Impact of Learning Transfer-focused Lab Writing Modules to the Writing Instructional Materials by Engineering Lab Instructors

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Impact of learning transfer-focused lab writing guides on writing instructional materials by engineering lab instructors

Instructors, including teaching assistants, who teach engineering lab courses are often challenged when instructing lab report writing due to a lack of available resources for supporting engineering lab report pedagogies. They are under-supported in writing pedagogies and are usually unfamiliar with the extent of students' prior writing knowledge. Through an NSF-funded project, engineering lab writing instructional guides (engineeringlabwriting.org) were developed for instructors and undergraduates to improve lab writing by promoting undergraduates' learning transfer from their general education writing courses to engineering labs. These web-based, learning transfer-focused engineering lab writing guides, or the guides, are distinct from other lab writing pedagogical materials because they are scaffolded from the writing knowledge that engineering students are already familiar with from general education writing courses such as first-year composition and technical writing. This study investigated how access to the guides impacted engineering lab instructors' instructional materials. The website containing the guides was introduced to seven participating engineering lab instructors from civil, electrical, and mechanical engineering programs across three universities. We collected their lab instructional materials before (control) and after (experiment) access to the guides to compare how they were changed to support students' lab writing. The results indicated that most instructors used the modules from the student's guide to provide instructions on lab report format, reasoning, and conventions directly to the students. Instructors included the content from those specific modules in the lab handouts. About half of the participants used the instructor's guide to update their lab assignments to include descriptions of the audience and their expectations. Some participants developed lab report assessment rubrics using the instructor's guide. Although there was a variation among the materials after instructors had access to the guides, all the participating lab instructors updated their lab instructional materials to use the terms and concepts introduced in the guides and adjusted their instructional content to consider students' prior knowledge.

1. Introduction

Engineering labs offer unique engineering experiences to students, ranging from hands-on experiments to safety and ethics [1]. Teaching engineering labs provides unique pedagogical opportunities for lab instructors; however, it is challenging to design, prepare, coordinate, instruct, and assess labs [2]. Out of multiple challenging aspects of lab instruction, writing instruction is often considered difficult for engineering instructors [3,4]. Engineering lab instructors, including undergraduate/graduate teaching assistants, are professional writers who document their engineering knowledge and practice for a technical audience. However, they are not trained to instruct writing and may not have opportunities for professional development in writing instruction. Also, they struggle to find time to add writing instruction to their labs.

There is widespread acknowledgment among engineering instructors regarding the significance of writing as a crucial skill for engineers, and multiple engineering programs house writing or communication programs or centers to support engineering instructors in writing pedagogies [5, 6]. Communication experts often oversee these institutional organizations to incorporate writing-intensive curricula within engineering programs. These models are robust approaches to

integrating writing into the curriculum [7] and/or training engineering faculty in writing pedagogies [8,9]. Nevertheless, not all engineering programs possess the financial resources or time to allocate support for such extensive and customized writing instruction. According to a survey result (n = 190) conducted by Buswell et al. [10], numerous engineering instructors highlight significant challenges in incorporating more writing into their courses, citing factors such as large class enrollments and insufficient time for providing meaningful feedback to the students. The survey's respondents also did not value professional development workshops or guidance from writing consultants as desired resources. Instead, the consensus suggests that instructors generally comprehend the reasons and methods for integrating writing into their courses. They seek additional support and resources, such as teaching assistants, handouts, and rubrics, to effectively implement their ideas [10].

An NSF-funded project conducted by a collaborative team with both engineering and English professors produced engineering lab writing instructional guides, or the guides, developed for instructors and undergraduates to improve lab writing by promoting undergraduates' learning transfer from their general education writing courses to engineering labs. Hosted at engineeringlabwriting.org, these web-based resources are distinct from other lab writing pedagogical materials due to several novel features. First, they are scaffolded from the writing knowledge that engineering students are already familiar with from general education writing courses such as first-year composition and technical writing [4]. Second, they are based on research investigating prior writing preparation by students in early lab courses [11,12] and transfer-focused pedagogy [13]. Finally, the content in the guides was developed and refined by a community of practice [14].

This paper aims to answer the following research question: "How did the project's learning transfer-focused lab writing guides impact engineering lab instructors' instructional materials?" To answer this question, we collected the lab syllabus, handouts, and assessment materials before and after the exposure to the guides from lab instructors across three colleges who volunteered to participate in the project. We reviewed the materials to assess how the modules have impacted their writing instructions. This study advances knowledge on how engineering instructors reform their writing education in labs using open educational resources focused on engineering students' learning transfer in writing.

2. Method of Approach

2.1 Study Area

This research was conducted across engineering programs at three distinct universities: a public polytechnic university offering ABET-accredited programs in civil, electrical, mechanical, and renewable energy engineering (Oregon Institute of Technology or OIT); a liberal arts-anchored private university with ABET-accredited programs in civil, electrical, and mechanical engineering (University of Portland or UP); and a branch campus of a research-one land grant university offering ABET-accredited programs in electrical and mechanical engineering (Washington State University Vancouver or WSUV). OIT's College of Engineering, Technology, and Management had around 650 students and 30 faculty members, offering multiple engineering lab courses, including sophomore-level lab courses in civil and electrical engineering, which is the focus of this study. UP's School of Engineering had approximately 550 undergraduate students and 20 faculty members, with participation from civil and mechanical

engineering sophomore-level lab courses in this study. WSUV's engineering programs, with about 350 students and 15 faculty members, included sophomore-level electrical engineering and junior-level mechanical engineering courses in the study, all taught by graduate teaching assistants supervised by instructors. Table 1 presents the basic information of the participating lab courses from the three schools we studied.

Table 1: Participating engineering laboratory courses in the study

Institution, Semester/Quarter	Major	Course	Topic	Term	Labs taught by
4-year public polytechnic college (OIT), Quarter	Civil	CE 212	Civil Engineering Materials	Fall	Instructor
4-year public polytechnic college (OIT), Quarter	Electrical	ENGR266	Engineering Computation	Fall	Instructor
4-year public polytechnic college (OIT), Quarter	Mechanical/ Civil	ENGR213	Strength of Materials	Fall	Instructor
4-year private college (UP), Semester	Mechanical	EGR 270	Materials	Spring	Instructor
4-year private college (UP), Semester	Civil	CE 376	Environmental Engineering	Spring	Instructor
4-year public college (WSUV), Semester	Electrical	ECE 214	Logic Circuits	Fall	Graduate teaching assistant
4-year public college (WSUV), Semester	Mechanical	MECH 309	Engineering Materials	Fall	Graduate teaching assistant

2.2 Research design and instrument

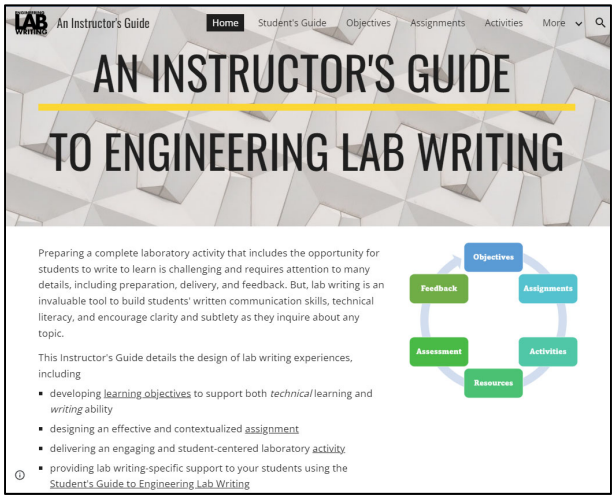
The web-based writing guides were introduced to the engineering instructors of the seven lab courses in the summer of 2021; therefore, the guides did not impact their lab report writing instructions in the academic years of 2019-2020 and 2020-2021. We define the lab writing instructional materials in these two academic years as the control. In the summer of 2021, the link to the web-based engineering lab writing draft modules was emailed to the instructors of the participating lab courses in Table 1. The instructors agreed to improve their lab writing instructions using the module content. They did not participate in any formal professional development training about the module content. The instructional materials developed in the academic years of 2021-2022 are defined as the experiment. We collected the participating lab courses' lab writing instructional materials, such as lab handouts, lab assignments, and lab report rubrics, to conduct a direct assessment.

Table 2. The structure of the based learning transfer-focused engineering lab writing guides

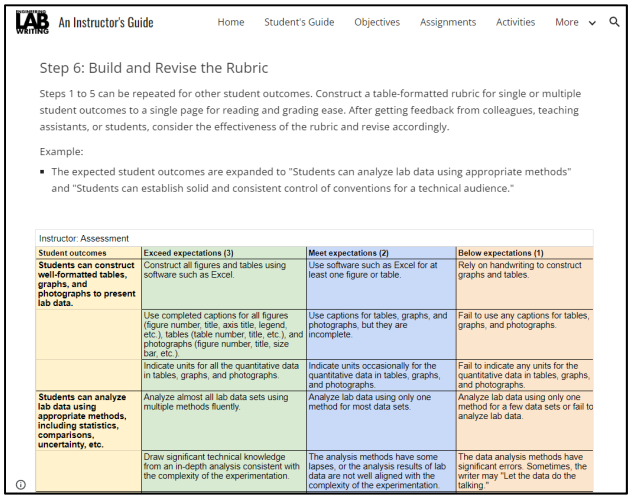
Guide:	Instructor's Guide	Student's Guide
Modules	Objectives	Organization-Format
	Assignments	Organization-Reasoning
	Activities	Organization-Conventions
	Assessment	Introduction
	Feedback	Methods
		Results
		Analysis (Home)
		Analysis-Simple Statistics
		Analysis-Trendlines
		Analysis-Error
		Analysis-Error Propagation
		Discussion
		Conclusions

We analyzed the instructor's updates to their lab writing instructional materials using our guide structure and module topics, which are shown in the following table. Our web-based learning transfer-focused engineering lab writing guides have two audiences: the instructor's guide, designed for lab instructors to assist their lab development, assignments, assessments, and feedback, and the student's guide, designed to support students in writing lab reports. The instructor's guide has six modules, while the student's has thirteen. Each module has a separate web page with graphics and example files. Figure 1 shows module page examples from each guide.

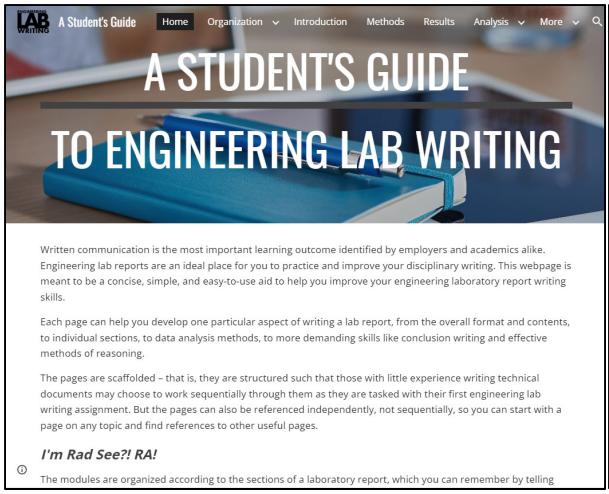
After collecting all the written lab instructional materials from the participating lab courses, we reviewed them quantitatively to identify which module(s) from the guides were used for each lab course in the experiment year. This approach showed how participating lab instructors used our modules to update their lab writing instructions. We also conducted a qualitative analysis to compare the lab writing instructional materials before and after the introduction to the web-based guides. Focus groups with some of the instructors included, among others, were also conducted in June 2022, January 2023 [15], and June 2023 to assess faculty implementation of the guides.

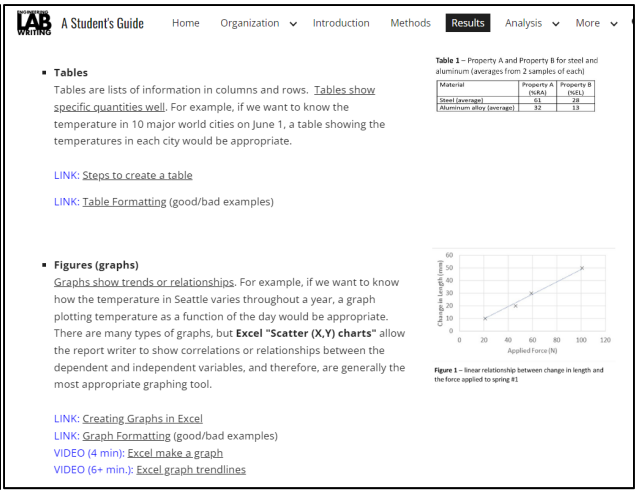


(a) The front page of the instructor's guide



(b) A portion of the assessment module





(c) The front page of the student's guide (d) A portion of the data analysis module

Figure 1. Sample pages from the Instructor's (a, b) and Student's (c, d) Guides

3. Results and Discussion

3.1 Quantitative analysis of the modules used by the participating lab instructors

Table 3 shows the results of our quantitative analysis. The instructor of ECE 214 used eleven different modules to update their lab writing instructions, while the ENGR 266 instructor used only two modules. Most participating instructors used four to seven modules to update their lab writing instructional materials in the experimental year. The most popular module was the organization-format module in the student's guide. This module bridges the typical first-year composition course's essay organization (Introduction, Body, and Conclusion) and the engineering lab report's typical organization: Introduction-Methods-Results-Discussion-Conclusions (IMRDC). The module specifies what content is expected in the IMRDC sections and how this is related to, but more explicit than, the Introduction-Body-Conclusion structure. Five lab instructors used the assignments module of the instructor's guide. The module introduces three goals for a writing assignment identified by Traci Gardner from the National Council of Teachers of English [16]. It also includes many examples of engineering lab assignments that any instructor can download for their use. Analysis modules in the student's guide were least popular among the participating lab instructors when updating their instructional materials. Those modules are designed to support students conducting lab data analysis with statistics, regression, and error analysis. Therefore, many lab instructors provided the link to those module pages to their students as a reference instead of implementing the content directly in their instructional materials.

Table 3. Quantitative analysis results of evaluating the instructional materials in the experiment year.

Institution		OIT			UP		WSUV	
Lab course		CE 212	ENGR 213	ENGR 266	EGR 270	CE 376	ECE 214	MECH 309
Instructor's guide	Objectives	O	O				O	O
	Assignments	O	O	O			O	O
	Activities		O				O	
	Assessment	O	O	O			O	O
	Feedback		O					
Student's guide	Organization-Format	O	O	O	O	O	O	O
	Organization-Reasoning							
	Organization-Conventions		O		O	O	O	O
	Introduction				O	O	O	
	Methods						O	
	Results				O	O	O	
	Analysis (Home)							
	Analysis-Simple Statistics							
	Analysis-Trendlines							
	Analysis-Error							
	Analysis-Error Propagation							
	Discussion						O	
	Conclusions						O	
Lab writing instructional content not included in the modules		O		O				

3.2 Qualitative comparative analysis between control and experimental years

We have conducted comparative analyses of the lab course instructional materials between control (before the module exposure) and experimental (after the module exposure) years for the participating lab courses. The qualitative analysis results are the following:

3.2.1 OIT's CE 212 Civil Engineering Materials

Control (Fall 2020):

For many years, this course has required three laboratory reports concerning (1) soil, (2) asphalt, and (3) concrete materials; the reports document a series of weekly experiments over ten weeks. Instructional materials from Fall 2020 control include only asphalt and concrete reports. The report format and guidance vary considerably, partly due to the co-taught nature of the course; one instructor taught the soil content while another taught asphalt and concrete.

Experiment (Fall 2021):

The course required three laboratory reports from a series of weekly experiments involving (1) soils, (2) asphalt, and (3) concrete. Each report was to use the same prescribed IMRDC format, with guidance provided by a draft version of the Student's Guide to Engineering Lab Writing.

A soils lab was conducted that required students to determine moisture content and soil classification for various soil samples, conduct a sieve analysis, and determine liquid and plastic limits. Instructional materials included procedures, examples, and guidelines for the necessary tests. The asphalt and concrete labs had similar supporting documents available to students, focusing on procedures.

To support report writing, the instructor provided students with a detailed report template that provided guidance in each of the IMRDC sections, with positive attributes in blue text and negative attributes in red text. The preamble to the template pointed students to draft lab writing modules with specific guidance to read the modules on lab report organization, lab report conventions, data analysis 1: simple statistics, and data presentation. The instructor also provided a graded lab report from a different institution with a similar IMRDC format. Still, instructions were clear that students were to use the lab report format specified in the template. This template and guidance were requested in the two other lab reports concerning asphalt and concrete materials.

During the June 2022 focus group, the instructor stated their intention to redesign the assignments to contextualize them per the "assignment" guide. In the follow-up focus groups, the instructor mentioned the assignments were more engaging and enjoyable for both the students and the instructor [15]. This instructor also designed and used an assessment rubric per the guides to evaluate the technical content and writing abilities of the students.

3.2.2 OIT's ENGR 213 Strength of Materials

Control (Spring 2019):

The instructor has taught this lab course for many years and has developed contextualized lab handouts in a memorandum format that indicate a client and request that students work on behalf of a materials testing firm to complete the week's assignments. Various attempts at scoring rubrics have been made; however, all include a technical score based on performing the required measurements and analysis, and a writing score focused on the quality of the written submission. An example lab report serves as the primary guidance for students writing weekly reports.

Experiment (Spring 2022):

The same instructor taught the experiment course offering and has been involved in the transfer-focused lab writing project since its outset. They have used this course to explore the approaches documented in the guides. Compared to the control, the changes in lab delivery are related primarily to writing preparation, with a more detailed presentation elaborating lab report sections, content, and conventions. The assessment was improved by using a lab writing rubric that scores the technical content of the lab report sections and their conventions.

The June 2022 focus group found similar results, with this instructor mentioning making incremental improvements over the years. The most recent change was the implementation of a specific lecture at the beginning of the first lab devoted to writing instruction [15].

3.2.3 OIT's ENGR 266 Engineering Computation

Control (Spring 2021):

The instructor for this course has taught it for many years and had used a structured laboratory report for the weekly exercises until it was discontinued during the COVID pandemic to streamline student online submissions of MATLAB-focused weekly activities. The instructor re-implemented the structured lab report format for the control year's offering. Students were asked to complete the computational exercises and answer questions in an electronic fill-in-the-blank format. The structure of the "report" requested (1) objectives of the lab, (2) responses to computational tasks in complete sentences and with screen captures of student work, (3) conclusions in complete sentences, including responses to "What did you learn in this lab" and "suggestions to the instructor to improve the effectiveness of this lab." Thus, the instructor requested a report that uses an introduction-body-conclusion format and specifically requests written responses. No further instruction in writing was provided.

Experiment (Spring 2023):

The same structured laboratory report template from the control offering was provided to students, but a more complete laboratory report was requested that employed the IMRDC format. With the modules only available in draft form, the instructor provided students with web-based laboratory report-writing instructional content from Monash University [17]. This prepared students with guidelines on the format and an introduction to the various sections of the report, including expectations for appropriate content. No updates to report scoring were made.

3.2.4 UP's EGR 270 Materials and CE 376 Environmental Engineering

The lab instructors had all taught the respective labs several times before our investigation began. These instructors were not actively looking to significantly change how they teach writing even after the exposure to the modules. Therefore, the primary impact on both labs' instructions from "control" to "experiment" was the "experiment" group making several of the modules available on the lab class web and encouraging students to use them as they deemed appropriate. Examples of good/poor reports and students' common mistakes in the student's guide were introduced in class. Other changes from "control" to "experiment" were observed in writing pedagogy; however, instructors reported that these were minor changes independent of our modules.

This finding was reinforced during the June 2023 focus group, as the instructor stated that they had been using many of the skills presented in the guides before being exposed to the Instructor's Guide and thus had not changed their approach beyond making the student's guides available.

3.2.5 WSUV's ECE 214 Logic Circuits

Control (Fall 2020):

The instructor of ECE 214 gave a PowerPoint presentation, "How to Write a Lab Report," to the class at the beginning of the semester and then posted the presentation on the course website for students' reference. This "How to…" presentation was based on the typical IMRDC organization and included the rubric used to grade the lab reports.

There were twelve labs during the semester, one each week. Each lab had a unique handout describing what was to be done in the lab. The first lab handout included the following instructions:

> "Make sure all your lab reports follow the requirements in "ECE 214 How to write a lab report.pdf" found in the lab folder of [the course website]. If you have questions, ask the T.A. who will be grading them, shown in the course syllabus available in the Course Information section of [the website]."

Subsequent lab handouts gave no further guidance about lab reports.

Experiment (Fall 2022):

ECE 214's instructor copied and pasted text from the module's *Student's Guide to Engineering Lab Writing/Format* page to create a one-page lab report template for all the labs in ECE 214. The template follows the IMRDC format ("methods" replaced by "procedures") and briefly describes the expected content in each section of the lab report. The default template served most labs, but the instructor added some lab-specific reminders to some templates. For example, reminding students to include a specific table in the results section. Students could download the templates in DOCX format from the course website. The instructor also put a link to https://labs.wsu.edu/engineering-lab-report-writing/sample-page/preface/ on the course website, but was unsure if any students used it.

The instructor gave the same PowerPoint presentation, "How to Write a Lab Report," to the class at the beginning of the term and again posted the presentation on the course website for students' reference. The same lab handouts describing what would be done in each lab were used unchanged. The instructor's only significant change was adding lab report templates based on the *Student's Guide Format* page.

The instructor mentioned during the initial focus group discussions that they had used the assessment guide to develop a rubric and that the guide was easy to use [15]. They and other newer faculty had never used rubrics before, but they had since developed them for use in their labs.

3.2.6 WSUV's MECH 309 Engineering materials

Control (Fall 2020):

The instructor of MECH 309 provided two instructional materials to explain the instructor's expectations and assist students with lab writing. The first was a sample lab report from a previous term. The sample's topic was not related to any of the labs offered in the term. The sample's structure is typical IMRDC with references and appendices. The sample was four pages with approximately 1000 words, excluding three pages of raw data and sample calculations in the appendices. The other material was the lab report grading guide, indicating the report format and grading policy applicable to all the labs in the course. The guide specified the content, the approximate number of pages, and the scores of each section. The instructor provided the handouts for each lab; however, there is no content related to lab writing.

Experiment (Fall 2022):

MECH 309's instructor significantly transformed the lab writing instructional materials using the modules. First, the instructor did not provide one writing guideline for all the labs. Instead, the lab writing instruction was added to each lab's handout, which originally had lab activities only. For example, Lab 2's report assignment defines the genre, audience, purpose, and writer of the Lab 2 report. The lab assignment also introduces the report's macrostructure, IMRDC, and why the technical audience values the IMRDC structure. It adds the typical content for each section from the audience's perspective. The analytical rubric with the four lab writing objectives is included in the lab handout; therefore, the students can read the instructor's expectations before writing their labs. The instructor updated all the lab handouts to scaffold the writing instructions. In Lab 1, the primary emphasis was on the accuracy of lab data analysis within a template format. Lab 2 centered around the macrostructure – IMRDC. Moving forward to Lab 3, the focus shifted towards developing skills in technical report writing, with particular attention to effective graphic and table presentations. Lab 4 introduced the technical report genre, focusing on lab data analysis. The genre of the last two labs (Labs 5 and 6) was the research paper, integrating outside sources to support students' lab data analysis results and interpretations.

3.3 Discussion

Quantitative and qualitative analyses of the instructional materials to support students' lab writing show that all the participating instructors used at least a couple of modules in the learning transfer-focused lab writing guides. Overall, we observed three aspects from the results of the analysis. First, lab instructors with less teaching experience used more modules and updated the lab writing instructional materials more extensively. The ECE 214 instructor was an assistant-level professor who might actively search for ways to establish their lab courses. Other new faculty included in the focus groups found that using the guides led to better assignments and more streamlined assessments. In contrast, ENGR 266, ENGR 213, EGR 270, and CE 376 instructors had a long teaching history and mentioned already using some of the skills covered in the guides. Their use of the modules was less extensive. Second, most participating lab instructors updated their lab writing instructional materials by specifying what they expected in the IMRDC format. Some instructors explicitly present the required content in each section. Some included samples to show satisfactory-formatted reports. Third, about half of the participating instructors used the instructor's guide to update their lab assignments to

contextualize the assignments in real-world settings and to identify the audience and their expectations from the audience's point of view. This is well aligned with the ABET outcome 3: an ability to communicate effectively with a range of audiences [18].

Not all participating lab instructors have had opportunities for professional development in writing education. Some participating instructors attended past ASEE conferences and writing workshops offered by schools or professional organizations. Although they did not take any formal professional development on writing pedagogies, all participating lab instructors used the developed modules to update their lab instructional materials in some way. We hypothesize that they could use our modules more effectively and enhance their understanding of writing pedagogies to support their students' lab writing if formal professional development, such as in-person workshops or webinars, is given to them.

4. Conclusion

Engineering lab writing instructional guides were developed and published online at engineeringlabwriting.org for instructors and undergraduates to improve lab writing by promoting undergraduates' learning transfer from their general education writing courses to engineering labs. These guides were introduced to a group of lab instructors to update their engineering lab instructional materials. After conducting the quantitative and qualitative analysis of the collected instructional materials before and after the exposure to the modules, the following conclusion can be drawn:

1. All participating instructors used the format module of the student's guide to support students' learning on the IMRDC format. Most instructors used the modules to directly instruct the students on lab report format, reasoning, and conventions.
2. About half of the participating instructors updated their lab assignments with the instructor's guide to include descriptions of the audience and their expectations. Some participants also used the assessment module from the instructor's guide to include lab report assessment rubrics.
3. Most participating lab instructors used the terms and concepts introduced in the guides and updated their lab writing instructions to consider students' prior writing knowledge. Many lab courses include information about the audience of the lab reports in the assignment to describe the expectations clearly.
4. Less experienced instructors used the modules more actively than highly experienced instructors. We hypothesize that engineering lab instructors can use our modules more effectively to support their students' lab writing when formal professional development is provided to them.

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