale [26] to organize the comments into categories of common themes, noting how many similar responses fit into the themes that emerged. This coding was conducted after the discussions with a small number of categories and the coder made no inferences before coding, which are three ways to ensure the reliability of the coding [26].

Prior to engaging in this research, Institutional Review Board approval was sought and received at all three universities to include participation by and results from both faculty and students.

Results

Several themes emerged from the discussions in the first focus group in June 2022.

Writing Quality

Discussions began with the question "What constitutes good writing?" General consensus was that writing should be "*clear, concise, and understandable to the audience."* Group members also all agreed that the writing should use context-appropriate terminology, with one person specifically stating that the writer and the audience should have "*shared language and a shared vocabulary*." It was also stated that the writing should be engaging. Interestingly, appropriate writing conventions was only mentioned once as was following a report structure.

Purpose of Lab Reports

All of the focus group participants assigned written lab reports to their students. When discussing why, one participant said "*writing can elucidate…better than a lot of other means of assessment*." Many of the participants said that it is easier to see students' misunderstandings and

missteps in written reports versus homework assignments or exams. Similarly, many agreed that written reports convey an understanding of the topic as opposed to just using the right formula. There was an intense conversation about whether it was more important to have the appropriate results or to have "good" writing, with one participant stating that the results do not have any meaning without the appropriate context that can only be provided in written reports.

> *Without the writing, the results have no meaning and no context. So the results by themselves just presented in data tables and graphs and charts and equations I think are insufficient because without context and conclusions drawn from the data the meaning is not successfully communicated.*

The new faculty stated that they assigned lab reports because they were expected to. They also unanimously expressed concerns about grading the written portion of the reports because they have no expertise or training in doing so.

> *We just pay more attention to students' calculations, formulas, and also to see if they are using the right diagram and drawing the charts in the proper way.*

The seasoned faculty, having spent many years grading reports, felt more comfortable in this role and felt that the written reports "*conveyed more meaning*."

Learning How to Write Lab Reports

When asked where and how students learn to write lab reports, the responses focused on three main themes. The first to emerge was that everyone assumed that students came to their lab courses with some writing abilities learned either in high school or college composition courses. The word "hope" was specifically used by several of the participants in that they hoped students were getting these skills somewhere before their lab courses.

> *We expect that they have received some training in English composition…we hope that they are getting instruction on how to write as part of their required writing curriculum.*

The second theme to emerge was that students learn by writing their lab reports, getting feedback on those reports, and then improving. Senior faculty said that they gave writing-specific feedback including style, conventions, grammar, spelling, and figures. New faculty mainly offered feedback on the technical content. When asked, none had evidence that this practice-feedback loop was working.

> *I rely on feedback on each report to see improvement through the course of the term, and if they don't pay attention to the feedback then they don't improve over the course of the term.*

Thirdly, the senior faculty spent some time at the beginning of the first lab giving writing instruction, explaining format, conventions, and expectations. The newer faculty did not do this, but all handed out samples of excellent lab reports for students to glean information from. Two participants said that they had not previously given instruction on writing, but after attending a

previous meeting of this CoP they had begun to do so. Others said that after their participation in this workshop, they planned to provide such information in the future.

> *During the first lab session, I gave the students a presentation: this is what I expect in lab reports, should have this format, this is how you present the data, I know this is simple but this is where we get started.*

Feedback on Modules
Participants were asked what modules would help them to develop better labs and their students to write better reports. They all agree that the modules should be compartmentalized such as a module on format, another on creating figures, and so on. Many said that video modules may be more useful than written modules.

> *Should it be broken up more into little chunks, let's worry about making graphs first…focus on things that build and maybe by the end they will know how to write a memo.*

One unexpected result was that while these modules were written for faculty to use, many of the participants wanted them to be targeted toward the students so that they could just hand them out and have the students apply them. The research team will be considering this approach in the future.

Follow-up focus groups were held in January 2023 to determine the outcomes from the CoP workshop. One major theme emerged.

Assignment and Rubric Improvements
The most significant finding from the follow-up discussions was that participants found the hands-on activities most useful and easiest to implement. All of the modules presented above were discussed at the CoP workshop, but two of them, Assignment Design and Assignment Rubric Design, included hands-on activities at the workshop. As a result, every single instructor who taught labs after the CoP mentioned redesigning their assignments and rubrics. The participants all mentioned that their assignments and rubrics were improved because of their efforts. Many noted that having the improved rubrics streamlined grading.

> *I was more aware of the design of the assignment…I was able to put more effort into designing the lab report, I used the design module from the workshop—from the website—that's one area where I think I did better.*

All of the new faculty stated that they had never used rubrics in grading before, but having rubrics now made grading much easier. All participants mentioned that they had started giving the rubrics to the students and that the students had an improved understanding of the assignment expectations because they had the rubric.

> *I did not have rubrics but I was able to have a rubric set up using the module and it was pretty easy to use.*

The Assignment Design module emphasizes putting the laboratory assignment into a real-world context. This type of design was modeled for participants at the CoP meeting and then each of the participants had a chance to redesign one of their own laboratory assignments. Those that implemented new assignments in the fall term found the assignments more engaging and enjoyable to teach.

> *I was more aware of the design of the assignment…I was able to put more effort into designing the lab report, I used the design module from the workshop—from the website—that's one area where I think I did better.*

No one had attempted to implement any of the other modules yet but mentioned that they had plans to do so. Several people said that with the large number of modules, it would be difficult to implement them all in a single term.

Discussion

Assigning written lab reports is common in engineering. This study found that professors felt it led to a deeper understanding of the material. Most graduate engineering programs, however, do not teach future professors how to prepare effective labs. The senior faculty in this study had taught many labs over time, making incremental improvements over the years. New faculty had little idea how to design and grade laboratory reports and felt inadequate at grading the writing portions of the reports. Meeting together as a community of like-minded individuals with the joint purpose of improving students' writing skills had a positive effect on all of the participants. Seeing some skills modeled in person and then implementing those skills in a hands-on workshop setting led to improved lab assignments and easier grading. For the new faculty, who had not previously used rubrics or contextualized labs, this experience was especially fruitful. All of the participants cited improved laboratory experiences after attending the CoP workshop.

Future Work

Another CoP workshop, with an expanded number of participants, is planned for June 2023. It is clear from this study that the hands-on experiences were the most beneficial. Having already modeled two of the modules, it might be useful at this future meeting to model and practice some of the other modules so that participants would be able to easily implement them as well. The researchers are also considering organizing more regular meetings of the CoP online to promote continued implementation of the modules and share experiences from doing so. Meeting on a set monthly or bimonthly schedule online would easily be able to accomplish this goal.

While it was evident that the CoP meeting had a positive effect on the instructors, there was little evidence that it improved students' learning. The larger study, of which this is just a portion, will be assessing student learning as a result of module use.

Conclusion

Whether called a Community of Practice or just a network of interested faculty, it is evident from this study that bringing people together to discuss the issue of lab report writing is helpful. The experience was a positive one for all and all had hopes to participate again in the future. It is difficult in the busy lives of engineering faculty to find 2.5 days to meet and discuss these issues,

but all felt that it is worth the time and effort. Increased communication and interaction between professors with a specific shared goal can have very effective results.

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