Focusing on Writing to Learn Approach to Increase Engagement and Performance in Digital Design Lab

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Abstract

In an effort to help students in the discipline build on their writing skills throughout the undergraduate curriculum, Georgia Southern University initiated a quality enhancement plan (QEP) with a focus on writing across the Electrical Engineering curriculum. As part of this plan, the Digital Design Lab course, offered at the sophomore level in the curriculum, implemented several strategies to help students build on their previous writing skills, and in the process improved their technical vocabulary, the ability to communicate using it, increased students' engagement, collaboration, and performance in the course. In this work, the effect of deliberately engaging students in their writing skills as a process to learn the content material and communicate it effectively is presented. Several strategies were used like faculty instruction, using rubrics as a guide for assessment, peer reviewing and engaging a student writing fellow to assist students in this process. The effectiveness of these strategies was verified using multiple statistical assessment methods and the students' performance before and after the intervention was compared with emphasis on the writing-to-learn process. Qualitative data is also presented to assess the benefit of the intervention for students learning the course content.

Introduction

In general, students' performance increases with their engagement in the learning process[1]. As part of the engineering curriculum, the engineering students start building their analytical and problem-solving skills from the very first semester, and by the time they graduate, they improve this skill substantially by gradually building on it. On the contrary, the writing skills are usually taught during the first couple of semesters at the university-level which introduces students to the concepts of how to write (i.e., Learning-to-Write). After that, this information is used as a medium to communicate information without realizing its importance as a tool to help students reflect on their thoughts and learn the content in the course throughout the process of writing (i.e., Writing-to-Learn)[2].

It is well-established that students in engineering engage in ample activities that require technical writing from writing lab reports, research reports, and capstone design project reports. However, the difference here is to have a structure to provide multiple formative feedbacks from the instructor, the peers, and the student writing fellow (trained by the writing center) to help students reflect on their weaknesses in writing through multiple interactions and assessment over a period of a semester. Furthermore, this vigorous writing-to-learn process is repeated in two subsequent courses to ensure students proficiency in the process. In this format, the benefits of using *writing-to-learn* methodology have been expressed in many ways in the literature, such as improved student writing, increased student learning and engagement, student-faculty interaction, collaborative learning, and critical thinking to name a few[3].

A number of strategies used in the literature were combined in a single course to provide students with an enriched writing experience. Strategies such as the importance of formative

feedback and revisions[4], the importance of learning the use of rubrics as assessment tools to guide writing expectations[5], using student writing fellows who are trained to help students improve their writing skills by working in a one-on-one or group setting[6], and using writing as a tool to develop students' comfort with the content information and to connect the results to theory[7].

The QEP "Writing-to-Learn" Model at the University

The goal of the "Writing-to-Learn" quality enhancement plan (QEP) is to focus on enhancing students writing skills throughout the undergraduate curriculum by promoting and supporting a culture of writing and critical thinking throughout the University, linking students and faculty with resources to ensure writing excellence, and to graduate students with strong writing skills that transfer to the workplace and beyond. The QEP is implemented over a span of five-years, rolled out in phases throughout the university, with the objective to have at least 60% of all programs in each college participating in supporting the writing culture. This entails assessing writing assignments, reporting the assessment results in an annual assessment report, and finally collaborating with faculty across the University to share experiences and strategies to improve student engagement and provide more effective student feedback.

The QEP requires the participating programs, known as writing enrichment programs (WEPs), to offer three writing enriched courses starting from the sophomore year, two of which should be sequential (sophomore to junior year), and the third to be offered preferably during the senior year. The program requires at least the first two courses to be core courses, with the third one preferably also a core course. All sections of the courses are required to participate in this activity, throughout the year (including summer terms), to allow all students to experience the process of writing-to-learn methodology and to scaffold the learning experience of this process. Each WEP starts by implementing one course per academic year and adds another course each year until all three courses are offered as mentioned above. As an example of the implementation process mentioned in Table 1, if the college has 7 programs, 5 programs should be part of the QEP process to have 60% programs participating by the end of 5 years. To rollout the QEP process, in the first year, one program participates as a WEP converting one of its courses to writing enriched. In the following year, two more programs join, while the first WEP program adds a second course that is writing enriched. During the third year, two more programs will join with at least one course as writing enriched. Therefore, by the end of the fifth year, all 5 programs should be offering three writing enriched courses at the sophomore- to the senior-level.

Table 1 – Rollout of the QEP implementation plan over a 5 year period

First Year	Second Year	Third Year	Fourth Year	Fifth Year
Colleges identify: Year 1 programs -Add course 1	Colleges identify: Year 2 programs -Add course 1	Colleges identify: Year 3 programs - Add course 1	Year 3 programs -Cont. Course 1 -Add course 2	Year 3 programs: -Cont. course 1,2 -Add course 3
	Year 1 programs: -Cont. course 1 -Add course 2	Year 2 programs -Cont. course 1 -Add course 2	Year 2 programs: -Cont. course 1,2 -Add course 3	Year 2 programs: -Cont. course 1,2,3
		Year 1 programs: -Cont. course 1,2 -Add Course 3	Year 1 programs: -Cont. course 1,2,3	Year 1 programs: -Cont. course 1,2,3

Student Learning Outcomes

The QEP program has two student learning outcomes (SLOs), SLO 1 related to the student writing skills and SLO 2 related to the process of writing. SLO 1 measures the student's ability to demonstrate argumentation, analysis, and synthesis skills through writing in a variety of contexts by:

- communicating a clearly defined purpose;
- pursuing a substantial or compelling inquiry;
- identifying, evaluating, and selecting credible evidence or relevant examples;
- organizing ideas and information consistent with the purpose;
- demonstrating a nuanced understanding of audience(s) and word choice;
- adhering to acceptable mechanical, structural, and format style guidelines appropriate to the discipline and purpose; and
- using effective visual representations to enhance, focus, and amplify written communication and text.

SLO 2 measures the voluntary student engagement in the process of writing through the use of the following practices and articulating the impacts of engaging in this process:

- Researching
- Drafting
- Reflecting
- Collaborating
- Revising
- Editing

As each program joins as a WEP, the QEP office at the University offers two different workshops, the first to help guide the design of a rubric to measure SLO 1, while the second to help align the program SLOs with the QEP SLOs to streamline the annual assessment efforts. The rubric used for the assessment of the writing assignments is included in Appendix I. The SLO 2 data is collected by the QEP office using quantitative and qualitative surveys in each writing enriched course at the beginning of the semester, and just before the end of the semester to measure student engagement with the process of writing. The survey questions addressed in SLO 2 are illustrated in Figure 1.

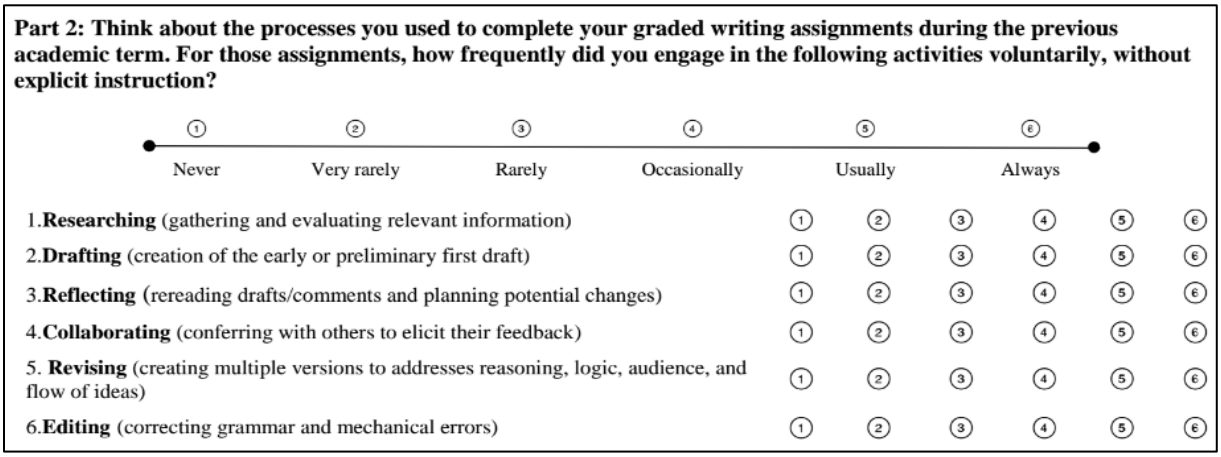


Figure 1 – Questions addressed in SLO 2 on a Likert scale of 1-6

Implementation and Evaluation

In terms of implementation of these SLOs in the course, the instructor, also known as writing enriched faculty (WEF), selects two writing assignments and converts them into writing enriched assignments by applying several strategies to help students understand the importance of writing and the presentation of information in these assignments. Each of the writing enriched assignment requires the student to submit a draft, get feedback, and submit a revised assignment. The nature of this process allows the assessment of student writing skills before and after the formative feedback which provides pre- and post-assessment data for these assignments. Furthermore, repeating this process twice in the semester, by submitting a draft and then a final paper, allows the students to scaffold the learning experience and allows the students to demonstrate improvement from the first writing enriched assignment to the second writing enriched assignment. Both writing enriched assignments, consisting of the draft and the final paper, are assessed by the WEF, the data of which is included in the program's annual report, and also submitted to QEP office for further discussion during the summer at auniversity-level retreat for all WEFs.

The Digital Design Lab course is a sophomore level, 2-credit hour course, which has one lecture hour, and three lab hours per week. The lecture component is mainly utilized to revisit concepts covered in the Intro. to Computer Engineering course, which is a prerequisite for the lab course. In addition, the lecture component is also used to introduce the students to what is required to be completed in the labs., This lab course also include a design project based on applying the digital design techniques addressing real world problems. Students work individually in all the labs and as a group for the final design project, and they are required to write individual lab reports at the completion of each lab.

To implement the QEP process in the course students are introduced to the writing expectations during the first week of the course. The expectations of the lab reports are explained to the students as a means of expressing the material learned and discussing the results obtained during the lab. Students are also introduced to the rubric used in the course and the expectations are addressed. In addition, the student writing fellow, an undergraduate/graduate student (trained by the writing center at the University) is introduced to the class as a peer mentor to guide them in improving their writing-to-learn skills over the semester.

So, how does the actual process work? After completing the first lab, students write a report and submit it the following week before they start the second lab. During this lab, the instructor uses half an hour of the lab time period to guide the students in peer-reviewing the first draft of the first lab report (lab 1 report), answering questions and giving examples as the students peer review and give valuable suggestions based on instructor guidance. This activity offers several opportunities for improvement for the students as they learn more about the expectations from the rubric while applying it, get feedback from their peers, and also learn to collaborate on helping each other improve. In addition, it allows them to come up with ideas of what they could improve in their own reports. Finally, they get a chance to engage with the instructor to learn about the detailed expectations of the items measured in the report using the rubric. After the peer review feedback, students revise their assignments and turn them in the following week. The instructor then grades the assignments and discusses the weaknesses observed in the lab reports with the student writing fellow, discussing with him where the students need guidance to

improve in terms of their description of lab details and results. The next week when the reports are handed back to the students, during the lab time, the student writing fellow reaches out to each student who had weaknesses in his/her lab report to explain the instructor's expectations based on the different rubric measures. During the interaction of the student writing fellow with the individual students, the role of the instructor is just to facilitate the student writing fellow interaction without contributing to it. Students then incorporate the feedback in the next week's reports (to avoid multiple grading of each report as students already got first feedback through peer review). Every week thereafter, the instructor collects and grades the reports, gives them to the student writing fellow, who goes through the reports which need improvement and talks to those students during lab time to make sure they understand the issues that need to be addressed to properly express their understanding of the process and the content. This exercise of the student writing fellow working with individual students greatly improves the quality of the reports and the discussion of the results, and each week the number of students whom the student writing fellow has to talk to also significantly decrease. This makes the process easier in terms of addressing student issues on an individual basis. For the second QEP assignment, lab 7 report is used to provide a writing enrichment experience. For this assignment, the faculty grades the draft version of the report and hands them out to students, and then the students incorporate the revisions and submit the final report.

In the Digital Design course for which the data is presented and analyzed, there were 39 students enrolled in the lab, and the lab sessions were divided in two days during the week, with about 20 students in the first lab session, and about 19 students in the second lab session. The students' original and revised lab reports 1 and 7 grades were recorded before and after revisions. The normal distribution fit of the lab reports' grades is illustrated in Figure 2.

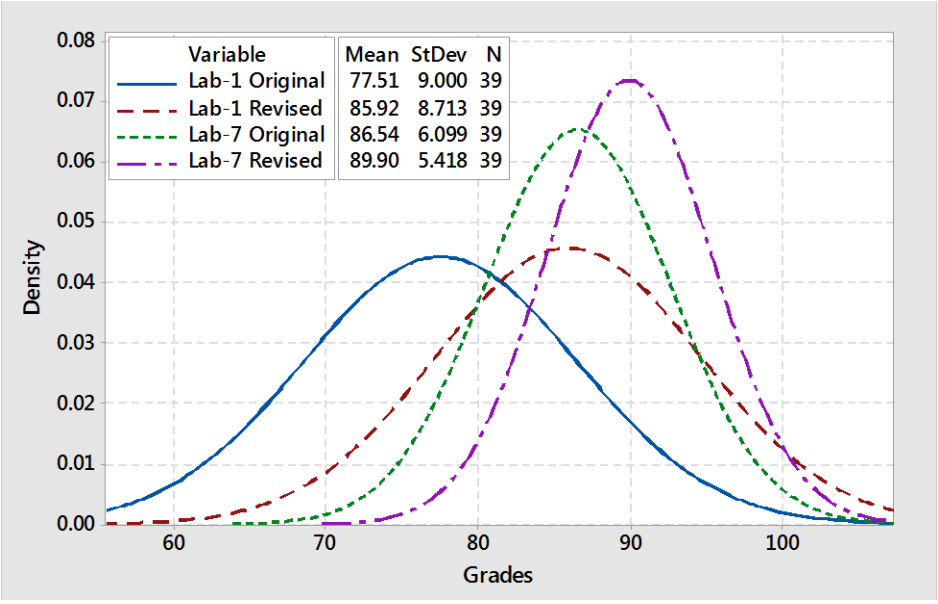


Figure 2- Normal distribution fitting of two QEP lab reports' grades before and after revisions

From Figure 2, it can be noted that the student performance on the first draft of lab 1 report had an average grade of 77.5%, whereas, after revisions, students had an average of 86% on the final report for the same lab. The improvement in the student performance is mainly due to the model implemented to provide feedback and allow for a revised lab report to be submitted. In addition,

it is also noted that the standard deviation didn't change significantly between these two versions of lab 1 report. As for the second QEP assignment, the lab 7 report was used to provide the students with feedback to improve upon their writing-to-learn experience. In the second assignment, it was noted that the students' first draft of the lab 7 report was slightly better in performance (in terms of the average result) than the final report of Lab 1, with an average of 86.5%. This indicates that the improvements in the students' writing obtained from the first revision were sustained. After the revisions, the average of the lab 7 reports increased to 90% indicating the continuous improvement throughout the process. Finally, the standard deviation of lab 7 grades was less than lab 1 indicating that the students had developed a better grasp of the writing requirement needed for the lab reports.

Statistical analyses using Minitab statistics software[8] were conducted to verify and validate these initial findings. The hypotheses of these analyses were to, 1) check the statistical differences in the students' writing skill before and after the revision of lab 1 report, 2) check the statistical differences in the students' writing skill in the first draft of lab 1 and lab 7 reports, and finally 3) check the statistical differences in the students' writing skill in the revised version of lab 1 and lab 7 reports. To test these hypotheses, a two-way analysis of variance (ANOVA) was used to analyze the data using a probability of error criterion with a significance level of 1% (p=0.01). The response variable for these analyses was the students' lab grades obtained for lab 1 and lab 7.

The main factors considered in these analyses are 1) the original and revised draft of lab 1 grades, 2) the original drafts of lab 1 and lab 7 grades, and 3) the revised drafts of lab 1 and lab 7 grades, respectively for the three analyses of interest. The two-level treatments are 1) the original versus revised draft of lab 1 (assessing the effect of the feedback provided on the students' writing), 2) the original draft of lab 1 versus lab 7 (assessing the sustained enrichment of the students' writing skills), and 3) the revised draft of lab 1 versus lab 7 (assessing the effectiveness of the second round of feedback provided compared to the first round). The difference among students was considered a random factor and was blocked within the analyses to eliminate the inherited variability in the response variable.

Figure 3 summarizes the statistical analysis conducted to test the treatment effect of the initial versus revised lab 1 reports (assessing the effect of the feedback provided to the students).

General Linear Model: Lab-1 Grades versus Treatment, Students

Factor Information

Factor	Type	Levels	Values
Treatment	Fixed	2	Original, Revised
Students	Random	39	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	1	1379	1379.28	51.81	0.000
Students	38	4951	130.28	4.89	0.000
Error	38	1012	26.62		
Total	77	7342			

Figure 3 – ANOVA analysis (assessing the effect of the feedback provided on the students' writing)

The analysis provided in Figure 3, generated a *p*-value less than **0.001** which is less than the **0.01** criterion for significance. Therefore, the null hypothesis stating that there is no significant difference between lab 1 initial and the final revised report drafts was rejected with a confidence level exceeding **99.999%.** This concludes that there is a statistically significant difference between the initial and the revised drafts of lab 1 report which validates the effectiveness of the initial part of the proposed process.

Figure 4 summarizes the statistical analysis conducted to test the treatment effect of the initial draft of lab 1 versus lab 7 (assessing the sustained enrichment of the students' writing skills).

General Linear Model: Lab Grades versus Treatment, Students

Factor Information

Factor	Type	Levels	Values
Treatment	Fixed	2	Lab 1 Draft, Lab 7 Draft
Students	Random	39	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	1	1589	1588.51	48.23	0.000
Students	38	3240	85.26	2.59	0.002
Error	38	1251	32.93		
Total	77	6080			

Figure 4 – ANOVA analysis (assessing the sustained enrichment of the students' writing skills)

The analysis provided in Figure 4, generated a *p*-value less than **0.001** which is less than the **0.01** criterion for significance. Therefore, the null hypothesis stating that there is no significant difference between lab 1 and 7 initial report drafts was rejected with a confidence level exceeding **99.999%.** This concludes that there is a statistically significant difference between the initial report drafts of lab 1 and 7 which validates the effectiveness of the second part of the proposed process.

Figure 5 summarizes the statistical analysis conducted to test the treatment effect of the revised report drafts of lab 1 versus lab 7 (assessing the effectiveness of the second round of feedback provided compared to the first round).

General Linear Model: Lab Grades versus Treatment, Students

Factor Information

Factor	Type	Levels	Values
Treatment	Fixed	2	Revised Lab 1, Revised Lab 7
Students	Random	39	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

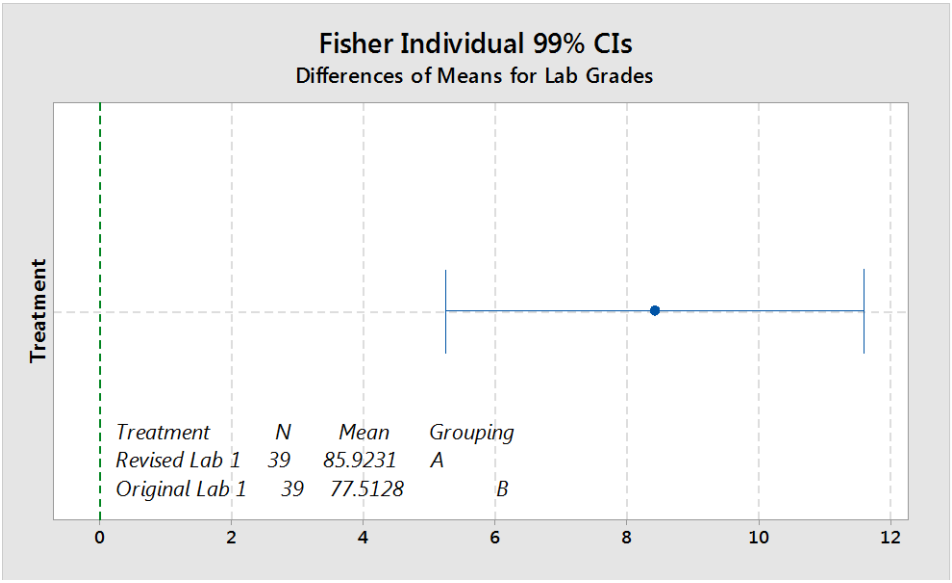
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	1	308.0	308.01	11.30	0.002
Students	38	2964.9	78.02	2.86	0.001
Error	38	1035.5	27.25		
Total	77	4308.4			

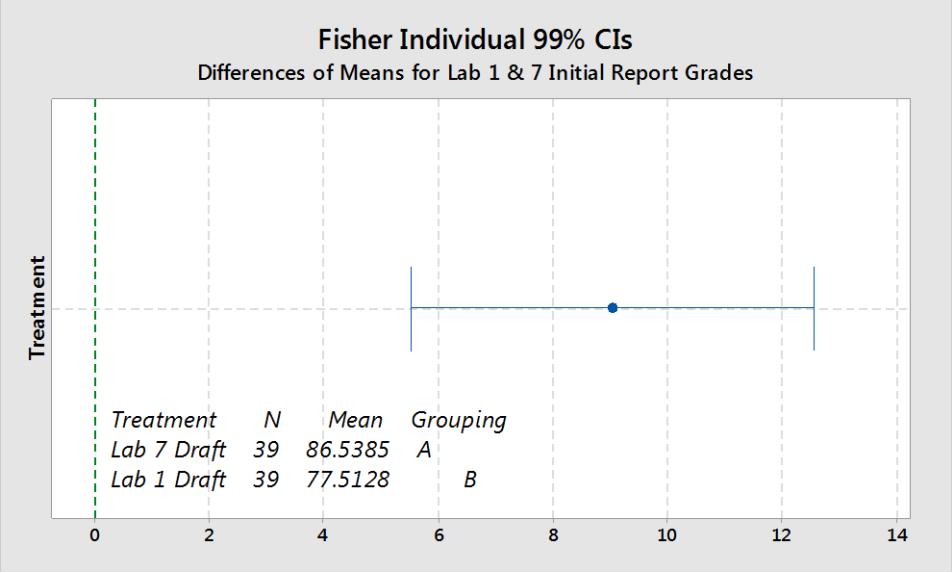
Figure 5 – ANOVA analysis (assessing the effectiveness of the 2nd vs the 1st round of feedback)

The analysis provided in Figure 5, generated a *p*-value equal to **0.002** which is less than the **0.01** criterion for significance. Therefore, the null hypothesis stating that there is no significant difference between lab 1 and 7 final revised reports was rejected with a confidence level of **99.998%.** This concludes that there is a statistically significant difference between the final reports of lab 1 and 7 which validates the continuous improvements throughout the proposed process.

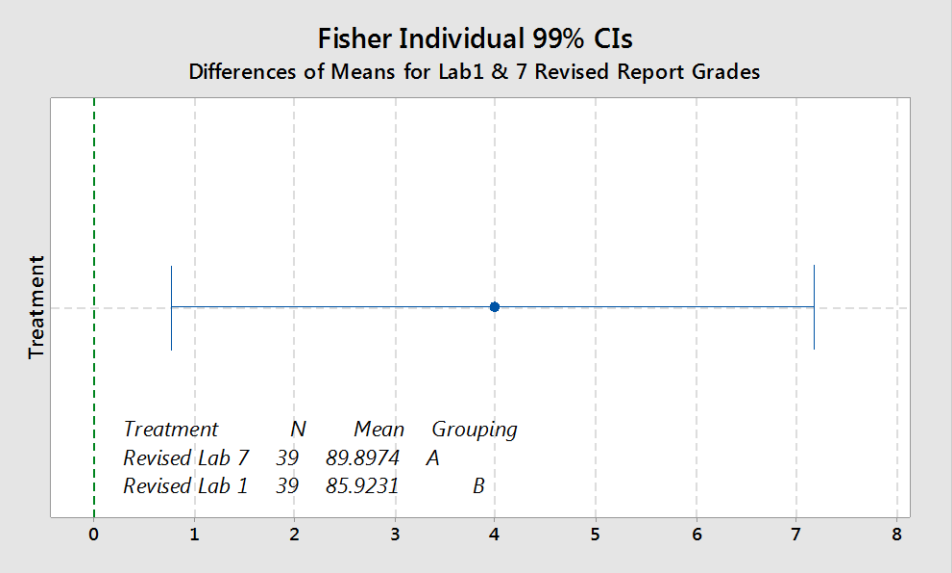
To further investigate these conclusions, Fisher's comparisons were conducted with a confidence level of **99%** as illustrated in Figure 6-a,b,c. The outcome of these comparisons further supports our initial conclusions that the improvement in students' writing performance due to the implementation of the proposed process is significant.



(a)



(b)



(c)

Figure 6 – Fisher pairwise comparisons of, (a) initial lab 1 vs revised lab 1; (b) initial lab 1 vs initial lab 7; (c) revised lab 1 vs revised lab 7

In addition to SLO 1, students also completed surveys at the beginning and just before the end of the semester to express their learning and practice of the different skills to improve upon their process of writing. The writing skills students gave input upon were: Researching, drafting, reflecting, collaborating, revising, and editing. Figure 7 illustrates the results in form of a bar graph illustrating the student responses before starting the QEP assignments in the course, and after completing both QEP assignments in the course.

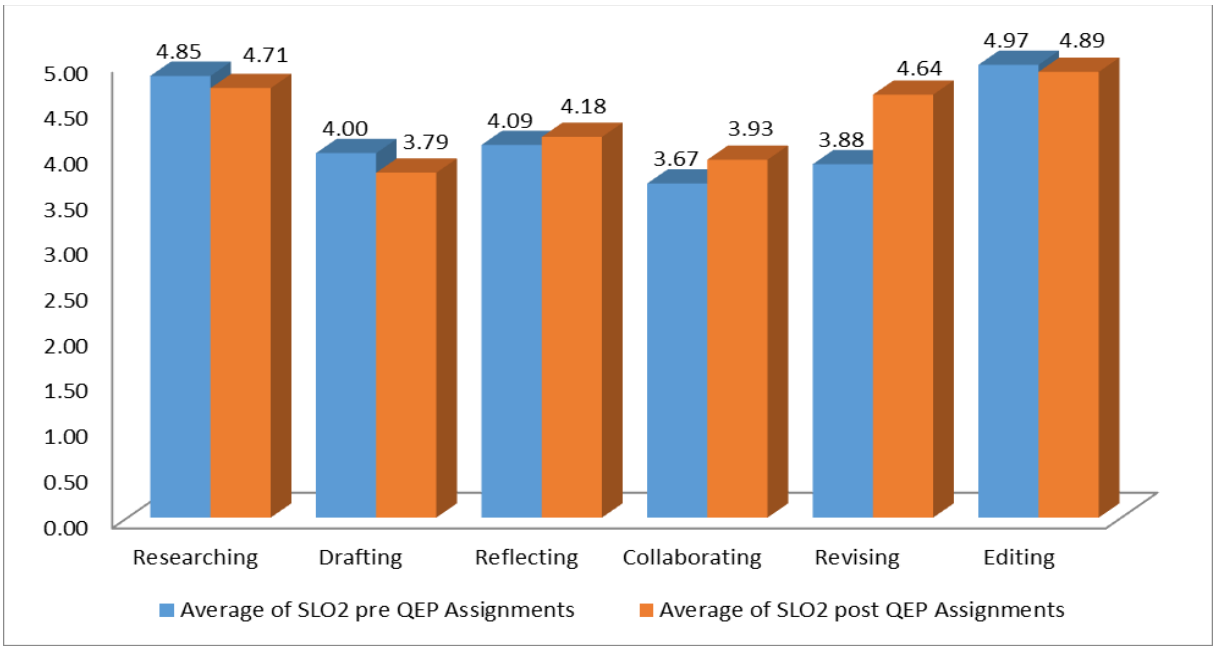


Figure 7 – Results of SLO 2 (process writing survey) on a Likert-scale of 1-6 (as seen in Figure 1). The blue bars indicate the average of student practices before the QEP writing enriched assignment, and orange bars indicate the average of student practices after the two QEP writing enriched assignments.

From the SLO 2 results expressed in Figure 7, the following can be observed about the different skills assessed.

- Students' researching skills (gathering and evaluating relevant information) in the course scored a little lower in the post-assessment (4.71 on a Likert scale of 6) compared to the pre-assessment (4.85). This may be due to the nature of the lab course, as most of the material was presented in the lab manual for the sophomore level class, so the students did not have to go out of their way to search for information but still had to evaluate the relevant information when explaining results in the lab report.

- Students' drafting skills (creation of the early or preliminary first draft) in the course also scored a little lower in the post-assessment (3.79) compared to the pre-assessment (4.00). An explanation of this could be that the students' understanding of the writing process had improved over the course of the period that the students were writing lab report drafts which resulted in high quality drafts. This can be noticed from SLO1 results of lab 7 draft, which indicates that lab 7 draft was of a higher quality compared to the revised draft of the final lab 1 report.

- Students' reflection skills (proofreading drafts/comments and planning potential changes) had increased over the duration of the course. This was reflected in the post-assessment (4.18) score increase compared to the pre-assessment (4.09). This is also in-line with the expectation as students were discussing the different issues they had to focus on via feedback provided by the instructor, the peer review process, and the student writing fellow.

- Students' collaboration skill (conferring with others to elicit their feedbacks) had also

increased over the duration of the course. This was reflected in the post-assessment (3.93) score increase compared to the pre-assessment (3.67). The improvement in the students' collaboration skill is mainly due to the peer review process that students engaged in after the first lab report which continued on a voluntary basis along with the availability of the student writing fellow for a few minutes during the lab time to address any student concerns. All labs were conducted individually by each student except for the final design project which was a group effort. The students did continue to seek feedback on reports from peers even though it was not required.

- Students' revising skills (creating multiple versions to address reasoning, logic, audience, and flow of ideas) did increase tremendously in the post-assessment (4.64) compared to the pre-assessment (3.88). This is a direct result of the formative feedback provided throughout the semester to the students via the instructor, peer reviews from students in the lab, and inputs from the student writing fellow. The improvement in revising also may be the reason that the quality of student writing increased and the need for drafts reduced with revisions increasing in the post-assessment.

- Students' editing skills (correcting grammar and mechanical errors) scored a little lower in the post-assessment (4.89) compared to the pre-assessment (4.97). Since the assessment was mainly measuring the students' correction of grammar and mechanical mistakes, it seems that with more revisions, the need for edits reduced for some of the students as the semester progressed.

In addition, the students were asked to reflect during the post-assessment survey for SLO 2 to express how their writing benefited from the processes mentioned in SLO 2. A few samples of the responses are as follows:

"*Notably benefited in a positive way in all aspects of writing"*

"I feel it benefited because it helps me to write more clearly. Get straight to the point but without leaving out important information."

"*My writing has benefitted a lot in this class*"

"I felt more confident about what I turned in."

"I know how to put more information in my paper"

Conclusions

In this paper, the writing-to-learn approach is used in a digital design lab course with several scaffolding activities to help students improve their writing skills and their understanding of the content of the lab. In addition, the approach helped the students' to improve their critical thinking skills in terms of expressing results while discussing them at a higher level instead of just presenting the results (thus improving students understanding of the digital design principles), and it also developed their ability to use the rubrics to assess and to collaborate and provide positive feedback. In general, students received multiple opportunities for formative

feedback, from their peers, student writing fellow, and their instructor. The extra class time that this activity took was about half an hour of the lab time during the second week of the lab to teach the students how to peer review. As the lab course had two sections, the instructor had to spend an extra hour in the semester outside of the lab time to assess the revised version of the lab 7 report per section. Lab 1 reports were peer reviewed, so it didn't require extra instructor time outside of the lab schedule. The student writing fellow dedicated nine hours per lab section to guide students on addressing the weaknesses in the lab reports, so a total of eighteen hours were invested in this activity for the lab course. The QEP office was responsible for paying the student writing fellow for the hours worked. As a result of these activities, students' collaboration increased which in return improved their writing abilities, and the students learned the process of giving positive feedback, which is exceptionally valuable in a group setting and in the field as a researcher or as an engineer.

The statistical analysis of the results of this study highlighted a significant improvement in student writing from initial lab 1 report to the final lab 7 report, illustrating the impact of scaffolding the writing-to-learn strategies throughout the semester. For future work, in the second QEP course that students are exposed to, the quality of discussion of results would be specifically focused to measure student analysis and synthesis skills on the content material. Currently, a general observation was made while looking at the overall report, but a targeted measure of the discussion section will give more vital information of students' higher order thinking skills using writing as a tool to assess student learning.

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Appendix I

Rubric for assessing writing enriched assignments used by the program and aligned with QEP SLO 1.

Write technical reports that conform to standard engineering terms and formatting					
Performance	**Exemplary**	**Proficient**	**Developing**	**Beginning**	**Introductory**
Indicators	**5**	**4**	**3**	**2**	**1**
Abstract communicating a clearly defined purpose	The abstract concisely covers the motivation, the problem statement and objective, the methodology, results, and conclusion. It is an insightful summary of the report.	The abstract covers the problem statement and objective, the methodology, results and conclusion, but may lack some adequate description in some areas.	The abstract, while present, does not include results and conclusions and/or includes inappropriate content.	An abstract is included but does not include objective, methodology, and major findings.	An abstract is not included.
organizing ideas and information consistent with the purpose	Introduction is complete and well written. Includes theoretical background, relevant equations, previews 100% of the topics and organization of paper; central hypothesis clearly defined; presentation organized into sections. Objectives clearly stated.	Introduction is present and appropriately conveys theoretical background, including equations, previews at least 80% of main topics of paper; central hypothesis defined but somewhat vague; presentation organized into sections. Objectives clearly stated.	Introduction contains some theoretical background but is missing some major points (background theory or relevant equations), outlines at least 70% of main topics; central hypothesis was very vague; organized in section. Objectives stated.	A technical introduction is present but does not include theoretical background, relevant equations, and/or includes incorrect information, outlines at least 60% of main topics, some sections; central hypothesis not clear. Objectives not clearly stated.	Introduction is missing or does not outline the paper; central hypothesis is missing; no organization; no objectives included.
Identifying, evaluating, and selecting **credible evidence** or relevant examples	Each section of report has supporting claim to advance central idea(s); substantial amount of evidence to support claim; Data clearly presented, references included.	Each section of report has supporting claim to advance central idea(s); expected amount of evidence to support claim; Data entirely presented, References included	Most sections of report have supporting claim to advance central idea(s); average amount of evidence. Most of data included. Not enough references	Some sections of report have supporting claim to advance central idea(s); very minimal evidence. Lack of required data recorded. No references.	Most sections of report do not have supporting claim to advance central idea(s). Issues with data collection. No references
Discussion pursuing a substantial or compelling inquiry	Insightful analysis of results, connecting it to theory, and reflecting on the physical significance of results. Completely supports the overall purpose.	Results summarized and adequate analysis/discussion. Some attempt at communicating physical significance. Discussion supports main purpose.	All results are summarized, but limited discussion. Discussion partially supports the main purpose.	Results summarized but are vaguely discussed and inconsistent with the purpose.	No discussion or reflection present and/or not related to the results and overall purpose of paper.
Demonstrating a nuanced understanding of **audience**(s) and word choice	Demonstrates an ability to write towards a specific audience and uses appropriate technical terminology.	Writes towards an appropriate audience and attempts to use correct technical terminology and word choices but minor lapses are present.	Write towards an appropriate audience but fails to consistently use technical terminology and word choices.	An attempt to write towards an appropriate audience was made. Terminology and word choice mostly not appropriate.	Inappropriate or inconsistent audience and/or word choice. Technical terminology absent.
Adhering to acceptable mechanical, **structural**, and **format style** guidelines appropriate to the discipline and purpose	IEEE style and format guidelines consistently and accurately followed (labeling figures/tables and proper citation of references). No spelling or grammar errors. Professional report presentation.	IEEE style and format guidelines used throughout paper (labeling figures/tables and proper citation of references), with few exceptions. Rare spelling or grammar errors present in paper but do not affect clarity. A neatly presented report.	IEEE style and format guidelines used in paper (including tables/figures and references), with multiple lapses. A limited variety of spelling or grammar errors exist, affecting readability. Average report.	IEEE style and format guidelines attempted but inaccurate, or multiple style guidelines mixed. Variety of grammar and spelling errors, affecting readability. Poor quality report.	Lack of adherence, or knowledge of, IEEE style and format guidelines. Multiple spelling or grammar errors in most sentences. Inappropriate for audience. No references.
Using effective **visual representations** to enhance, focus, and amplify written text	Tables and figures used effectively to explain concepts and/or results; greatly enhances the written text.	Tables and figures used adequately to explain concepts and/or results appropriately.	Tables and figures used to support text appropriately, but presentation is distracting and some information may be incorrect.	Tables and figures present but used inappropriately and/or visuals do not clearly convey information.	Tables and figures not present.
Provide comprehensive **conclusions**	Conclusion overwhelmingly reinforced central hypothesis	Conclusion reinforced central hypothesis as expected	Conclusion adequately reinforced central hypothesis	Conclusion did a poor job in reinforcing central hypothesis	Missing conclusion or it didn't reinforce central idea