Write from the Start in Engineering: Mixed-Methods Results of a Collaboration between a First-Year Biomedical Engineering Class and a University Writing Center

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Abstract

This Evidence-based Practice paper presents the mixed-methods results of an interdisciplinary program to improve engineering undergraduate writing in technical classes. We find that our students struggle with "writing transfer," or the ability to draw from prior writing experience to learn new genres. Our University Writing Center was established to help with such challenges; however, students have historically neglected its consultants' expertise. In addition, writing center research questions whether non-specialist writing consultants can help engineering students. We hypothesized that training the consultants to assist with specific engineering writing assignments could unlock this resource. Here, we summarize the program design and present key results from a Fall 2020 intervention in a first-semester Biomedical Engineering course. The program design featured modifications made in the intervention class and parallel training sessions for writing center consultants. The quantitative assessment investigated (1) students' confidence in their writing skills from self-efficacy surveys gathered pre- and post- the modified assignment and (2) draft and revised writing samples from the intervention class and a control. For the quantitative analysis, we used paired t-tests to compare the pre- and post-self-efficacy surveys, and MANCOVA to compare the draft and final writing sample scores. The qualitative assessment drew from students' views on the intervention and course from reflection essays, analyzed for themes. Results for the intervention showed significantly improved self-efficacy scores in assignment content, as well as in higher and lower order writing skills. Assessed writing samples showed significantly improved scores between the control and intervention, particularly in the categories of paragraph coherence and avoiding mechanical errors. Qualitative results supported the quantitative ones. We conclude that trained non-specialist writing center consultants can help improve undergraduate writing for first-year engineering students.

Introduction

Engineering educators have long known that their undergraduate students need to write well, often, and for a range of audiences [1]–[4]. At the Cockrell School of Engineering at The University of Texas at Austin, engineering undergraduates are taught writing through a dedicated, required communication course. Nonetheless, students falter when assigned to write technical documents in laboratory or capstone courses. From an educational perspective, our students suffer from failed or delayed student "writing transfer," the process in which students apply writing principles and skills learned in one class to practice in another. The term adapts the broader concept of "learning transfer" from Perkins and Salomon [5]–[6].

Such problems with writing transfer are well-known among education researchers and genre theorists who study technical communication [7]. STEM undergraduates often fail to transfer skills from a dedicated writing class to an advanced content-driven class in which writing serves as a means to an end [3], [8]–[10]. In engineering education, rhetorical approaches [11] and writing transfer theories have been applied to support students writing engineering laboratory reports [12]–[15]. Our project complements this research while extending work on using university writing centers to support engineering undergraduates [16]–[19].

Our own University Writing Center (UWC) has been an underutilized resource by engineering students [20], likely because they do not expect the UWC's Humanities-trained consultants to assist effectively with technical writing. Writing center research reflects controversy over the relative value of specialist vs. non-specialist writing consultants for engineering students [18], [21]–[23]. Leading engineering colleges such as MIT and Stanford run their own Writing Centers, staffed by engineering graduate students. Yet at our public university, building on existing resources is more economical than creating a new, specialized center. Our multi-disciplinary team hypothesized that training UWC consultants to assist with specific engineering writing assignments could be as effective as establishing a specialized center.

To test this hypothesis, we launched the program Engineering Sentences with two pilots in 2019-2020. We started small, focusing on two laboratory courses that required writing assignments. For each assignment, we designed training programs for UWC consultants along with parallel interventions for students. Promising results encouraged us to continue the intervention discussed here.

In this convergent mixed-methods study [25, p. 65], we summarize the methods, design, and key assessment results of a Fall, 2020 (F20) intervention in a required, first-year laboratory course in Biomedical Engineering (BME). The intervention consisted of enhanced writing instruction in the classroom, a BME writing training program for the UWC consultants, and a requirement that each BME student meet with a specially trained consultant to improve a draft assignment. The class of about 106 students provided a viable sample size.

Methods

To evaluate the changes in the BME students' writing skills during the intervention, we used a convergent mixed-methods approach that gathered (1) quantitative data from analyses of students' Qualtrics self-efficacy surveys and writing samples and (2) qualitative data from students' written reflections. We used this approach for "illustrating quantitative results with qualitative findings" [25, p. 68]. Quantitative data from the surveys were analyzed to measure the students' self-efficacy in targeted writing skills. In addition, quantitative data from the assessed student writing samples were analyzed to measure improvements from draft to final, and from control to intervention. The qualitative data from students' reflections supported the quantitative results.

BME Laboratory Course, Writing Assignment, and Intervention Background

Entering BME students enroll in the laboratory course during their first year; for fall semester students, it is one of their first university courses. Unlike the engineering undergraduates studied in [12]-[13], most students in this study had not completed a first-year writing course. Thus, most of our entering students (aside from transfers) lack on-site university-level writing experience.

Early in the semester, the course challenges BME students with a discipline-specific writing assignment: an Introduction to a BME research paper of 700-750 words. The relatively modest scope of this assignment matters because the students face varying degrees of writing transfer difficulties in adapting their skills from secondary-school classes to an engineering laboratory class. The assignment prompt and grading rubric emphasize the primary content components of a research introduction in the BME field (Table 1). In addition, students are required to cite published articles using one of three standard formats. The grading rubric specifies that students begin the introduction with an "appropriate attention-grabber"; otherwise, the rubric includes only a global impression of writing skills.

Table 1: Primary Content Components of a Typical BME Research Introduction

1. Describe the anatomy/physiology involved
2. Describe the impact of the problem
3. Describe current treatments (standard of care)
4. Describe current efforts to improve those treatments
5. Evaluate these improvement efforts
6. Recommend further improvements or new treatments.

The instructor already employed several proven strategies for teaching writing, such as using a detailed grading rubric, showing students a positive example from published literature, and requiring drafts and peer reviews. In addition, the assignment duration of four weeks, with two weeks between draft and final papers, presented relatively controlled conditions for introducing and assessing an intervention.

We selected the F20 class for the intervention primarily because of its large enrollment (106). We could also draw from our recent positive experience with the Spring 2020 pilot, expanding the pilot cohort of trained UWC consultants. As a control, we selected the Fall, 2019 (F19) class because the course instructor was the same, the assignment nearly identical in design, and the course enrollment, similar. One complication in our choice of both intervention class and control was the COVID-19 pandemic. The intervention class was, like most of our university's classes in

F20, taught online. By contrast, the control class from F19 took place during the last semester of entirely face-to-face classes before the pandemic. Thus, the F20 intervention and F19 control classes closely resembled each other except in course modality.

Research Questions

The study was grounded in the following research questions:
1. What was the influence of the program on students' self-efficacy? (Quantitative)
2. What was the influence of the program on the students' writing performance? (Quantitative)
3. What were the students' perceptions of the program? (Qualitative)

Program Participants

The Engineering Sentences program participants in the F20 BME intervention represented four departments in three colleges. Table 2 introduces the participants' respective roles and backgrounds. The BME engineering writing instructor was employed primarily to teach the dedicated BME Engineering Communication course, which students take as sophomores. Most UWC consultants had been hired from humanities, fine arts, and communication, joined by one from engineering. Building on the Sp20 pilot, the trained consultant cohort had been growing for nearly a year. Participants for the F19 control group included only the BME course instructor, course teaching assistants, and 101 students; two who did not complete assignments were dropped from the assessment group.

Table 2: Intervention Participants, F20 semester

Program Role	**Field**
PI, Engineering Writing Instructor/evaluator	Writing/Technical Communication/Writing Centers
BME Engineering Writing Instructor	Writing/Technical Communication/Writing Centers
BME Engineering Course Instructor	BME
Students (106 participants)	BME
Teaching Assistant #1	Educational Psychology/Statistics
Director and Assist. Dir., University Writing Center	Rhetoric & Writing/Liberal Arts
University Writing Center Consultants	Engineering (1), Liberal Arts, Fine Arts, and Communication (22)
Research Assistant	Liberal Arts

Intervention Program Design

The F20 intervention comprised four parts: (1) the creation of materials for teaching students and training consultants, (2) an in-class student workshop and two consultant training sessions, (3) students' one-on-one consultations with trained UWC consultants, and (4) assessments of self-efficacy surveys, writing samples, and reflections. The BME course instructor added a third draft to the course assignment and a fifty-minute Writing Workshop by the BME writing instructor to the normally scheduled classroom activities. The team worked with the UWC to ensure that they could train enough consultants to meet the demand. All F20 students met with a specifically trained consultant. Table 3 shows a simplified timeline of the intervention.

Table 3: Semester Timeline of F20 Intervention

Timeline	Descriptions
Pre-Semester	The BME writing instructor meets with (1) the BME course instructor and (2) the UWC Director and Assistant Director to review materials and coordinate the training schedule. UWC consultants receive basic training in engineering writing laboratory reports.
Week 1	*In class:* The BME course instructor introduces BME research, leading to the Research Introduction Assignment. *Class homework*: Students write their first draft introduction, due Week 2.
Week 2	*In class:* Students turn in their first draft and take the first Self-Efficacy Survey. The BME writing instructor delivers a workshop on writing research introductions. *Class homework*: Students apply what they learned in the workshop to their second draft. Students begin meeting UWC consultants. *At the UWC:* The BME writing instructor runs training sessions for consultants. Consultants begin working with students.
Week 3	*In class:* Students bring to class the second draft for peer review. (This second draft is not included in the Assessment.)
Week 4	Students submit their final (third) draft.
Week 5	Students complete the first set of short reflections on their UWC consultation
Post-Semester	The BME writing instructor administers the second self-efficacy assessment. Students complete a second set of reflections on the entire course. (The second reflection is not included in this conference paper.)

In designing training materials and running the workshops, the writing instructor targeted two sets of writing skills: one higher-order and one lower-order. The Higher-Order (HO) and Lower-Order (LO) writing skills, introduced by Reigstad and McAndrew [26] and incorporated into Purdue University's Online Writing Lab (OWL) [27], were adapted to incorporate goals for writing the BME Research Introduction, shown in Table 4.

Table 4: Target Writing Skills for Teaching and Training (modified from [27])

Higher-Order Writing Skills: Organize the introduction's contents in a reader-friendly way Group the main ideas into coherent paragraphs Show how different parts of the introduction are related (paragraph transitions) Avoid extraneous information Avoid or define specialized terms that readers may not understand in context
Lower-Order Writing Skills: Begin the introduction with an appropriate attention-grabber Craft cohesive sentences that help readers move from one idea to the next Craft efficient sentences that balance concision with appropriate levels of detail Incorporate in-text citations into the introduction

To teach these skills, the writing instructor drew from the BME Assignment, interviews with the Engineering course instructor, and literature on scientific communication [28]-[29] and general academic and professional writing [30]-[31].

The target writing skills in Table 4 were foundational for all four parts of the intervention design. The course instructor located an introduction from a peer-reviewed primary research paper in BME as an exemplary model. The writing instructor used this exemplar and the target skills list to create an electronic worksheet for the student workshops, where he guided the students through a reading and annotation of the introduction. For instance, they pointed out examples of skills such as beginning with an "appropriate attention-grabber" or defining terms. The writing instructor also developed an instructor copy of the worksheet for UWC consultants' training, which the consultants could then use as a reference in the student consultations. Finally, the assessment team developed the self-efficacy survey and writing evaluation rubric to match as closely as possible the Table 4 skills. Thus, the targeted skills supported the alignment of student teaching, consultant training, consultations, and assessment.

Data Collection and Analyses

We examined the effects of the BME intervention through students' quantitative and qualitative data in three measures: 1) our self-efficacy survey for writing ability, 2) anonymized writing samples evaluated separately from the class, and 3) two sets of students' reflections. Necessary assumptions for inference statistical testing such as normality were ensured, and all quantitative data were analyzed by using the R-studio program [32].

Self-efficacy Survey: The self-efficacy survey captured information about students' writing experiences prior to entering the class. The survey asked students to (1) describe their previous experiences with technical or scientific writing and (2) indicate their levels of self-efficacy in the assignment content (Table 1) and the nine writing skills listed in Table 4. The assignment content and writing skills were organized into seven constructs with a four-point Likert scale: Assignment Content, Lower Order Content, Lower Order Style, Higher-Order Content, Higher Order Style, Higher-Order Structure/Organization, and Avoiding Extraneous Information. To indicate levels of self-efficacy, students used a four-point scale, with one indicating the lowest level of self-efficacy (“This task is new to me”) and four indicating the highest (“I am confident I can complete this task without additional training, practice, or assistance”).

Students read an informed consent form and then took the survey. All responses were collected by a web-based Qualtrics system. Survey data were analyzed in a pre-test/post-test control group design to identify if the intervention program had a significant effect on self-efficacy scores. The pairwise t-test was used to compare the means of the pre-survey and post-survey responses.

Writing Assessments: Samples of student work for the target writing assignments were gathered and anonymized. We gathered 212 (drafts and revisions) from the intervention and 206 (drafts and revisions) from the control. The evaluator scored the samples by using a rubric that followed the list of nine skills in Table 4 as closely as feasible, and scores were on a five-point scale, ranging from “0” (missing or no credit) to “5” (excellent). This evaluation was independent from the class, although the evaluator validated the rubric and scoring method with the BME instructor. Two skills, “Uses appropriate level of formality” and “Free from mechanical errors” were added to the rubric because they are a common focus of UWC consultations. However, one skill, “Assignment Content,” was dropped because the consultations would have likely focused on writing rather than content. The writing assessment thus measured ten constructs in both drafts and revisions. To find meaningful results, we conducted a one-way multivariate covariance analysis (MANCOVA).

Student Reflections: We collected 102 reflection responses after the intervention consultations and 106 at the end of the semester to identify students’ perceptions towards the training program or their writing work. (All 106 students met with a trained consultant, but not all completed the first reflection.) We analyzed them by using both open-coding and concept-driven methods [34, Ch. 4]. First students’ reflections on the intervention consultations were read for codes corresponding to the constructs of the self-efficacy surveys and the writing assessments. We marked instances in which the students recalled skills such as “define specialized terms.” Meanwhile, new patterns of students’ responses emerged, particularly about consultation techniques such as “reading aloud.” In the next iteration, we read for such codes, which we organized into a theme of consultants’ techniques. Finally, we drew an overarching theme of the students’ overall positive/neutral/negative impressions of the consultation experience. For validation, we used member-checking and drew from years of experience working with student feedback on courses.

Results in Response to Research Questions

RQ1: What is the influence of the program on students' self-efficacy?

This study investigated changes in the self-efficacy in the writing of students who participated in the intervention. The descriptive statistics and the results of statistical tests for the students' self-efficacy are presented in Table 5 and Table 6, respectively.

Table 5: Descriptive statistics for the self-efficacy pre and post survey for BME F20

Self-efficacy constructs	Pre				Post			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Assignment Content	1	4	2.298	0.858	1	4	2.971	0.858
Lower Order_Content/Writing	1	4	2.652	0.881	1	4	3.175	0.689
Lower Order_Style	1	4	2.843	0.713	2	4	3.213	0.688
Higher Order_Content/Writing	1	4	2.657	0.785	1	4	3.250	0.899
Higher Order_Style	1	4	2.293	0.836	1	4	2.925	0.888
Higher Order_Structure&Organization	1	4	2.702	0.718	1	4	3.288	0.766
Higher Order_Avoid Extraneous Info	1	4	2.434	0.731	1	5	3.075	0.859

Table 6: Paired t-test results for the self-efficacy pre and post survey for BME F20

Self-efficacy constructs	Mean difference (Post– Pre)	*t* or Z statistic	df	Sig	Cohen's D
Assignment Content	0.674	t =7.088	38	<0.001**	0.974
Lower Order_Content/Writing	0.564	t =5.178	38	<0.001**	0.840
Lower Order_Style	0.359	t =3.018	38	0.0045*	0.546
Higher Order_Content/Writing	0.461	t =2.471	38	0.0181*	0.529
Higher Order_Style	0.641	t =4.938	38	<0.001**	0.730
Higher Order_Structure&Organization	0.526	t =4.418	38	<0.001**	0.800
Higher Order_Avoid Extraneous Info	0.641	t =5.665	38	<0.001**	0.758

Note: * represents significant difference at 0.05. ** represents significant difference at 0.001.

The seven constructs showed normal distribution, and thus the pairwise *t*-test was used. Table 6 shows that all seven components changed significantly. The effect sizes for each self-efficacy construct are calculated by Cohen's d [35]. The sizes ranged from 0.529 for the high order content writing skills to 0.974 for the assignment content, indicating medium to large effect sizes. Figure 1 displays the results in chart form.

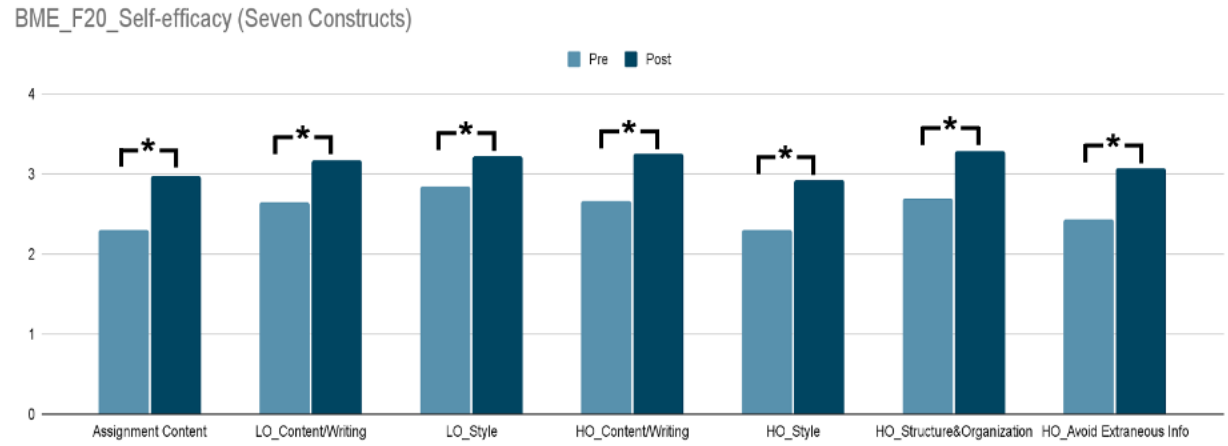

Figure 1: Mean comparison of seven constructs from the self-efficacy survey

RQ2: What was the influence of the program on the students' writing performance?

We initially analyzed the writing assessment results by means of descriptive statistics. The preliminary results showed expected significant differences between the draft and revision in both the control and the intervention (treatment) group. In the intervention group, the difference between the draft and revision scores was higher than it was in the control. However, the draft scores for the intervention group were lower to begin with than the draft scores for the control group.

As an alternative, we conducted a one-way multivariate covariance analysis (MANCOVA) to examine the statistical differences in multiple variables of writing assessment scores between the control and intervention groups, while controlling for students' writing draft (pre) scores. As indicated by Creswell (2005), the pre-test scores can serve as a covariate to eliminate the initial difference between groups, thereby making pre-tests equivalent across groups. In our study, we controlled for the influence of the pre-scores on the writing assessments, which allows us to reduce the effect of draft scores on the difference in post-writing scores between the two groups.

We first validated the three assumptions of the MANCOVA: a) homogeneity of the regression slopes, b) multivariate normality, and c) equality of the covariance matrices. The MANCOVA met the assumption of homogeneity of regression slopes because the interaction effects were not significant. The Shapiro-Wilk test of multivariate normality yielded a low p-value (<0.001), but the Central Limit Theorem ensured that the distribution was relatively normal for large samples ($N>30$). As for the assumption of homogeneity of covariance matrices, Box's M test was not statistically significant, indicating that the covariance matrices were not significantly different ($F=87.869$, $df=55$, $p=0.003$). Given the almost equal sample size in each group (101 vs. 106) and a large number of participants, we adopted a significance level of 0.001 [37].

The results of the main MANCOVA analysis shown in Table 7 indicate statistical significance in the writing assessments (e.g., Wilks' Lambda = 0.905, F = 2.029, p = 0.03). In other words, the results show a significant difference between the control and intervention groups in the writing assessment scores. Considering the significance of these overall tests, a post hoc analysis was employed to determine which specific dependent variables are significantly different between two groups when the overall test has detected a significant difference. Table 8 shows these univariate test results. Among the 10 separate writing constructs, writing performance in Paragraph Organization (F = 4.345, p = 0.038) and Mechanical Error (F = 3.932, p = 0.049) were significantly improved in the intervention group. Figure 2 shows the results in bar graph form.

Table 7. Results of Multivariate Tests

		Value	F	df1	df2	p
Group	Pillai's Trace	0.09514365	2.029352	10	193	0.0323
	Wilks' Lambda	0.9048564	2.029352	10	193	0.0323
	Hotelling's Trace	0.1051478	2.029352	10	193	0.0323
	Roy's Largest Root	0.1051478	2.029352	10	193	0.0323
Prescore	Pillai's Trace	0.68421720	41.817959	10	193	< .0001
	Wilks' Lambda	0.3157828	41.817959	10	193	< .0001
	Hotelling's Trace	2.1667336	41.817959	10	193	< .0001
	Roy's Largest Root	2.1667336	41.817959	10	193	< .0001

Table 8. Results of Univariate Tests

	Dependent Variable	Group	Mean (SD)		F	*p*
			Pre	Post		
HO	Content Org.	Treatment	2.590 (0.902)	3.542 (0.751)	0.149	0.700
		Control	2.655 (1.099)	3.495 (0.768)		
	Par. Org.	Treatment	2.689 (1.170)	3.632 (0.881)	4.345	0.038*
		Control	2.424 (1.431)	3.424 (0.919)		
	Par. Transitions	Treatment	2.788 (1.195)	3.571 (0.855)	1.734	0.189
		Control	2.505 (1.410)	3.449 (0.853)		
	Formality	Treatment	2.052 (0.853)	3.486 (0.815)	3.647	0.058
		Control	3.404 (0.751)	3.646 (0.659)		
	Terms defined	Treatment	3.142 (0.861)	3.712 (0.816)	0.666	0.415
		Control	3.505 (0.741)	3.778 (0.636)		
LO	First sentence	Treatment	2.608 (0.897)	3.377 (0.786)	0.491	0.484
		Control	2.924 (0.910)	3.313 (0.816)		
	Cohesiveness	Treatment	2.618 (0.794)	3.425 (0.736)	0.132	0.717
		Control	3.091 (0.708)	3.399 (0.681)		
	Efficiency	Treatment	2.542 (0.793)	3.425 (0.777)	1.979	0.161
		Control	3.056 (0.685)	3.323 (0654)		
	Mechanical Error	Treatment	2.660 (0.901)	3.425 (0.771)	3.932	0.049*
		Control	3.348 (0.774)	3.581 (0.654)		
	Citation	Treatment	3.292 (0.831)	4.467 (0.728)	0.239	0.626
		Control	4.157 (0.930)	4.419 (0.804)		

Note. SD=Standard Deviation

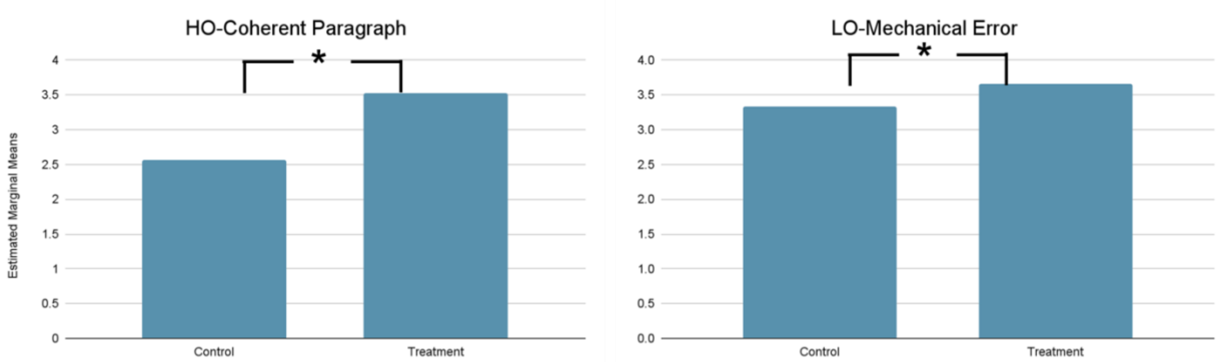

Figure 2. Significant Effects of Two Dependent Variables in MANCOVA Analysis.

RQ3) What were the students' perceptions of the program?

The F20 students wrote a reflection capturing their recalled experiences with the intervention. The prompt asked students to specify what they had learned. We received 102 reflection papers, which we analyzed for constructs corresponding to those from the self-efficacy and writing assessments. Table 9 shows that a high number of students mentioned that the consultations helped with Higher Order skills "Content Organization" (84) and "Paragraph Organization" (64). Most frequently mentioned Lower Order skills were "Efficiency" (50) and "Cohesiveness" (47), followed by "Mechanics," or grammar (38). We added one construct, "Conclusion" because a small but noticeable group of students (12) mentioned needing help with how to end their paper.

Table 9: Frequency of Themes in Student Reflections about the Intervention and Consultations

	Construct	Frequency
HO	Content Org.	84
	Para. Org.	64
	Para. Transitions	24
	Formality	15
	Terms defined	22
	Conclusion	12
LO	First sentence	19
	Cohesiveness	47
	Efficiency	50
	Mechanics	38
	Citation	26

Note: Org. = Organization, Para. = Paragraph, HO = High-Order skills, LO = Low-Order skills, The total number of students is 106, of whom 102 completed the Reflections.

Several students mentioned their initial anxiety about asking for help:

Going into the appointment, I was expecting to have my paper (and self-esteem) ripped to shreds by the writing consultant... That was not the case; she actually seemed relieved that we did not have to spend much time editing for mechanical issues.

Others appreciated the opportunity to talk about the writing process and the idea that they would have to learn multiple writing genres and adjust for different audiences. Similar observations of how engineering undergraduates value audience awareness were noted by [13] in their study of a junior-level laboratory course. Table 10 shows that the students' evaluation of the intervention and consultations was overwhelmingly positive (100/102).

Table 10: Frequency of Overall Evaluation from the Student Reflections about the Intervention and UWC Consultations.

Construct	Frequency
Positive	100
Mixed	2
Negative	0

Discussion and Conclusion

The Engineering Sentences BME intervention elicited positive comments overall from the students. In self-efficacy surveys, students reported significantly improved confidence in all targeted areas of writing skills. Clearly, students believed that the intervention benefited them.

The initial writing assessment results raised a challenge and a question in our analysis. The discrepancy between the draft scores in the intervention and control groups may have been related to the impact of the pandemic on student learning [38]. The MANCOVA, however, showed that the intervention significantly improved student performance overall, specifically in paragraph organization and mechanics. These results agree with qualitative results from the students' reflections, which mentioned both constructs as areas of improvement.

These results show that trained non-specialist UWC consultants can improve undergraduate engineering writing, at least for first-year students. They also support Kim and Olsen on the value of a rhetorical (versus a mode-based) assignment design [11] and multi-disciplinary collaborations [12]. Such collaborations open the process of learning transfer so that it benefits not only students, but also the consultants and instructors dedicated to their learning. In the future, we would like to measure how similar interventions affected the students' writing quality across the span of their undergraduate years.

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