Investigating the effect of engineering undergraduates' writing transfer modes on lab report writing in entry-level engineering lab courses

Dr. Charles Riley P.E., Oregon Institute of Technology

Dr. Riley has been teaching civil engineering structures and mechanics concepts for over 12 years and has been honored with both the ASCE ExCEEd New Faculty Excellence in Civil Engineering Education Award and the Beer and Johnston Outstanding New Mechanics Educator Award. While he teaches freshman to graduate-level courses across the civil engineering curriculum, his focus is on engineering mechanics. He values classroom demonstrations and illustrative laboratory and field experiences. He has served as an ASCE ExCEEd Teaching Workshop mentor for five years as well as the founding coordinator for the Oregon Tech Excellence in Teaching Workshop.

Dr. Dave Kim, Washington State University-Vancouver

Dr. Dave Kim is Professor and Mechanical Engineering Program Coordinator in the School of Engineering and Computer Science at Washington State University Vancouver. His teaching and research have been in the areas of engineering materials, fracture mechanics, and manufacturing processes. In particular, he has been very active in pedagogical research in the area of writing pedagogy of engineering laboratory courses. Dr. Kim and his collaborators attracted close to $1M research grants to study writing transfer of engineering undergraduates. For the technical research, he has a long-standing involvement in research concerned with manufacturing of advanced composite materials (CFRP/titanium stack, GFRP, nanocomposites, etc.) for automotive, marine, and aerospace applications. His recent research efforts have also included the fatigue behavior of manufactured products, with the focus of fatigue strength improvement of aerospace, automotive, and rail structures. He has been the author or co-author of over 200 peer-reviewed papers in these areas.

Dr. Ken Lulay P.E., University of Portland

BSME, University of Portland, 1984 MSME, University of Portland, 1987 PhD, University of Washington, 1990 Hyster Co., 1984-1987 Boeing 1990-1998 Associate Prof, University of Portland, Current

Dr. John D Lynch, Washington State University Vancouver

John D. Lynch received a B.S. in Electrical Engineering, Cum Laude, from the University of Utah in Salt Lake City in 1979. From 1979 to 1995 he worked in the high-tech industry in California and Oregon as a computer engineer, including positions at Floating Point Systems, Intel, AMD, Pyramid Technology, and Adaptive Solutions. From 1995 to 1998 he managed ASIC Design Engineering for InFocus Corporation. From 1998 to 2002 he was Director of IC Design Engineering at Pixelworks, Inc. In 2002 he joined the School of Science and Engineering (formerly the Oregon Graduate Institute) of Oregon Health & Science University as an Instructor, where he developed and taught courses in a variety of computer engineering subjects. In 2007 he was appointed Director of OHSU's Computer Engineering and Design Education Program. In 2009, after completing his Ph.D. in electrical engineering at OHSU, he joined the engineering faculty at Washington State University Vancouver. Since 2012 he has served as Coordinator of the electrical engineering program at WSU Vancouver.

Dr. Sean St. Clair, Oregon Institute of Technology

Sean St.Clair is a Professor of Civil Engineering at Oregon Tech, where he teaches structural engineering courses and conducts research in engineering education. He is also a registered Professional Engineer.

©American Society for Engineering Education, 2021

Investigating the Effect of Engineering Undergraduates' Writing Transfer Modes on Lab Report Writing in Entry-Level Engineering Lab Courses

Abstract

Engineering undergraduates are exposed to a variety of writing curricula, such as first-year-composition courses, in their early program of study; however, they have difficulties meeting the expectations of writing in early engineering courses. On the other hand, instructors in entry-level engineering lab courses struggle to instruct lab report writing due to a wide range of student writing backgrounds and pressure to focus on technical content. When using the lens of learning transfer theories, which describe the processes and the effective extent to which past experiences affect learning and performance in a new situation, we can classify engineering students in three writing transfer modes: 1) concurrent transfer, which occurs when a rhetorically-focused technical writing class is taken concurrently or prior to engineering labs in the major; 2) vertical transfer, which occurs when a rhetorically-focused general education writing class is taken prior to engineering labs in the major; and 3) absent transfer, which occurs when no rhetorically-focused writing class exists (rather literature-focused) or writing-intensive courses are not required in the general education curriculum. This study aims to investigate how the engineering sophomore's past writing experience, specifically in collegiate writing or writing-across-the-curriculum courses, affects their engineering lab report writing.

Lab reports from four sophomore engineering courses (1 civil, 2 electrical, 1 general engineering) across three institutions collected for analysis consisted of two sets: the sample sets in early labs (for example, Lab 1) and in later labs (for example, the last lab) of the courses. A total of 46 reports (22 early and 24 later) were collected from 22 engineering sophomores during AY2019-2020. Four engineering faculty (1 civil, 1 electrical, and 2 mechanical engineering) developed a rubric based on lab report writing student outcomes, which are aligned with the existing outcomes such as ABET outcomes and the student outcomes from the Council of Writing Program Administrators (WPA). The data suggest that the greatest writing gains in a first lab course are made by vertical transfer students, while concurrent transfer students enter with skills developed in prior writing coursework. The largest improvements among the three transfer modes were found in the student outcomes related to lab data presentation, analysis, and interpretation. In these outcomes, the concurrent transfer students had relatively high scores for both early and later reports, while the vertical transfer students improved their scores from relatively low in early reports to meet expectations in later reports. Absent transfer students demonstrated inconsistent outcomes and deserve greater study with more data than was available for this study.

1. Introduction

Writing can provide an effective means of measuring student engagement and understanding as well as prepare students for technical writing activities in engineering practice. Early laboratory courses in engineering curricula are often the first place students encounter writing about technical subjects. Lab reports allow students to document appropriate experimentation methods and lab data analysis and interpretation results (related to ABET Outcome #6) in basic professional forms, characteristics, and conventions associated with engineering literacy [1-3] and to offer conclusions that are meaningful for both a technical audience and as a demonstration of their own learning (ABET Outcomes #3 and #6).

Most engineering undergraduates are exposed to general education writing courses in the early stage of their programs of study. General education writing courses are the primary source of direct instruction in writing, with first-year composition, technical writing/technical communication, or writing-across-the-curriculum approaches being most common. Therefore, most engineering undergraduates take general education writing courses before having writing assignments, such as lab reports, in engineering courses. The institutions participating in this study were selected to represent these three most common examples of general education writing curricula.

We build on existing research in engineering education [4-7] by introducing research on "writing transfer" as the core of our theoretical approach. Theories of learning transfer [8,9] describe the processes and the effective extent to which past experiences (the transfer source) affect learning and performance in a new situation (the transfer target). Writing transfer for most engineering undergraduates can be considered as "far transfer" because the transfer of writing skills from one discipline (general education writing courses offered mostly by English programs) to another (engineering) contains few abstract or general overlapping features. Therefore, describing engineering undergraduates' writing transfer is a complex process that requires a deeper understanding of the transfer context, which is related to both the transfer source and the transfer target.

Informed by historical research on general education writing curricula [10], general education writing programs in the United States offer multiple general education writing courses as the transfer source to engineering undergraduates. Therefore, the transfer source in this study was varied by investigating three different approaches to writing preparation, which we describe as *far transfer models* (represented nominally, but not explicitly, by the three institutions involved in the study):

1. Absent transfer - no rhetorically focused writing class exists (rather literature-focused), or writing-intensive courses are not required in the general education curriculum (University of Portland)

2. Vertical transfer - a rhetorically focused general education writing class is taken prior to engineering labs in the major (Washington State University – Vancouver, Oregon Institute of Technology)
3. Concurrent transfer - a rhetorically focused technical writing class is taken concurrently or prior to engineering labs in the major (Washington State University – Vancouver, Oregon Institute of Technology)

In this study, we identified the transfer target as entry-level engineering lab courses. Here, the transfer target can be varied by engineering discipline: civil, mechanical, and electrical engineering, for the study. However, each engineering laboratory course used as a transfer target is considered to be one of the first in the curriculum that employs experimentation and some form of laboratory report writing as a deliverable. While report formats may vary by instructor, discipline, or institution, this study takes the view that the so-called IMRDC (Introduction-Methods-Results-Discussion-Conclusion) format should be taught to students in early engineering courses [2,3]. The IMRDC structure is considered as the preferred engineering lab report organization due to its ubiquity in science writing literature and its consistency with general education writing courses that focus on the introduction/body/conclusion in document preparation [11]. The research instrument (a lab report assessment rubric) is based on the IMRDC lab report structure and will be further described in the Research Instrument section.

The authors aim to investigate how the engineering undergraduates' prior writing experience in college affects their lab report writing in sophomore engineering lab courses. According to the lens of transfer learning theories, we can group engineering students in three writing transfer modes: 1) concurrent transfer; 2) vertical transfer; and 3) absent transfer. Lab reports from four sophomore engineering courses (1 civil, 2 electrical, 1 general engineering) across three institutions were collected for analysis. To assess the effectiveness of engineering course instruction on students' lab report writing, we collected the sample sets in early labs (for example, Lab 1) and in later labs (for example, the last lab) of the courses. The lab report assessment rubric was based on lab report writing student outcomes, which are aligned with the existing outcomes such as ABET outcomes [12], which must be satisfied by accredited engineering programs, and the student outcomes from the Council of Writing Program Administrators (WPA), which are used commonly as a guide for first-year-composition courses [11]. Four engineering faculty (1 civil, 1 electrical, and 2 mechanical engineering) conducted sample lab report analyses after having extensive norming to compare three writing transfer modes.

The study results are expected to enhance understanding of engineering undergraduates' writing practices; therefore, both engineering educators and writing educators can improve their writing pedagogies to improve engineering students' writing transfer from various general education courses to multiple writing courses in the major. Ultimately, these results could be leveraged to support a study of learning strategies that enhance the quality of engineering students' writing in college.

2. Scope of Data

The participating instructors were recruited to ensure a diversity of submission formats and engineering disciplines. Instructors signed a consent form that had been approved by each institution's Institutional Research Board (IRB). Instructors were compensated for their efforts collecting student samples. Students were recruited by visiting classrooms and providing an explanation of the project. IRB-approved consent forms providing a description of the project, as well as benefits and risks of participation, were distributed and collected for all students who volunteered to participate.

The students from each institution were surveyed to document demographics and perspectives on prior writing experiences and lab writing instruction. The results are reported in a separate paper [13]. The populations had no statistically significant differences other than the distribution of majors, which is consistent with the program offerings at the participating institutions.

The four participating lab courses included sophomore-level Civil Engineering Materials and sophomore-level Circuits courses at a rural public polytechnic university (Oregon Institute of Technology), a sophomore-level Circuits course at a public research university (Washington State University Vancouver), and a sophomore-level Engineering Materials course at a private comprehensive university (University of Portland). The student samples consisted of 22 early lab submissions and 24 later lab submissions. Of these 46 submissions, 14 were concurrent transfer students, 26 were vertical transfer, and six were absent transfer. Table 1 further identifies the number of submissions according to institution, course, submission format, and writing transfer model. Although four lab courses use four different submission formats, all the submissions have at least one element of the IMRDC structure. Further information about the course instructors, policies, and submission types and requirements is provided in the appendix.

Table 1. Number of writing samples according to institution, course, submission format, and writing transfer model.

Institution	Course	Submission Format	Transfer Model	Number of Samples
OIT	Circuits I	Fill-in-the-blank	Vertical	8
			Concurrent	4
	Civil Engineering Materials	Technical Memorandum	Vertical	6
			Concurrent	6
WSU-V	Circuits	Technical report	Vertical	12
			Concurrent	4
UP	Engineering Materials	Letter to the instructor	Absent	6

3. Research Instrument and Hypotheses

This section outlines the development of the research instrument (report scoring rubric), the rater norming process and report scoring approach, and the hypotheses explored in this study.

Research Instrument Development

Lab report samples from earlier and later labs in sophomore lab courses across three institutions were collected and assessed according to a rubric developed by the authors (Table 2). The rubric outcome language is drawn from the WPA outcomes and ABET outcomes #3 and #6. WPA outcomes are grouped according to (1) rhetorical knowledge, (2) critical thinking, reading and composing, and (3) processes and emphasize that writing skills should be applied in the context of a discipline using the audience expectations and genre conventions of the discipline [11]. ABET outcome #3 states that students should demonstrate “an ability to communicate effectively with a range of audiences” and ABET outcome #6 expects “an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions” [12]. To facilitate assessment, the rubric outcomes are organized according to the IMRDC format, representing the lab report genre convention. Outcomes that are more specific to a particular report section are placed at the beginning and more holistic outcomes are placed at the end to facilitate the ease of use of the rubric as a lab report is being scored.

Student writing samples were scored according to each outcome on a 5-point ordinal scale from 1 to 3:

- 1.0 = does not meet expectations
- 1.5 = somewhat does not meet expectations
- 2.0 = meets expectations
- 2.5 = somewhat exceeds expectations
- 3.0 = exceeds expectations

Table 2. 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

Norming and Scoring

A total of four engineering faculty rated the student writing samples, and each sample was scored by two evaluators; an average of their scores was taken. Prior to the formal scoring, a norming process was used in which three of the same reports were evaluated by each rater and then calibrated. During the norming process, variations in some scores were considerable (greater than 1 point) for certain outcomes (e.g., outcome 1); however, these outcomes and expectations were discussed extensively among the raters to improve interrater reliability.

An approach was adopted that each rater would start with the assumption that an outcome met expectations and then move from that mark according to the significance of the met or unmet expectations. After this norming process, the interrater reliability improved considerably and was within 0.43 points on average. The average of rater scores was then assumed to be a representative assessment of the student lab performance. The potential for institutional bias was minimized by using evaluators from two different institutions, de-identifying the samples, and selecting samples at random for review.

Hypotheses and Methods

Two hypotheses were prepared, the first to explore how prior writing knowledge and transfer model influence lab report writing generally and the second to explore if prior writing knowledge and transfer model influence the writing knowledge a student can gain during an early laboratory course.

Hypothesis 1: ***Engineering students' lab report writing is related to their prior writing knowledge***. To explore this, student writing performance was measured according to the rubric in Table 2, and the results were compared based on the transfer model (absent, vertical, concurrent). The scores on early lab reports were evaluated relative to "meets expectations" for each outcome and transfer model. Scores for both early and later lab reports were evaluated as well. Three categories of performance were used to evaluate the results among three transfer models:

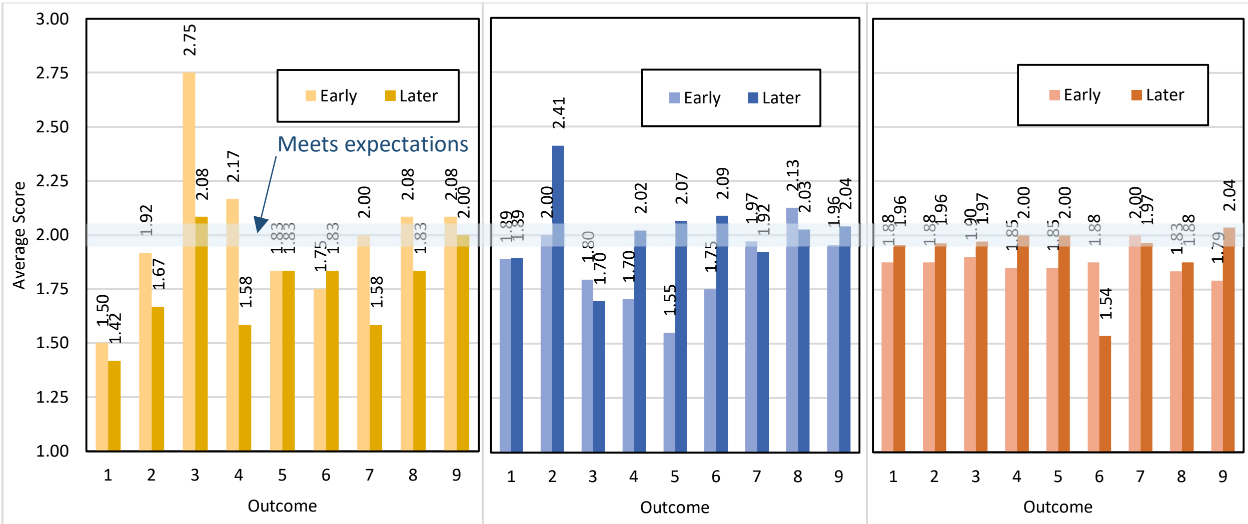
- Does not meet – a negative result less than 1.95 indicates expectations not met
- Meets expectations – a result between 1.95 and 2.05 indicates meets expectations
- Exceeds expectations – a positive result greater than 2.05 indicates that performance exceeds expectations

Hypothesis 2: ***Engineering students' writing knowledge gained from lab courses is related to their prior writing knowledge.*** To explore this, the change in student writing performance between early and later labs was measured according to the rubric in Table 2 for each transfer model and trends were identified in the writing before and after laboratory instruction. Three categories of change were identified, with the ±0.10 bounds selected at natural boundaries that appeared in the results (Figure 2):

- Regression – a negative result less than -0.10 indicates regression or a decrease in performance
- No Change – a result between -0.10 and +0.10 indicates no change in performance
- Improvement – a positive result greater than 0.10 indicates an improvement in performance

4. Results

Results related to Hypothesis 1, *engineering students' lab report writing is related to their prior writing knowledge*, are presented first. Student writing performance in each outcome was evaluated for early and later labs for each transfer model on the 1-to-3 scale described previously. Figure 1 depicts these scores for absent, vertical, and concurrent transfer, respectively. Table 3 presents these results in terms of meeting expectations, using the difference from the "meets expectations" score of 2.0.



(a) absent transfer (b) vertical transfer (c) concurrent transfer

Figure 1. Average performance scores for each outcome (2.0 = meets expectations) on early and later reports for (a) absent, (b) vertical, and (c) concurrent transfer students.

Table 3. Student writing performance expressed as does not meet (DNM), meets, and exceeds expectations (difference from "meets expectations" score of 2.0)

Transfer Model	**Lab Report**	**Outcome (Mostly Related to)**								
		1 (I)	**2 (M)**	**3 (RD)**	**4 (RD)**	**5 (RD)**	**6 (RD)**	**7 (IMRDC)**	**8 (IMRDC)**	**9 (IMRDC)**
Absent	Early	DNM (-0.50)	DNM (-0.08)	Exceeds (0.75)	Exceeds (0.17)	DNM (-0.17)	DNM (-0.25)	Meets (0.00)	Exceeds (0.08)	Exceeds (0.08)
	Later	DNM (-0.58)	DNM (-0.33)	Exceeds (0.08)	DNM (-0.42)	DNM (-0.17)	DNM (-0.17)	DNM (-0.42)	DNM (-0.17)	Meets (0.00)
Vertical	Early	DNM (-0.11)	Meets (0.00)	DNM (-0.20)	DNM (-0.30)	DNM (-0.45)	DNM (-0.25)	Meets (-0.03)	Exceeds (0.13)	Meets (-0.04)
	Later	DNM (-0.11)	Exceeds (0.41)	DNM (-0.30)	Meets (0.02)	Exceeds (0.07)	Exceeds (0.09)	DNM (-0.08)	Meets (0.03)	Meets (0.04)
Concurrent	Early	DNM (-0.13)	DNM (-0.13)	DNM (-0.10)	DNM (-0.15)	DNM (-0.15)	DNM (-0.13)	Meets (0.00)	DNM (-0.17)	DNM (-0.21)
	Later	Meets (-0.04)	Meets (-0.04)	Meets (-0.03)	Meets (0.00)	Meets (0.00)	DNM (-0.46)	Meets (-0.03)	DNM (-0.13)	Meets (0.04)

Results related to Hypothesis 2, *engineering students' writing knowledge gained from lab courses is related to their prior writing knowledge*, are presented next. The change in student writing performance in each outcome was evaluated between early and later labs for each transfer model (Table 4). The change in performance was described as regressed, no change, or improved with bounds on "no change" between -0.10 and +0.10, based on natural boundaries observable in the data (Figure 2).

Absent transfer students appear to have regressed in all outcomes except 5 and 6 where only small improvements were identified. Vertical transfer students registered meaningful improvements in outcomes 2, 4, 5, and 6 related to methods, results, and discussion. Concurrent transfer students registered small improvements or no change in nearly all outcomes and regression in outcome 6, related to effective conclusion writing.

Table 4. Change in performance from early to later lab submissions (change < -0.10 = regressed, -0.10 < change < +0.10 = no change, change > +0.10 = improved)

Transfer Model	**Outcome (Mostly Related to)**								
	1 (I)	**2 (M)**	**3 (RD)**	**4 (RD)**	**5 (RD)**	**6 (RD)**	**7 (IMRDC)**	**8 (IMRDC)**	**9 (IMRDC)**
Absent (n=3)	No change (-0.08)	Regressed (-0.25)	Regressed (-0.67)	Regressed (-0.58)	No change (0.00)	No change (0.08)	Regressed (-0.42)	Regressed (-0.25)	No change (-0.08)
Vertical (n=12)	No change (0.01)	Improved (0.41)	No change (-0.10)	Improved (0.32)	Improved (0.52)	Improved (0.34)	No change (-0.05)	No change (-0.10)	No change (0.08)
Concurrent (n=11)	No change (0.08)	No change (0.09)	No change (0.07)	Improved (0.15)	Improved (0.15)	Regressed (-0.34)	No change (-0.03)	No change (0.04)	Improved (0.24)

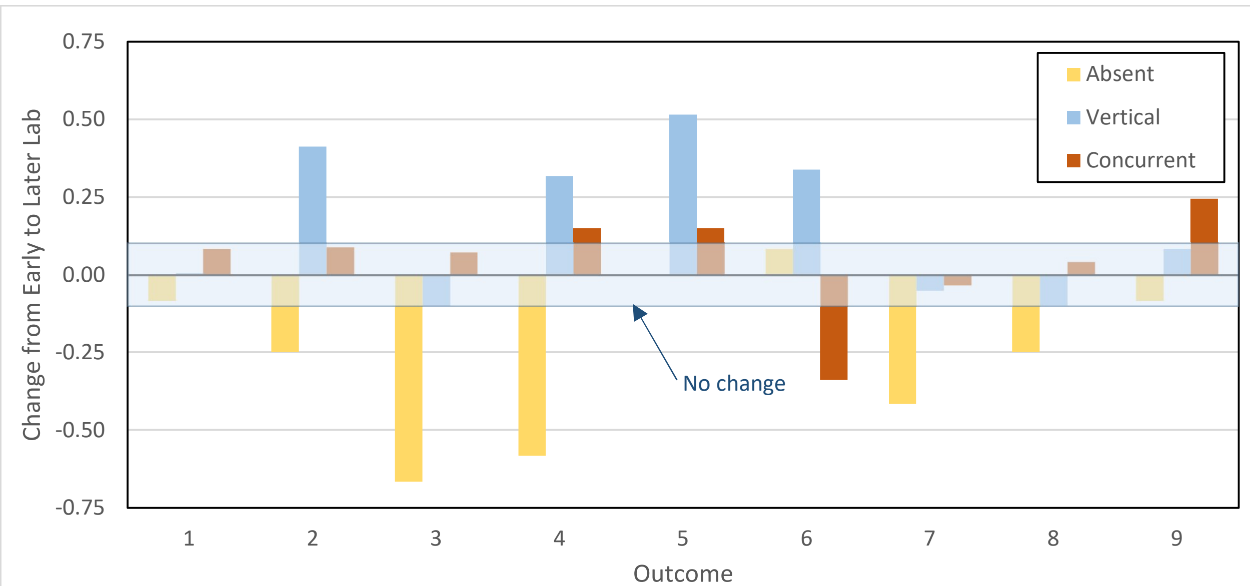


Figure 2. Change in performance from early to later lab submissions (-0.10 < change < +0.10 = no change).

Overall writing performance was evaluated by calculating grand averages of writing performance in each outcome. The grand averages of performance scores for all reports (both early and later) evaluated for each transfer group were 1.87 for absent transfer, 1.93 for vertical transfer, and 1.93 for concurrent transfer. The overall performance scores for early and later labs are presented in Figure 3. In terms of meeting expectations, performance was met on average for only early absent transfer reports and later vertical transfer reports and only then on the lower end of the 2.0 ± 0.05 range. The change in performance overall indicates regression (-0.22, n=3) for absent transfer students and small improvements for vertical (0.11, n=11) and concurrent (0.07, n=12) transfer students, while the reports for all groups on average do not meet expectations.

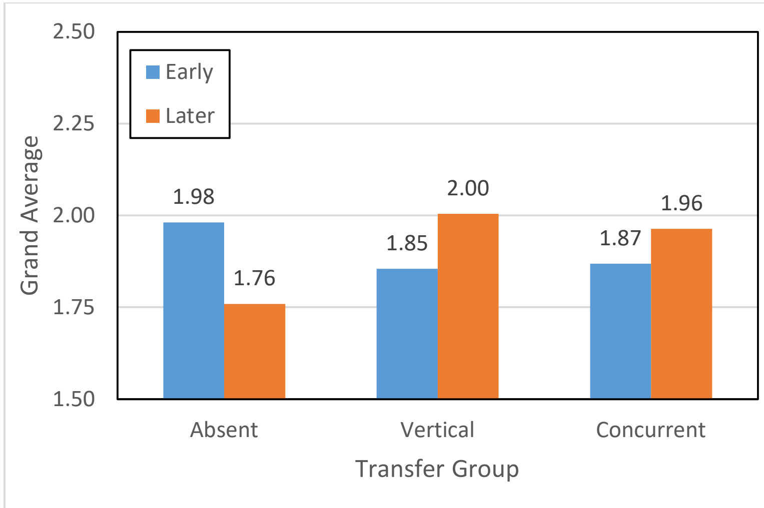


Figure 3. Grand average of student writing performance in early and later lab reports for each transfer model (2.0 = meets expectations).

5. Discussion

Based on the grand average of the performance scores (Figure 3), it is unclear if lab writing performance is related to prior writing knowledge. The absent transfer group appeared to regress on average, but their early report scores were higher than the vertical and concurrent transfer groups. These data are plagued by small sample size, particularly for the absent transfer group (n=3), so while it appears that this group may struggle more with lab report writing, these data cannot support this conclusively. Potential explanations abound when such small sample sizes are used. Instructor emphasis on the format and details for an early lab report can ensure this lab report is better than a later report when the emphasis may be more on the technical content and writing conventions may not be encouraged as explicitly. Individual student experience is important when interpreting results from small sample sizes and points to mixed methods and other tools to ensure that strong conclusions can be made. It is recognized that later assignments, while intended to reflect the students' best work may also be submitted at a busier time during the term and may not be the students' best effort. On the other hand, increased instructor expectations at the end of the term may also play a part. These considerations may have been exacerbated in the small absent transfer group.

Examining the results according to each rubric outcome provides greater clarity, particularly when reviewing Table 3, which summarizes performance by outcome on early and later reports and can inform hypothesis 1: *lab writing is related to prior writing knowledge*. Reviewing both Table 3 and Table 4 can inform hypothesis 2: *the writing knowledge gained during a lab course is related to prior writing knowledge*. In addition to these hypotheses, differences in the performance and learning of the transfer groups can tell us if a particular writing curriculum might better support engineering students with respect to technical writing. These results can also help to identify where particular emphasis in writing may be necessary for students with different writing preparation. Below, the results for each transfer group will be discussed, first in terms of overall performance, then in terms of improvements during an early engineering laboratory course.

Absent Transfer Group

Considering overall writing performance as summarized in Table 3, the small absent transfer data set had mixed results. In early lab reports, absent transfer students seem to struggle most to address audience expectations and providing purpose and context (outcome 1), to interpret lab data (outcome 5), and to provide an effective conclusion (outcome 6). The few students (n=3) in this group excelled in working with graphical and table-based presentation of results (outcome 3) and demonstrated control of genre conventions (outcome 8) and audience awareness (outcome 9). In later reports, this group continued to struggle with effective introduction (outcome 1), data interpretation (outcome 5) and conclusions (outcome 6). But they seemed to do more poorly presenting their methods (outcome 2), working with tables and plots (outcome 3), and analyzing data (outcome 4). Overall patterns of reasoning (outcome 7) appeared to suffer in later reports as well. Taken as a whole, these results indicate that absent transfer students may struggle in all areas, depending on the assignment and when it is submitted during the term. This would be consistent with a relative lack of direct writing preparation, especially in technical genres, but more writing experience in the context of general education courses.

Considering the change in writing performance over the course of a term in an early engineering laboratory course (Table 4), the limited data collected on absent transfer students for this study showed regression in numerous areas, including the presentation of methods (outcome 2), presentation of data in graphics and tables (outcome 3), data analysis (outcome 4), effective reasoning (outcome 7), and lab format genre conventions (outcome 8). The small improvement registered in drawing conclusions occurred with a poorer representation of methods, results and evidence. This may be related more to the expectations of the instructor as compared to the expectations of the rubric we used in the study. Ultimately, the student performance on later reports did not meet expectations for conclusions and the small improvement may not be significant.

Taken as a whole, these data indicate a relative difficulty to learn effective lab report writing in many outcome areas for students in the absent transfer group. It appears that these students would benefit from a broad introduction to the laboratory report genre and specific instruction in the various elements of a laboratory report.

Vertical Transfer Group

In early lab reports, vertical transfer students tended to struggle most with data presentation (outcome 3), analysis (outcome 4), interpretation (outcome 5), and conclusions (outcome 6). They had a better command of larger patterns of organization (outcome 7), genre conventions (outcome 8) and audience and tone (outcome 9). This is consistent with a group of students that is not initiated in the more technical conventions and reasoning of a laboratory report. In later reports, they continued to struggle to identify purpose and provide context (outcome 1) and work with tabular and graphical forms (outcome 3) but made marked improvements in presenting methods (outcome 2) and analyzing, interpreting, and drawing conclusions from lab results (outcomes 4-6). Their command of overall organization, conventions, and audience remained relatively unchanged while meeting performance for the most part (outcomes 7-9). These results indicate that direct writing instruction, especially involving rhetoric, may be durable and effective for students beginning to write more technically.

Considering the change in writing performance over the course of a term in an early engineering laboratory course (Table 4), the data collected on vertical transfer students for this study showed consistency in many areas with expectations nearly met at the end of the term (Table 3). These included specific elements like effective introduction (outcome 1) and graphic/table forms (outcome 2) as well as more comprehensive aspects of the lab report genre like reasoning, format, and audience (outcomes 7-9). The most significant improvements measured for any group were measured for this group in their ability to present methods (outcome 2) and analyze, interpret, and draw conclusions from lab results (outcomes 4-6).

These results point to particular aspects of the laboratory report that vertical transfer students may need to have emphasized: genre conventions (outcome 8) related to the introduction (outcome 1) and formatting and presentation of data in tables and figures (outcome 3). While they appear quite capable of making improvements in other areas of lab report writing, like presenting methods (outcome 2) and analyzing, interpreting, and drawing conclusions from lab results (outcomes 4-6), they may still need to have these features emphasized, especially in the holistic context of a laboratory report (outcomes 7-9).

Concurrent Transfer Group

In early lab reports, concurrent transfer students had fairly uniform performance, slightly below expectations, in all categories of the rubric. In later reports, they met expectations in all areas on average, except for effective conclusions (outcome 6) and overall genre conventions (outcome 8), which is related to the difficulty in writing conclusions. These results indicate that concurrent transfer students enter with a reasonably good command of the lab report genre, conventions, and reasoning and that they can make reasonable improvements in all areas. The struggle with conclusion writing is consistent with other experiences of the authors that students in technical settings tend to expect results to speak for themselves and do not readily engage in the exercise of summarizing and synthesizing results that a strong conclusion requires. These activities also appear at the top of Bloom’s taxonomy of cognitive ability and may simply be too challenging for these students in a setting when they are making sense of new technical knowledge.

Considering the change in writing performance over the course of a term in an early engineering laboratory course (Table 4), the data collected on concurrent transfer students for this study showed some improvements in data analysis (outcome 4), interpretation (outcome 5), and audience-related conventions (outcome 9) to the point of meeting expectations in those areas. These are areas ripe for improvement in a group that already has a reasonable command of the lab report genre. Regression appeared in conclusion writing (outcome 6) and performance in other areas was otherwise flat, with expectations met in all but genre conventions (outcome 8). As suggested for the absent transfer group, these students may be neglecting conclusions at the end of the term when their workload has increased. As with each group, a larger sample size and qualitative approaches to measuring student performance and learning will help to paint a clearer picture.

Concurrent transfer students, given their more significant preparation for technical writing, could benefit from a broader instruction in all facets of laboratory report writing and may be capable of greater learning as a result.

6. Conclusion

This study investigated the writing performance and improvements in 46 writing samples consisting of early and later laboratory reports by students with three types of writing preparation, defined by transfer model (absent, vertical, and concurrent) according to increasing levels of direct instruction in writing. A rubric was developed by the authors to combine elements of ABET and WPA outcomes and organize them according to the traditional laboratory report format often expressed as IMRDC (introduction, methods, results, discussion, conclusions). In general, absent transfer students appeared to demonstrate inconsistent results in many areas of the rubric and deserve greater study and more data than was available for this study. Vertical transfer students demonstrated that they are capable of learning to write effectively in the lab report genre after a first course requiring lab reports, particularly in the presentation of methods, data analysis and interpretation, and conclusions. These students may benefit from additional instruction in genre conventions related to an effective introduction and graphical and tabular presentation of data, both of which can improve the development of ideas using effective reasoning and productive patterns of organization. Concurrent transfer students can perform somewhat effectively with the lab report genre initially and meet expectations by the end of an early engineering laboratory course and appear to be capable of improving their data analysis and interpretation but may require additional encouragement to write effective conclusions.

The results from this work are interesting for a variety of reasons. First, as the authors suspected, the results identify measurable differences in the writing performance and writing improvements for students with different types of writing preparation. Second, the differences in performance and improvement according to each outcome in the lab writing rubric indicate that instruction might be varied according to prior writing knowledge to greater effect.

7. Future Plans

The most significant caveat related to this work so far is the small sample size, particularly for the absent transfer group. The authors are working to remedy this and look forward to future results from a larger dataset, allowing for stronger conclusions to be drawn. Mixed methods approaches are also anticipated in future publications. Instructional materials related to this study are also planned and will be carefully curated to be effective for the broadest cross section of students and instructors.

Acknowledgments
The authors greatly appreciate the support of NSF (IUSE #1915644).

References

[1] N. S. Thompson and E. M. Alford, "Developing a Writing Program in Engineering: Teaching Writing to Teach Engineering Literacies," in *48th Annual Meeting of the Conference on College Composition and Communication*, Phoenix, AZ, 1997.
[2] J. Parkinson, "The Student Laboratory Report Genre: A Genre Analysis," *English for Specific Purposes,* vol. 45, pp. 1-13, 2017.
[3] K. Walker, "Using Genre Theory to Teach Students Engineering Lab Report Writing: A Collaborative Approach," *IEEE Transaction on Professional Communication,* vol. 42, no. 1, pp. 12-19, 1999.
[4] D. Kim and W. M. Olson, "Improving Student Lab Report Writing Performances in Materials and Manufacturing Laboratory Courses by Implementing a Rhetorical Approach to Writing," in Proceedings of the 2015 American Society of Engineering Education Annual Conference and Exhibition, Seattle, WA, 2015.
[5] D. Kim and P. Sekhar, "A Preliminary Study on Supporting Writing Transfer in an Introductory Engineering Laboratory Course," in Proceedings of the 2016 American Society of Engineering Education Annual Conference and Exhibition, New Orleans, LA, 2016.
[6] D. Kim, W. Olson, "Using a Writing-transfer Focused Pedagogy to Improve Undergraduates' Lab Report Writing in Gateway Engineering Laboratory Courses," IEEE Journal of Technical Communications, 63 (1), 64-84, 2020.
[7] D. Kim, C. Riley, and K. Lulay, "Preliminary Investigation of Undergraduate Students' Zone of Proximal Development (ZPD) in Writing Lab Reports in Entry-level Engineering Laboratory Courses at Three Universities," Proceedings of the 2019 American Society for Engineering Education Annual Conference, 2019.
[8] D. N. Perskins and G. Salomon, "Transfer of Learning," *International Encyclopedia of Education,* vol. 2, pp. 6452-6457, 1992.
[9] R. Haskell, *Transfer of Learning*, Elsevier Inc. 2001, ISBN 978-0-12-330595-4
[10] K.B.Yancey, K. B. (Ed.) *Delivering College Composition into the Future*, The Fifth Canon. Portsmouth, NH: Boynton/Cook, 2006.
[11] C. Lowe, "WPA Outcomes Statement for First-Year Composition (3.0), Approved July 17, 2014," The Council of Writing Program Administrators, 2014 [Online]. Available: http://wpacouncil.org/positions/outcomes.html. [Accessed 2 February 2021].

[12] ABET, “Criteria for Accrediting Engineering Programs, 2019 – 2020,” ABET, [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/ [Accessed 2 February 2021].
[13] S. St.Clair, D. Kim, C. Riley, “Undergraduates’ Perspectives on Readiness, Writing Transfer, and Effectiveness of Writing Instructions in Engineering Lab Report Writing,” in Proceedings of the 2021 American Society of Engineering Education Annual Conference and Exhibition, Long Beach, CA, 2021.

Appendix

Participating institution instructor/course/grader/submission style information:

Oregon Institute of Technology EE221 Circuits

1) Lab course instructor: an instructor (20+ years experience in industry and teaching)
2) Lab report grader: the instructor
3) Lab course content: first course in circuit analysis
4) Lab report style: Educational (instruct how to operate), fill-in-the-blank lab handouts
5) Lab report assessment instrument: Completion/correctness determined by instructor
6) Delivery of assessment instrument to students: Discussed orally, in some cases embedded in laboratory handout

Oregon Institute of Technology CE212 Civil Engineering Materials

1) Lab course instructor: an associate professor (7 years experience in teaching)
2) Lab report grader: the instructor
3) Lab course content: Soil, concrete, and asphalt materials testing procedure, results and evaluation; design project.
4) Lab report style: Educational/Research
5) Lab report assessment instrument: Instructor assessment, with comparison to good/bad examples provided by instructor.
6) Delivery of assessment instrument to students: Good/bad lab report examples provided at the start of the term. Grading policy for labs outlined in syllabus.

Washington State University Vancouver ECE214 Circuits

1) Lab course instructor: an adjunct (8 years experience of teaching)
2) Lab report grader: an undergraduate TA (no prior grading experience)
3) Lab course content: design and application of digital logic circuits
4) Lab report style: Educational
5) Lab report assessment instrument: grading policy
6) Delivery of assessment instrument to students: Each lab's lab report cover page was given. The cover page has the grading policy.

University of Portland EGR 270 Materials

1) Lab course instructor: instructor (5 years of teaching experience)
2) Lab report grader: undergraduate TA
3) Lab course content: Standard methods of processing and evaluating engineering materials
4) Lab report style: Research
5) Lab report assessment instrument: grading policy (points per element and overall quality)
6) Delivery of assessment instrument to students: instructor provides grading rubric