# Effectiveness of Transfer Focused Writing Pedagogy on Undergraduates' Lab Report Writing in Entry-Level Engineering Laboratory Courses at Three Universities

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## Abstract

This study focuses on the effectiveness of learning transfer-focused or transfer-focused lab report writing instructional modules on engineering undergraduates' lab report writing in entry-level engineering laboratory courses. The modules are novel due to their shared language to describe and reinforce foundational writing terms used by the writing faculty and are ready for immediate use by engineering lab instructors. Three different universities, consisting of a polytechnical university, a liberal arts-anchored private university, and a branch campus of a research-one land grant university, participated. Student lab report samples from six various sophomore-level engineering courses were collected. For the control group, none of the participating lab instructors accessed the transfer-focused modules (academic years of 2019-2020 and 2020-2021); sixty-four control group lab report samples were collected (n = 64). In the academic year 2021-2022, the lab instructors had access to the transfer-focused modules via the web to be encouraged to update their lab instructions; the experimental group lab report samples were collected from forty-two students (n = 42). Using defined writing outcomes, a panel of engineering lab instructors assessed the participating students' early (one of the first reports in the class) and late lab reports (written near the end of the course). The lab report assessment analysis indicates that only 30% of the control group students could write their early lab reports at a satisfactory level, while 60% of the experimental group students reached a satisfactory level in their early labs. For both early and late lab reports, the experimental group students outperformed most outcomes over the control group. The notably improved outcomes were related to audience awareness, data presentation, data analysis, and data interpretation. The transfer-focused lab report writing pedagogy enhanced engineering undergraduates' ability to engage in critical thinking practices, including analysis, interpretation, and evaluation of their lab data/products. Additionally, students appeared to improve their awareness of a technical audience, expecting engineering language, styles, and conventions commonly shared by writers in engineering.


## 1. Introduction

Undergraduate students entering engineering programs possess years of educational experience that impact their learning in the major. Once in college, most engineering undergraduates take general education writing courses, so-called first-year composition, in their freshman year. Writing educators across US post-secondary schools have used student outcomes, called Writing Program Administrator (WPA) Outcomes Statement for First-Year Composition (3.0) [1], focusing on rhetorical knowledge, critical thinking, and reading for first-year composition courses, composing, writing processes, and knowledge of conventions. The first-year

composition curriculum emphasizes the rhetorical situation (writer, audience, purpose, and context), rhetorical appeals (logical, ethical, and emotional), and genre awareness in the writing process [1]. Most first-year composition courses are taught and/or administrated by English or Communication departments.

Although engineering undergraduates learn academic writing in first-year composition or other general education writing courses, they often struggle to transfer the writing knowledge from those courses to engineering courses [2]. This is particularly true for the lower-division introductory engineering lab courses where students are required to write intensive lab reports. These introductory engineering lab courses are often students' first experience writing in a genre with the primary audience of engineering instructors and teaching assistants.

There have been many efforts to support engineering students' writing in lower-division engineering courses. Genau [3] implemented a 4-page technical writing guide in a sophomore materials lab course, along with reading assignments of a short technical journal article, peer reviews, and multiple graded/ungraded submission steps. Gravé [4] integrated standardized writing assignments seamlessly from two physics courses to two engineering lab courses. Alba-Flores [5] implemented the peer review process in a Circuit Analysis lab course resulting in an increase in students' awareness about the importance of technical writing and improved writing assessment results. Corneal [6] developed a sequence of three templates to guide students through the process of technical report writing and implemented it in a first-year engineering lab course.

According to the theories of learning transfer [7], describing how past experiences affect learning and performance in a new situation, the transfer of writing skills from first-year composition to engineering can be classified as 'far transfer' that contains very few abstract or general overlapping features [8]. In a previous study to improve engineering undergraduates' writing in the major, engineering lab instruction was reformed in one mechanical engineering lab course, which required multiple lab report writing submissions. This pilot study provided strong empirical evidence that the rhetorically informed instructional materials improved mechanical engineering undergraduates' lab report writing performance by reinforcing the rhetorical knowledge of writing skills that they experienced before the engineering lab course [8,9].

To expand the use of learning transfer-focused writing pedagogy to other institutions and majors, we developed web-based instructional modules [10] for engineering instructors to use in lower-division labs. The developed modules are designed to enhance engineering undergraduates' learning transfer in lower-division writing curriculum because they use shared language to describe and reinforce foundational writing terms used by writing instructors, packaging them for immediate use by engineering lab instructors who are not necessarily versed in foundational writing instruction. This paper presents the study results of the past three years to investigate the effectiveness of learning transfer-focused or transfer-focused writing pedagogy on undergraduates' lab report writing in entry-level engineering laboratory courses at three universities.

## 2. Methods of Approach

### 2.1 Study Area

This study took place in the engineering programs at three different universities, consisting of a polytechnic university (Oregon Institute of Technology in OR), a liberal arts-anchored private university (the University of Portland in OR), and a branch campus of a research-one land grant university (Washington State University Vancouver in WA). The participating polytechnic university has four ABET-accredited engineering programs: civil, electrical, mechanical, and renewable energy. In total, these programs have approximately 650 students and 30 full-time faculty members, and sophomore-level lab courses of civil and electrical engineering programs participated in this study. All the participating labs were taught by the faculty. The liberal arts-anchored private university's School of Engineering has three ABET-accredited engineering programs: civil, electrical, and mechanical. These engineering programs have approximately 550 undergraduate students and 20 full-time faculty members. Civil and mechanical engineering sophomore-level lab courses have participated. The branch campus of the research-one land grant university offers two ABET-accredited engineering programs: electrical and mechanical. Together these programs have approximately 350 undergraduate students and 15 full-time faculty members. Sophomore-level electrical engineering courses have participated in this study. All the labs are taught by graduate teaching assistants supervised by faculty.

### 2.2 Research Study Design

This study was intended to test the following research question: *How much of the student lab report writing can be improved when implementing transfer-focused writing pedagogy in lower-division engineering labs?* This study was conducted with student volunteers in the six lower-division engineering lab courses listed in Table 1 for the three academic years (2019-2022). The student volunteers signed their consent, which was approved by each institution's internal review board (IRB). The independent variable in this study is the implementation of the learning transfer-focused modules or the transfer-focused modules in the labs. The modules were introduced to the engineering instructors of the six lab courses in the summer of 2021; therefore, their lab report writing instructions in the academic years of 2019-2020 and 2020-2021 were not impacted by the modules. We define the participating students in these two academic years as the control group. We collected the control group lab report samples from sixty-four students (n = 64). Beginning in the summer of 2021, the lab instructors of the six courses could access the transfer-focused modules via the web, and they used them to update their lab report writing instructions by themselves without significant professional development. We define the experimental group for the participating students in the academic year of 2021-2022 who were intervened by the transfer-focused writing pedagogy. The experimental group lab report samples were collected from forty-two students (n = 42). We collected two of each student's lab reports - an early lab report (mostly the first lab), and a late lab report (mostly the last lab) to investigate how early students could meet the instructors' expectations in lab report writing during the courses.

The three academic years for the study were impacted by the COVID-19 pandemic; therefore, the labs were offered via online, in-person with distance, or fully in-person. The stress of the COVID-19 pandemic might affect the lab instructor's writing instructions and students' lab report writing. However, the impact of the lab or course delivery mode or the COVID-19 pandemic was not considered in this study.

Table 1: Participating engineering laboratory courses and the participating students in the study

| **Institution, Semester/Quarter** | **Major** | **Course** | **Topic** | **Term** | **Labs taught by** | **Participating students in the control group (2019-2021)** | **Participating students in the experimental group (2021-2022)** |
|---|---|---|---|---|---|---|---|
| 4-year public polytechnic college, Quarter (Oregon Institute of Technology) | Civil | CE 212 | Civil engineering materials | Fall | Instructor | 15 | 12 |
| 4-year public polytechnic college, Quarter(Oregon Institute of Technology) | Electrical | EE 221 | Circuits | Fall | Instructor | 10 | 0 |
| 4-year public polytechnic college, Quarter(Oregon Institute of Technology) | Mechanical/ Civil | ENGR213 | Strength of materials | Fall | Instructor | 3 | 7 |
| 4-year private college, Semester (the University of Portland) | Mechanical | EGR 270 | Materials | Spring | Instructor | 14 | 8 |
| 4-year private college, Semester (the University of Portland) | Civil | CE 376 | Environmental engineering | Spring | Instructor | 11 | 8 |
| 4-year public college, Semester (Washington State University Vancouver) | Electrical | ECE 214 | Logic Circuits | Fall | Graduate teaching assistant | 11 | 7 |

### 2.3 Transfer-focused Engineering Lab Report Writing Modules and Implementation

The transfer-focused engineering lab report writing instructional modules are prepared to assist engineering lab instructors with the topics of (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. Additional modules address assignment design and assessment rubric design. Table 2 presents the organization of the modules. Note that English-major professors of college writing programs have collaborated with engineering professors when developing the modules. The details of the module development were introduced in [10].

The modules were published on the project's website with password protection. The web password of the modules was provided in the summer of 2021 to the engineering instructors of the six participating lab courses listed in Table 1. The participating lab instructors ranged from assistant professors to full professors. All of them indicated to the authors that they had implemented the modules in the lab report writing instructions of the participating lab courses in the academic year of 2021-2022 (the experimental group). According to the interviews with multiple participating lab instructors, they used the web modules to update lab handouts, templates provided to the students, and/or lab report assessment rubrics. They mentioned the preface modules and fundamental topic modules were most helpful [10].

Table 2. Module organization and titles

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

### 2.4 Research Instrument and Sample Assessment Process

This study refined or adapted the instrument from Refs [1,11,12] to characterize the purpose, content, and assessment of the lab reports assigned to students in the lower-division engineering labs. Table 3 is the lab report writing rubric drawn from the WPA (Writing Program Administrators) outcomes and ABET outcomes #3 and #6 [11]. The WPA outcomes are widely used by first-year college writing course instructors as their student outcomes, focusing on rhetorical knowledge, critical thinking, reading and composing, and processes [1]. They also emphasize the audience expectations and genre conventions of the discipline when the writing skills are applied to specific disciplines [1]. Most engineering lab reports follow the IMRDC or introduction-methods-results-discussion-conclusion format [12], and the lab report writing rubric is designed to connect with IMRDC.

A panel composed of five engineering faculty assessed sample lab reports. Before the full-scale rating session, the developed rubric (need improvement = 1, satisfactory = 2, exemplary = 3) was

tested for validity and interrater reliability during norming sessions: the raters' norming scores were compared between the academic years 2019-2020 and 2021-22, which are the independent variable. Each rater scored 1 to 3 on each of the nine writing outcomes. Each lab report was assessed by two raters. When two rater's average scores of the same report varied by more than 1 point, a negotiation session was conducted between the two raters to alter the scores and calibrate for future scoring.

Table 3. Lab report writing outcomes [12]: Lab report writing outcomes rubric (I = introduction; M = methods; R = results; D = discussion; C = conclusion).

| **Writers in early engineering lab courses are able to** | **Mostly related to** |
|---|---|
| 1) Address technical audience expectations by providing the purpose, context, and background information, incorporating secondary sources as appropriate. | I |
| 2) Present experimentation processes accurately and concisely. | M |
| 3) Illustrate lab data using the appropriate graphic/table forms. | R |
| 4) Analyze lab data using appropriate methods (statistical, comparative, uncertainty, etc.). | RD |
| 5) Interpret lab data using factual and quantitative evidence (primary and/or secondary sources). | RD |
| 6) Provide an effective conclusion that summarizes the laboratory's purpose, process, and key findings, and makes appropriate recommendations | C |
| 7) Develop ideas using effective reasoning and productive patterns of organization (cause-effect, compare-contrast, etc.). | IMRDC |
| 8) Demonstrate appropriate genre conventions, including organizational structure and format (i.e., introduction, body, conclusion, appendix, etc.). | IMRDC |
| 9) Establish solid and consistent control of conventions for a technical audience (grammar, tone, mechanics, citation style, etc.). | IMRDC |

## 3. Results and Discussion

### 3.1 Impact of the modules on the early lab reports

We classified the lab reports with an average score above 2.0 as "satisfactory" lab reports. When the report's average score is below 2.0, we consider it a "need-improvement" lab report. Table 4 shows the number of students who resulted in satisfactory vs. need-improvement lab reports in their early labs. Often the reports from the early labs are the students' first lab reports in the major. Therefore, the students might rely on their prior writing knowledge and experience and the lab instructor's instructional materials provided for the lab when writing lab reports. In the control group, 30% of the early lab reports were rated satisfactory, while in the experimental group, 60% of the early lab reports were satisfactory. The implementation of the transfer-focused

modules positively impacted students' first lab report writing. A systematic study of which content and how the participating instructors used to update their lab course materials is in progress, but a sample of early feedback is provided in [10].

Table 4. Numbers of students resulting in satisfactory and need-improvement lab reports in their early labs.

| | Control group<br>Student no. (%) | Experimental group<br>Student no. (%) |
|---|---|---|
| Satisfactory (average score of 2.0 or above) | 19 (30%) | 25 (60%) |
| Need improvement (average score of less than 2.0) | 45 (70%) | 17 (40%) |
| Total | 64 (100%) | 42 (100%) |

Figures 1 and 2 show the average scores of individual lab report writing outcomes and the grand average scores of the early labs. As shown in Figure 1, the satisfactory lab reports of the control group showed average scores of 2 or above in all outcomes 2 to 9, except outcome 1 (Address technical audience expectations). The experimental group's satisfactory lab reports had average scores of above 2 for all the outcomes. The satisfactory lab reports of the experimental group outscored the control group in all outcomes, except outcome 6 (Provide an effective conclusion). Large differences between the two groups were found in writing outcomes 1 (Address technical audience expectations), 4 (Analyze lab data), and 5 (Interpret lab data). The use of the modules positively impacted students' lab report writing in these outcomes.

Figure 2 presents the need-improvement lab reports' outcome scores for the two groups. Average scores of all outcomes are lower than 2, which is a satisfactory grade in the assessment. Students who wrote need-improvement lab reports could struggle when writing their first lab reports in the engineering majors. Among all outcomes, outcomes 5 (Interpret lab data), 6 (Provide an effective conclusion), and 7 (Develop ideas) are the three lowest for both groups. Students who struggle with writing engineering lab reports seem to have difficulties in these areas. As shown in Figure 2, we could find a positive impact of the modules on underachieving students' lab report writing. Regardless of the outcomes, the experimental group's outcome scores are higher than that of the control group. The two groups show large differences in outcomes 2 (Present experimentation processes), 3 (Illustrate lab data), 4 (Analyze lab data), and 5 (Interpret lab data); this may mean that the writing pedagogy updated with the modules helped students to improve in writing experimental process presentations and lab data illustration/analysis/interpretation of engineering lab reports.

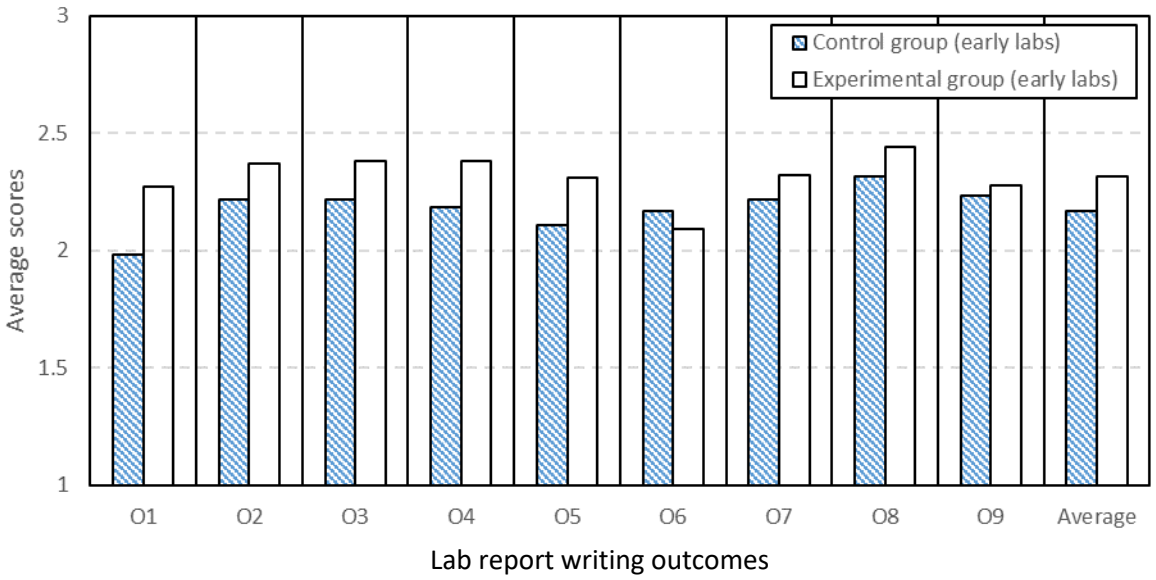


Figure 1. Average scores of lab report writing outcomes of the satisfactory lab reports (average scores of 2.0 or above) in the control and experimental groups.

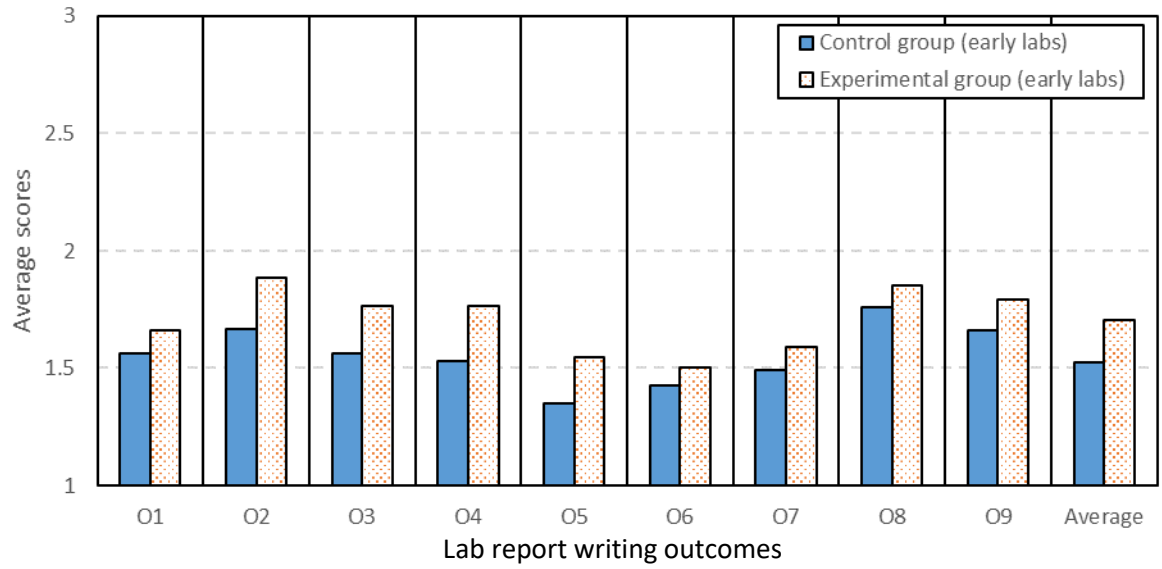


Figure 2. Average scores of lab report writing outcomes of the need-improvement lab reports (average scores of less than 2.0) in the control and experimental groups.

### 3.2 Impact of the modules on the late lab reports.

Table 5 shows the breakdown of student performance (satisfactory or needs improvement) for early and late labs for the control and experiment groups. Among the 19 control group students who wrote satisfactory reports in their early labs, 12 students went on to write satisfactory lab reports in the late labs, while seven students (about one-third) ended up with need-improvement lab reports. When looking at the 45 control group students who wrote need-improvement lab reports, a majority of them (39 students) went on to write lab reports with need-improvement scores. Approximately 61% of the students in the control group could not write satisfactory-level lab reports in both early and late labs. This group of students might not improve their writing in the major before moving up to the next courses in the engineering curricula. However, six students out of 45 students did improve their labs to a satisfactory level. This is a positive sign that some students could improve their lab report writing under the lab instructions without the modules.

The trend in student distributions between early and late labs is unchanged in the experimental group. Among the 25 experimental group students who got satisfactory scores in early labs, approximately one-third or eight students resulted in need-improvement scores in their late labs. This can be interpreted that students who got good scores in early labs might not spend much time or effort to write high-quality lab reports in the late labs during the end of the term. Or, the instructors' feedback or instructions confused these students when writing lab reports in the late labs. Like the control group's underachieving students, a majority of students (14 out of 17) had need-improvement scores in late labs. Although the lab instructors used the modules, approximately 33% of students in the experimental group could not write satisfactory lab reports for both early and late labs. This is less than the approximately 61% of the control group. It is a topic of ongoing research to study how to intervene with the students who struggle in writing lab reports.

Table 5. Breakdown of satisfactory and need-improvement lab reports for early and late labs for the control and experiment groups.

| | Early labs | | Late labs | |
|---|---|---|---|---|
| Control group, student no. (%) | Satisfactory (average score of 2.0 or above) | 19 (30%) | Satisfactory | 12 (19%) |
| | | | Need-improvement | 7 (11%) |
| | Need-improvement (average score of less than 2.0) | 45 (70%) | Satisfactory | 6 (9%) |
| | | | Need-improvement | 39 (61%) |
| | Total | 64 (100%) | Total | 64 (100%) |
| Experimental group, student no. (%) | Satisfactory (average score of 2.0 or above) | 25 (60%) | Satisfactory | 17 (40%) |
| | | | Need-improvement | 8 (19%) |
| | Need-improvement (average score of less than 2.0) | 17 (40%) | Satisfactory | 3 (7%) |
| | | | Need-improvement | 14 (33%) |
| | Total | 42 (100%) | Total | 42 (100%) |

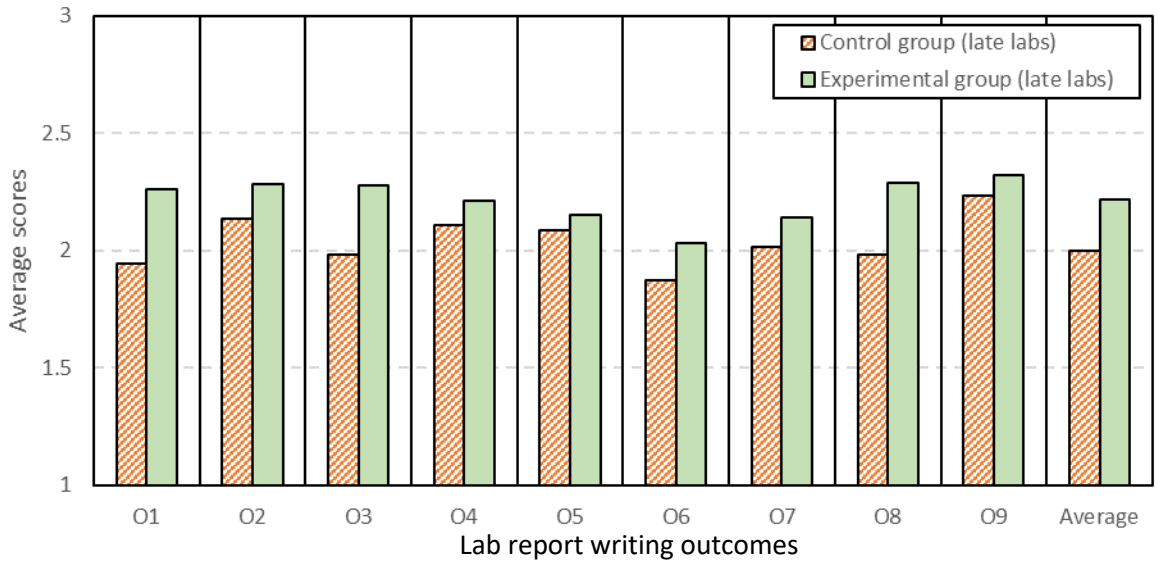


Figure 3. Average lab report scores in late labs from the students who wrote satisfactory lab reports (average scores of 2.0 or above) in the early labs for the control (n = 64) and experimental groups (n = 42).

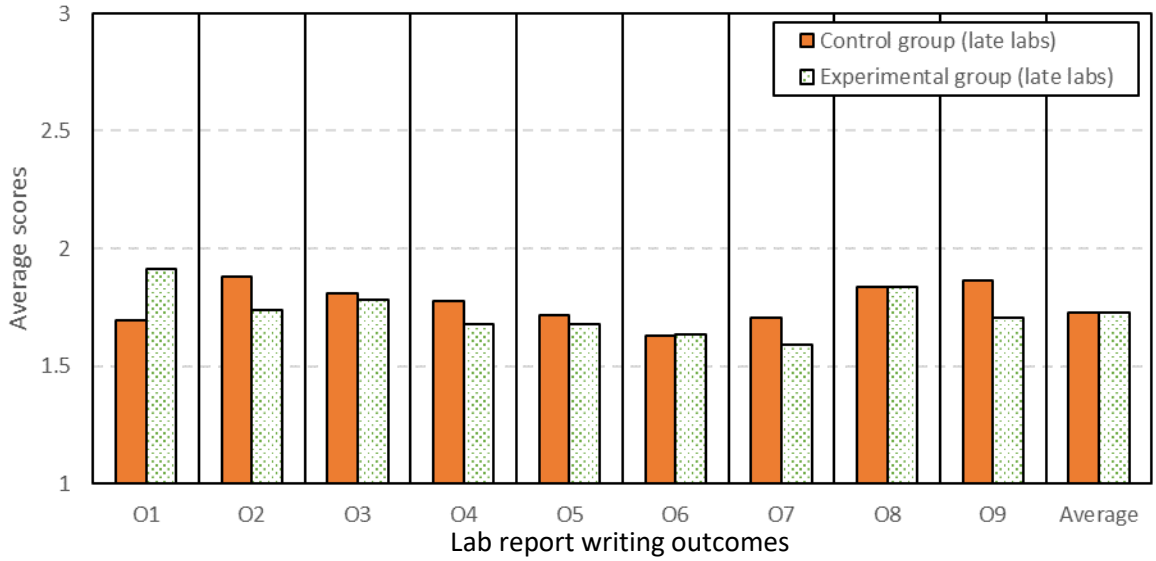


Figure 4. Average lab reports scores in late labs from the students who wrote the need-improvement lab reports (average scores less than 2.0) in the early labs for the control (n = 64) and experimental groups (n = 42).

To investigate the areas of improvement by the module implementation, the average scores of late lab reports are plotted in Figure 3 for the students who wrote satisfactory lab reports in the early labs. As shown in Figure 3, the experimental group students outperformed the control

group in all outcomes. The large differences are found in outcomes 1 (Address technical audience expectations), 3 (Illustrate lab data), and 8 (Demonstrate appropriate genre conventions), which suggests that the transfer-focused modules could highly impact these areas of student writing addressed in the fundamental topic modules.

Figure 4 shows the average scores of nine outcomes and the grand average of late lab reports from the students who wrote need-improvement early lab reports. This group of students struggled at the beginning of the term when writing their lab reports in early labs. As shown in Figure 4, this group of students continued to struggle writing lab reports even in the late labs, regardless of the control or experimental groups. Both groups' averages are quite similar across the outcomes. Outcomes 5 (Interpret lab data), 6 (Provide an effective conclusion), and 7 (Develop ideas) are the worst among all outcomes, which means these are the areas where the students who struggled in the beginning also had difficulty at the end.

### 3.3 Discussion on the effectiveness of the modules on engineering students' lab report writing

As shown in Tables 4 and 5, undergraduates' lab report writing in the entry-level engineering labs was improved when instructors used the transfer-focused modules. The percentage of experimental group students who wrote satisfactory-level reports in the early labs was doubled (See Table 4), and almost all outcomes were improved over the control group students (See Figures 1 and 2). The improved student performance is also observed in late labs. According to Table 5 and Figure 3, 18 students or 28% of the control group wrote satisfactory-level lab reports in their late labs while 20 students or 48% of the experimental group resulted in satisfactory-level for their late labs.

Figure 5 presents the average outcome scores and the grand averages of all the reports for both control and experimental groups. The scores of all outcomes were improved with the implementation of the modules, which shows their positive impact on students' lab report writing. Among the nine outcomes, outcomes 1 (Address technical audience expectations), 3 (Illustrate lab data), 4 (Analyze lab data), and 5 (Interpret lab data) were the experimental group's top four outcomes that improved by the most significant margins over the control group. The transfer-focused modules contain fruitful content on lab data presentation (module F-5), lab data analysis (modules F-4, I-3, A-2, A-3), and logical appeals (module A-1), which aim to enhance engineering undergraduates to engage in critical thinking practices, including analysis, interpretation, and evaluation of their lab data/products. Additionally, audience awareness (modules F-1, F-3) is well covered in the modules; therefore, students could improve their awareness of a technical audience, an audience expecting engineering language, styles, and conventions commonly agreed upon in the community of writing in engineering.

Although the positive impact of the modules is evident, we found room for improvement in outcomes 6 (Provide an effective conclusion) and 7 (Develop ideas). The average scores were relatively low for both groups, and the improvement in the experimental group was also

relatively minimal. Were the modules not effectively written in these areas or did the participating instructors struggle when implementing the modules? A study on how effectively the participating instructors acquire the module contents in the areas students struggle with is ongoing.

We also indentify the limitations of this study, including relatively small participating student sample size, the variation of student numbers across the labs, and the lack of inclusion for the impact of COVID-19.

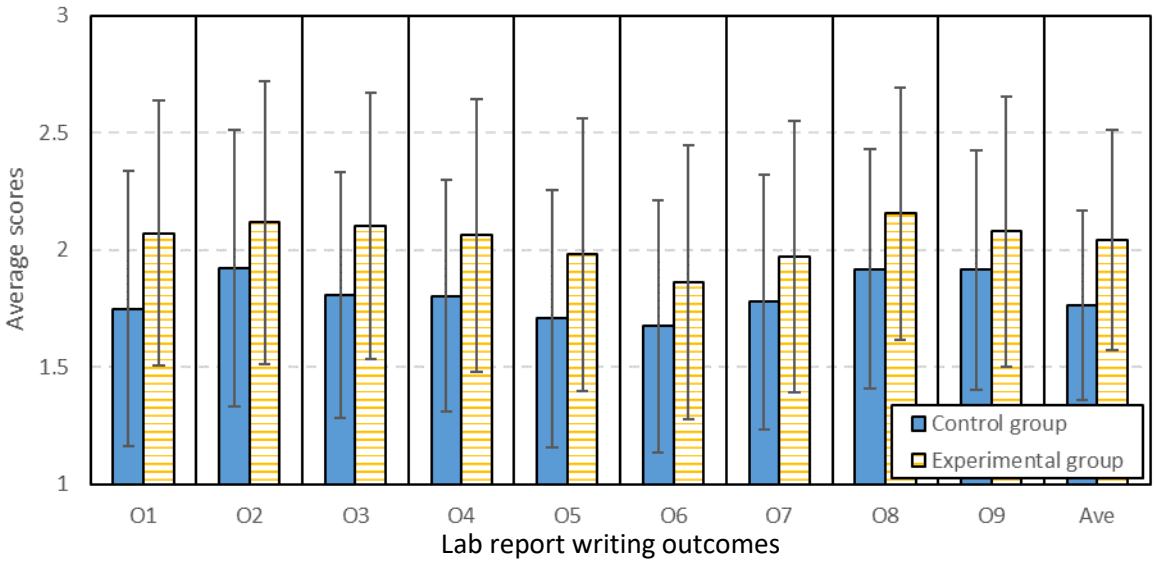


Figure 5. Average scores of all lab reports for the control and experimental groups. (Error bars are the standard deviations.)

## 4. Conclusion

This study aims to investigate the effectiveness of the transfer-focused lab report writing instructional modules on engineering undergraduates' lab report writing in entry-level engineering laboratory courses. The control and experimental groups were designed before and after the implementation of the modules in six participating lower-division lab courses. After assessing students' lab reports collected in early and late labs of those courses, the following conclusions can be drawn:

1. Only 30% of the control group students could write their lab reports at a satisfactory level, while 60% of the experimental group students reached a satisfactory level in their early labs.

2. The experimental group has improved scores over the control group for all nine lab report writing outcomes. The implementation of the modules appears to positively impact students' lab report writing.
3. The most notably improved writing outcomes in the experimental group over the control group include more foundational outcomes related to addressing technical audience expectations, illustrating lab data, analyzing lab data, and interpreting lab data.
4. Although the instructors used the modules in lab report writing instructions, approximately 33% of students in the experimental group could not write satisfactory-level reports for early and late labs.
5. The outcomes related to providing an effective conclusion and developing ideas in the lab reports marginally improved for the experimental group.

The authors are conducting systematic studies on 1) how the participating instructors updated particular content in their lab course materials, 2) how best to intervene with engineering students who struggle in writing lab reports, and 3) how effectively the participating instructors used the module contents in the areas where students struggle.

## Acknowledgments

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