Evaluating Interventions Intended to Increase Self-Efficacy of Graduate Engineering Students as Professional Writers

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Abstract

Graduate students in engineering are expected to perform a significant amount of writing as part of their degree program. This includes major writing projects such as journal and conference papers, theses, and dissertations. However, minimal systematic writing support is provided to these students, with the burden for mentoring writing typically resting on research advisors who similarly have limited formal training in technical writing. These challenges in writing education are compounded by a mindset that often puts writing as a last step in the research process, rather than being integrated throughout as a way of generating and synthesizing knowledge. Further, variations in writing expectations across disciplines introduce challenges to teaching technical writing in STEM at the graduate level. Our educational goal in this work is to improve graduate engineering students' self-efficacy and writing outcomes through systematic writing instruction. We implemented four interventions at a Carnegie R1 (research intensive) university over the span of a three-year NSF study. The four interventions are: 1. graduate writing workshops, 2. discipline-specific graduate-level technical writing courses, 3. facilitated peer writing groups, and 4. an Open Educational Resource (OER). These interventions represent a range of durations and levels of independence for the students. Although educators in different contexts have individually implemented and evaluated such interventions, their individual and combined effectiveness has not been studied in the context of graduate-level engineering education. To evaluate the effectiveness of these interventions for improving self-efficacy and self-regulation in writing, students participating in individual program components were invited to complete the Metacognitive Strategy Knowledge Test (MSKT) Survey and an adapted Writing Self-Regulatory Efficacy Scale (WSRES). After completing the surveys, students were invited to participate in a semi-structured interview to provide additional qualitative information about their experiences participating in the writing interventions. The surveys and interviews were analyzed to evaluate changes in students' writing self-efficacy. An analysis of responses from 24 participants indicated that engineering graduate students possess a generally high sense of writing self-efficacy. It was observed that students were proficient at identifying gaps in the literature and monitoring their writing for content alignment. Opportunities exist for targeted instruction on managing digital and physical distractions and for integrating writing processes as a discovery tool into the research workflow.

1. Introduction

Writing represents a significant requirement for graduate students in engineering, but these students are frequently unprepared or underprepared for this task. Writing tasks for graduate students in engineering vary in duration and breadth and include artifacts such as term papers or class reports (short-term), conference or journal papers (medium-term), and theses or dissertations (long-term). In each of these writing activities, students must synthesize knowledge from their classes, published literature, and their own research. Beyond understanding technical content, students must have knowledge of the writing process, genre, and rhetorical strategies to write effectively. However, these writing activities are frequently approached with little systematic support.[1], [2], [3] Most frequently, students learn technical writing skills by reading peer-reviewed literature and through one-on-one, ad-hoc meetings with their advisor [4], [5]

(who likely learned technical writing skills the same way). This results in inconsistent writing support which varies among advisors and even among students mentored by the same advisor. Numerous stakeholders have identified writing and communication as a continued critical need in graduate education, including national organizations on doctoral preparation [6], [7], numerous voices in STEM education [1], [8], [9], [10], [11], and researchers in the field of writing studies [12], [13], [14], [15].

The self-perception of a deficit in writing skills, coupled with a lack of experience in high-level, discipline-specific writing may contribute to writing anxiety and reduce self-efficacy [16], [17], which, coupled with the demands of subject matter knowledge generation, results in students delaying writing until the end of their research tasks. Self-efficacy is defined as the perception that one is able to carry out a specific task to a desired result. Self-efficacy is a central factor in writing ability and is vital for students achieving the outcomes that they need to be successful in future writing situations. Research in the learning sciences ties the development of self-efficacy to four factors [18]: (1) the ability to practice and draw on previous successful experiences, (2) the ability to compare others to oneself, (3) positive and negative feedback from the community, and (4) the ability to use healthy emotional and psychological strategies to approach new challenges. Herein, we seek to determine the relationships among self-efficacy, self-regulation of writing, and writing ability in the context of engineering graduate education that includes systematic writing instruction and intervention structures. Previous research has not investigated these relationships systematically, it has not accounted for the specific disciplinary context of engineering, and it has not focused on graduate students as a specific population with unique experience and needs vis-a-vis self-efficacy.

We implemented the *Writing SySTEM* (program name stylized as it appeared in the NSF study) in three engineering departments at a Carnegie R1 institution. The specific challenge related to technical writing for engineering students we sought to address was the lack of formalized writing instruction and the resulting non-uniform support from advisors. This was addressed through four implemented interventions, and we measured the impact of these interventions on the self-efficacy of engineering students in writing tasks. The program comprises four interventions: 1. technical writing workshops [19], 2. discipline-specific graduate-level technical writing courses [20], 3. peer writing groups [21], and 4. and an Open Educational Resource (OER). All interventions were led by faculty in their respective departments of different sizes: biosystems engineering (small), aerospace engineering (medium), and civil and environmental engineering (large). The effort was supported by faculty in a Writing Across the Curriculum (WAC) program. Students who participated in program interventions were invited to complete Metacognitive Strategy Knowledge Test (MSKT) Survey [22], [23], [24] and an adapted version of the Writing Self-Regulatory Efficacy Scale (WSRES) [25] surveys to evaluate the effectiveness of these interventions individually and in concert. After completing the surveys, students were invited to participate in semi-structured interviews, and their responses were analyzed to evaluate changes in self-efficacy and self-regulation of students as technical writers.

2. Context

The *Writing SySTEM* was implemented at a land-grant university with a Carnegie R1 classification. For the 2025-2026 academic year, the total enrollment at the university was

28,953 undergraduate students, 1,035 professional students, and 4,994 graduate students. In the college of engineering at the university, there were 5,614 undergraduate students and 1,185 graduate students across nine departments. The SySTEM was implemented in three departments: biosystems engineering (small, 49 graduate students), aerospace engineering (medium, 98 graduate students), and civil and environmental engineering (large, 150 graduate students). Demographic information for these departments is presented in **Table 1** for reference. However, no attempt was made to correlate the results with demographic data due to the limited number of responses. Finally, the university includes a centralized Writing Across the Curriculum program with a large writing center.

Table 1 Demographic data for graduate enrollments in pilot departments.

Biosystems Engineering *49 students*			**Aerospace Engineering** *98 students*			**Civil and Environmental Engineering** *150 students*		
Overall	Female	Male	Overall	Female	Male	Overall	Female	Male
	41%	59%		14%	86%		33%	67%
Asian								
0%	0%	0%	5%	1%	4%	3%	1%	1%
Black or African American								
2%	2%	0%	1%	0%	1%	3%	1%	3%
Hispanics of Any Race								
2%	2%	0%	2%	1%	1%	3%	2%	1%
Native Hawaiian or Other Pacific Islander								
0%	0%	0%	0%	0%	0%	1%	1%	0%
Nonresident Alien								
80%	31%	49%	37%	5%	32%	35%	9%	26%
Two or More Races								
2%	2%	0%	2%	0%	2%	1%	1%	1%
White								
14%	4%	10%	53%	7%	46%	54%	19%	35%

3. Methods

In this section, we describe the implemented interventions and our approach to evaluating the effect of these interventions on self-efficacy, self-regulation, and writing ability for engineering graduate students as technical writers. The interventions included: writing workshops, technical writing courses, facilitated peer-writing groups, and an OER. The evaluations included the MSKT, the adapted WSRES, and semi-structured interviews.

3.1 Interventions

Four interventions were implemented as part of this program: writing workshops, discipline-specific writing courses, peer writing groups, and an OER. Participation in all interventions was voluntary, except for the writing workshops which were integrated into departmental seminars for graduate students. Although these interventions have been studied individually elsewhere,

previous studies have not considered how the interventions relate to one another and their effectiveness in the context of graduate programs in engineering.

3.1.1 Writing Workshops

A common approach to teaching technical writing is the use of writing workshops. Workshops are typically delivered by non-engineers and use a broad approach to address the needs of all STEM fields. These one-off events provide training on specific aspects of writing. In the *Writing SySTEM*, we implemented technical writing workshops presented by affiliated engineering faculty in the participating departments. These workshops were offered during departmental seminar hours to increase participation. Workshops have been offered on the following topics: abstracts, introductions, and literature reviews. These topics were chosen because of their challenging nature and the existence of frameworks, although typically implicit, for structuring these elements. Further, the workshops were used to recruit students into other program interventions.

3.1.2 Discipline-Specific Writing Courses

Faculty in each participating department offered a 3-credit-hour, discipline-specific, graduate-level course on technical writing, which could be counted towards degree requirements. Faculty teaching the discipline-specific writing courses were self-selected based on their interest in the topic and past interactions with the Writing Across the Curriculum program. The writing courses are taught annually in all three academic programs for the period reported in this study. These courses promoted critical writing habits, created opportunities for students to receive direct instruction on the expectations and values for academic writing in the disciplines as well as professional communication for industry, and taught students to implement strategies for effective drafting and revising.[26], [27] Each course was divided into three phases: preparing to write, writing, and adapting work to alternate contexts. When preparing to write, students were taught strategies for identifying the research question, literature searching, and structuring introductions and literature reviews. During the writing phase, students progressively worked through a first draft of a major writing project, typically a conference or journal paper. This phase involved extensive peer review and feedback processes. Finally, the portion on adapting work to alternate contexts included information on posters, conferences, and outreach. During this phase, students participated in a mock-single-blind review process of their manuscripts, followed by a revision and resubmission process.

3.1.3 Peer Writing Groups

Writing groups are a social means of supporting students as they work on writing projects. They create an opportunity for a small group of students (typically 5-10) to get together at a scheduled, recurring time to focus on their writing activities. Scholarship on writing groups in graduate student education[21], [28], [29] links the practice to a social theory of learning which encourages graduate students to participate in and form communities of practice that can serve them throughout their professional careers. There are many ways to structure writing groups depending on the needs of the participants. Further, writing groups can last for any duration, with many typically lasting one semester or an academic year. For our implementation, semester-long writing groups were facilitated by engineering faculty associated with the *Writing SySTEM*.

Faculty facilitators led discussions and presented strategies for effective writing based on student requests. However, the groups would need to be fully student led to be sustainable.

3.1.4 Open Educational Resource

The Writing Across the Curriculum program at the university hosts an OER on their website (https://aub.ie/writing_resources). OER materials operate under an Attribution-NonCommercial-ShareAlike Creative Commons license, which means faculty developers, faculty, and students can download and adapt them for use in other contexts. We created new or modified existing OER materials to be specific to the participating engineering disciplines and gave these materials a common tag (*Writing SySTEM*) to make them more easily discoverable.

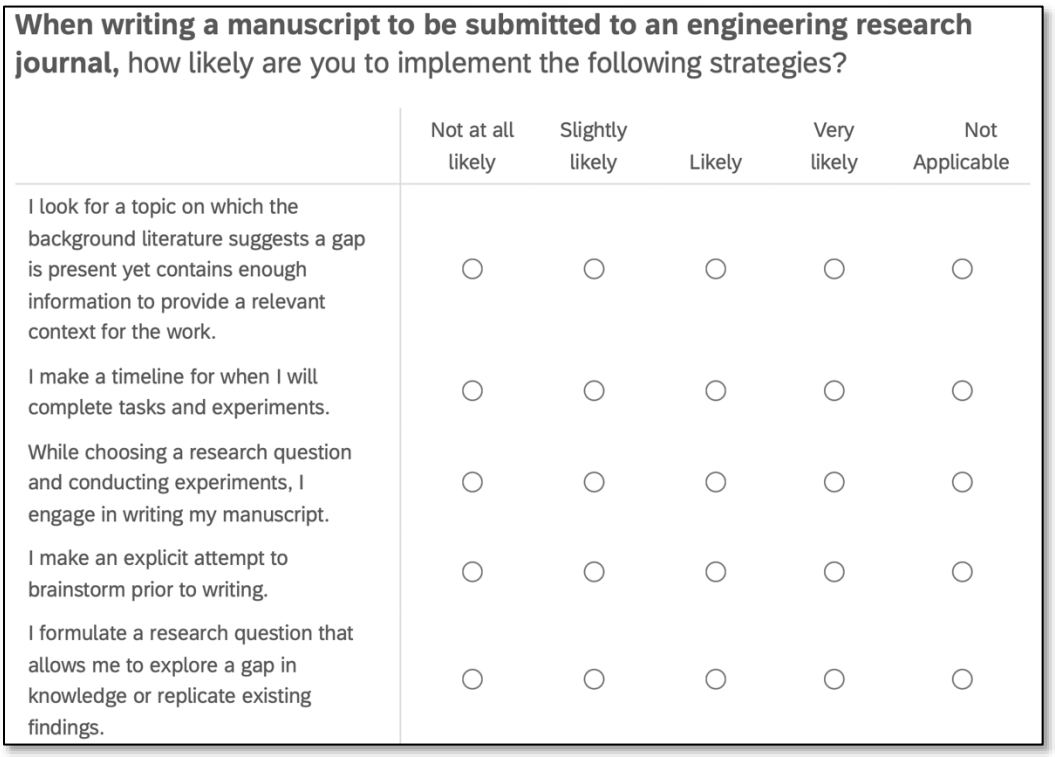
Over the period of the grant, we prepared nine unique OER materials (see **Table 2**). Through the OER website, we tracked each material's views, downloads, and geographic location of access for the most recent 365-day period. Each material was published in Word and PDF formats. The totals reported in **Table 2** reflect combined views and downloads across formats, as these formats represent identical content accessed according to user preference. Views indicate discovery or use of *Writing SySTEM* resources, and downloads may suggest users intend to reuse, adapt, or teach with these materials. Although the data represents a 365-day period, only two materials (Finding Relevant Papers; How to Read an Article) were available for that entire period. The remaining materials had been published for approximately seven months at the time of data collection.

Table 2 Writing SySTEM materials published to the OER

Title	Total Number of Views	Total Number of Downloads	Countries of Access
1. Finding Relevant Papers	158	23	USA, Germany, Libya
2. How to Read an Article	24	16	USA
3. Writing a Literature Review (from Scratch)	28	19	USA, Canada
4. Practicing Writing for Different Audiences	19	12	USA
5. Writing Research Objective Statements	32	12	USA
6. Analyzing a Journal for Submission	45	19	USA
7. Writing Introductions	51	20	USA
8. Ending with Strong Conclusions	22	11	USA
9. Organizing Weekly Writing Groups	22	11	USA

3.2 Surveys

To determine the relationships among self-efficacy, self-regulation, and writing ability, measures for each were administered to students who participated in program interventions. Self-regulation strategies in writing were measured using the previously validated MSKT.[22] This inventory was used to measure strategies mapped to the three stages (pre-writing strategies, mid-writing adjustments, and post-intervention adoption) predicted by the MSKT framework,[23], [24] which provides natural subscales. Example questions for the MSKT are shown in **Figure 1**. To measure self-efficacy and self-regulation, the WSRES [25] was adapted and administered to students who participated in the *Writing SySTEM* interventions. Example questions from the WSRES are shown in **Figure 2**. The adaptation process involved minor rewording to items to make them more realistic for a graduate engineering student. A small sample ($N \sim 10$) of engineering faculty were recruited to provide content validity (*i.e.*, confirm or refute that instruments measured what we intended them to) to validate any adaptations of instruments. Surveys were optional and were distributed in the second half of the semester, with invitations sent to anyone who participated in a program component. This meant data collection involved only a few dozen students at a time. Data was then aggregated at the end of the project to build an adequate sample.



When writing a manuscript to be submitted to an engineering research journal, how likely are you to implement the following strategies?

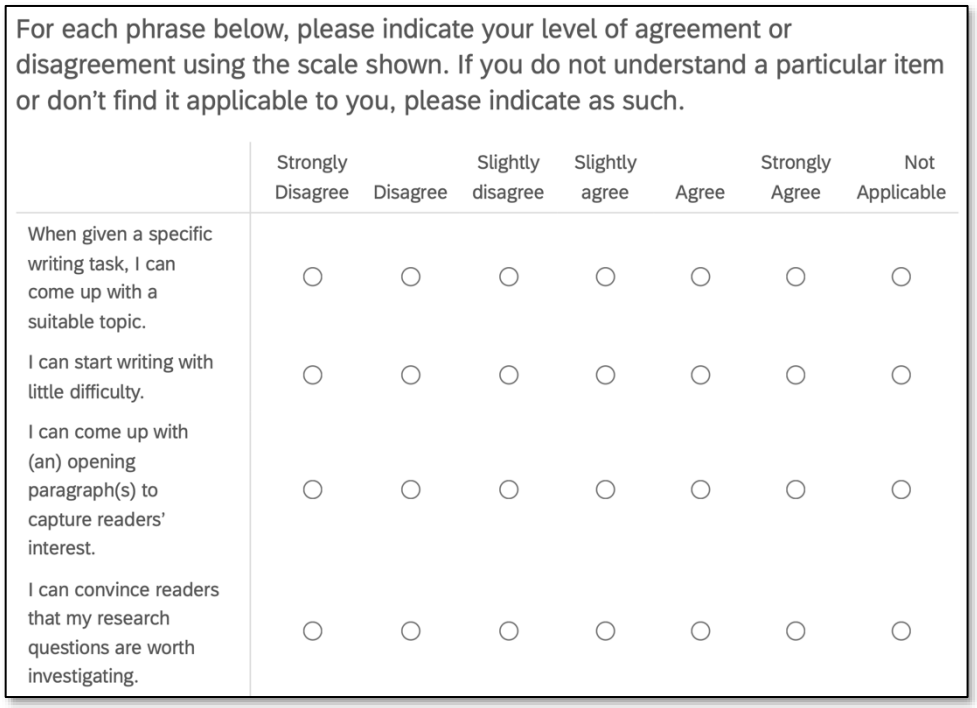
	Not at all likely	Slightly likely	Likely	Very likely	Not Applicable
I look for a topic on which the background literature suggests a gap is present yet contains enough information to provide a relevant context for the work.	○	○	○	○	○
I make a timeline for when I will complete tasks and experiments.	○	○	○	○	○
While choosing a research question and conducting experiments, I engage in writing my manuscript.	○	○	○	○	○
I make an explicit attempt to brainstorm prior to writing.	○	○	○	○	○
I formulate a research question that allows me to explore a gap in knowledge or replicate existing findings.	○	○	○	○	○

Figure 1 *Sample questions from the MSKT survey administered to program participants.*

3.3 Interviews

While quantitative survey results yielded important insights, further depth was warranted to uncover the unique context of engineering education in the relationship of self-efficacy, self-regulation strategies, and writing outcomes. For this reason, we also conducted semi-structured

interviews [30] with 24 participants (target was approximately 30) with the intention of providing supplementary evidence to these relationships for the purpose of triangulation. Like the surveys, interviews were also optional. The interview protocol was built by adapting questions from several other qualitative efforts [31] that examine writing self-efficacy (e.g., "How do you think of your abilities in academic writing?" [32]), impact of content and writing experts (e.g., "Describe your interaction with the mentor and other peers during the writing process" [31]), and self-regulation strategies (e.g., "What do you remember learning about writing or having reinforced about writing from being in the writing seminars?" [33]). All interviews were analyzed via deductive coding according to the four factors of self-efficacy, providing a framework from which to develop themes.



For each phrase below, please indicate your level of agreement or disagreement using the scale shown. If you do not understand a particular item or don't find it applicable to you, please indicate as such.

	Strongly Disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly Agree	Not Applicable
When given a specific writing task, I can come up with a suitable topic.	○	○	○	○	○	○	○
I can start writing with little difficulty.	○	○	○	○	○	○	○
I can come up with (an) opening paragraph(s) to capture readers' interest.	○	○	○	○	○	○	○
I can convince readers that my research questions are worth investigating.	○	○	○	○	○	○	○

Figure 2 *Sample questions from the WSRES survey administered to program participants.*

3.4 Writing SySTEM Participation

This work reports on program participation and survey responses for a period from February 2023 and December 2024. During this period, 85 students participated in *Writing SySTEM* workshops, 51 students completed the graduate technical writing courses, and approximately 20 students participated in the peer writing groups (participation fluctuated throughout the semester). Survey responses are reported from 24 engineering graduate students at the university, and represent biosystems engineering (11 students), civil and environmental engineering (9 students), and aerospace engineering (4 students). In their survey responses, 9 students indicated they attended a writing workshop, 20 students indicated they enrolled in the graduate writing course, and 1 student did not select any interventions in their response (note: all participants were recruited based on their *Writing SySTEM* participation, so this is believed to be a response error). Survey and interview data was anonymous, and for interview responses, each

participant was assigned a random number and deidentified in transcripts. Due to the limited number of responses, logistical challenges, and use of anonymous surveys, longitudinal tracking was not performed.

4. Results

The results have been divided into pre-writing strategies (Section 4.1), mid-writing adjustments (Section 4.2), post-intervention adoption (Section 4.3), and writing self-efficacy (Section 4.4).

4.1 Pre-Writing Strategies

Ten items in the MSKT correspond to pre-writing behaviors of graduate engineering students, *cf.* **Figure 3**. Overall, 87.3% of students responded that they were either "Very Likely" (65.7%) or "Likely" (21.6%) to implement specific pre-writing strategies, suggesting strong self-regulatory intentions in the pre-writing phase of writing. Four strategies emerge as high-adoption strategies (70%+ "Very Likely"): literature review, advisor feedback, knowledge gap identification, and peer-reviewed focus. Five strategies indicate moderate-adoption strategies (50 – 69% "Very Likely"): outline creation, research question formulation, brainstorming, timeline development, and related topics organization. Finally, one strategy indicated a lower adoption strategy: writing for discovery. During an interview, one student summarized this as, "First we do the experiment, we have the result, and then we are trying to say, 'Okay, where does it fit?'" This indicates a fundamental compartmentalization issue where students view research and writing as sequential rather than integrated processes.

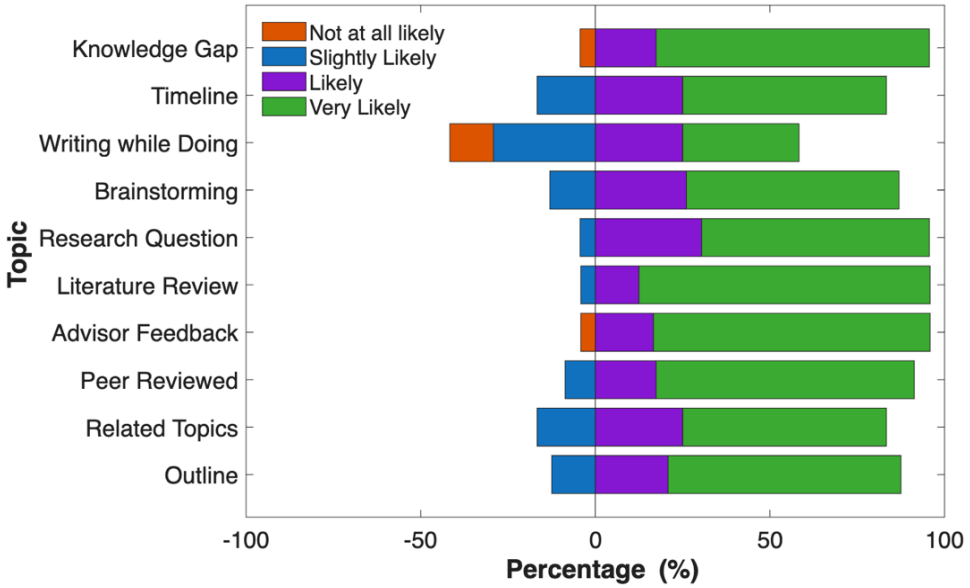


Figure 3 *Survey responses related to pre-writing strategies. The plot shows percentages of each response for a specific question on the MKST. The total of each bar is 100%. Negative percentages represent responses with negative connotation.*

4.2 Mid-Writing Adjustments

Eight items in the MSKT correspond to mid-writing adjustments or the performance phase of self-regulated learning, *cf.* **Figure 4**. These items focus on self-control and self-observation while drafting a manuscript. Overall, 80.6% of students selected they were either "Very Likely" (51.8%) or "Likely" (28.8%) to implement these process monitoring behaviors. Of note is the significant variation in adoption rates across different types of strategies in this category. Four strategies emerge as high adoption strategies: literature notes, hypothesis alignment, methods alignment, and question alignment. Three strategies indicate moderate adoption strategies: outlining points, writing as discovery, and read aloud. Finally, one strategy indicated a lower adoption strategy: distraction minimization. These results indicate that students have effectively internalized the importance of maintaining coherence between their research questions, data, and the supporting literature. However, the lower adoption strategy for distraction minimization indicates a major challenge for student students and managing their writing environment and maintaining focus. During an interview, one student commented, "…there's too much distraction if I try to write here in the grad office," which indicates shared spaces may create physical barriers to productive writing.

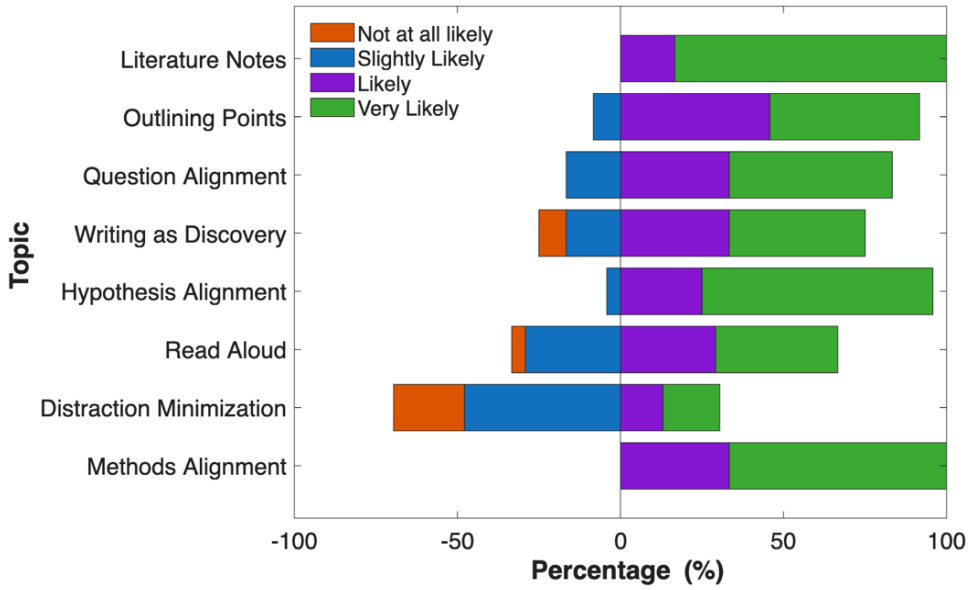


Figure 4 *Survey responses related to mid-writing adjustments. The plot shows percentages of each response for a specific question on the MKST. The total of each bar is 100%. Negative percentages represent responses with negative connotation.*

4.3 Post-Intervention Adoption

Six survey items indicate the likelihood of students to adopt specific strategies after participating in W*riting SySTEM* interventions such as the courses or workshops, *cf.*, **Figure 5**. There is a strong positive trend in the adoption of post intervention strategies with 88.2% indicating that they were either "Very Likely" (66%) or "Likely" (22.2%) to implement one of these strategies, suggesting that the writing interventions were largely successful. Three strategies emerge as high adoption strategies: peer feedback, argumentation alignment, and check

and revise. One strategy emerges as a low adoption strategy: intermittent editing. Again, this last strategy is consistent with the tendency of students to compartmentalize research and writing phases.

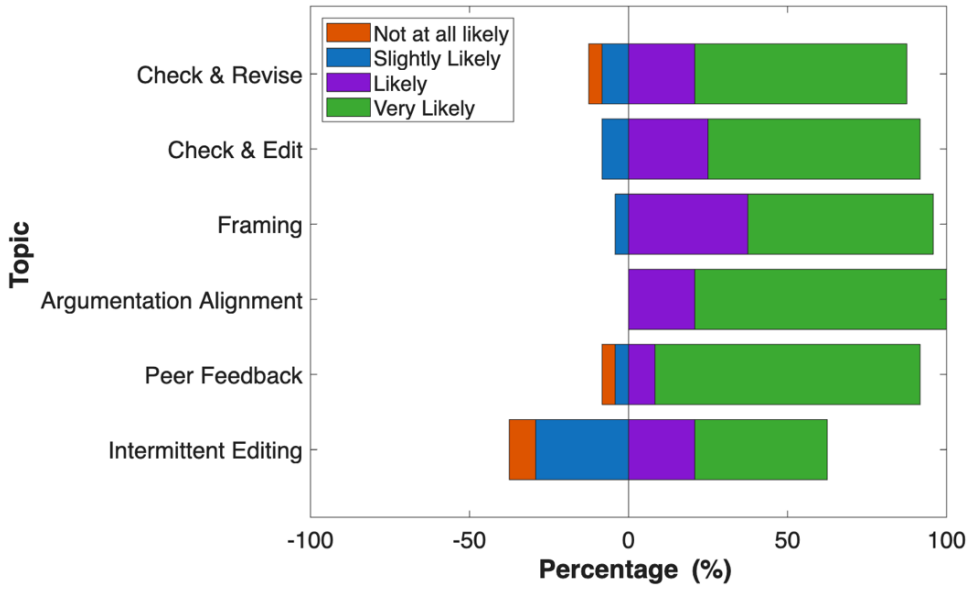


Figure 5 *Survey responses related to post-intervention adoption. The plot shows percentages of each response for a specific question on the MKST. The total of each bar is 100%. Negative percentages represent responses with negative connotation.*

4.4 Writing Self-Efficacy

Twenty-seven survey items in the WSRES measure writing self-efficacy, *cf.* **Figure 6**. The results indicate that engineering graduate students in this sample generally possess a high sense of self-efficacy with 86.3% of all responses falling into the "Strongly Agree", "Agree", or "Slightly Agree" categories. Areas of high self-efficacy include research and referencing, revision and planning, and incorporating feedback. Areas of lower self-efficacy include managing distractions and time and initiating the writing process". The data indicates that students construct their sense of self-efficacy through social comparison and self-assessment of specific skills. Further, they describe their confidence as being on a continuum. One student survey respondent mentioned having seen "better writings than mine and then the worser than mine too".

5. Discussion

In terms of pre-writing strategies, the data indicates students have developed stronger, foundational pre-writing strategies in the areas of literature engagement and synthesis, mentor relationship utilization, and research planning and gap identification. These results indicate the educational interventions in the future could target concurrent writing practices, process integration, and timeline optimization. All three of these activities related to embedding writing activities within experimental workflows and throughout the research process.

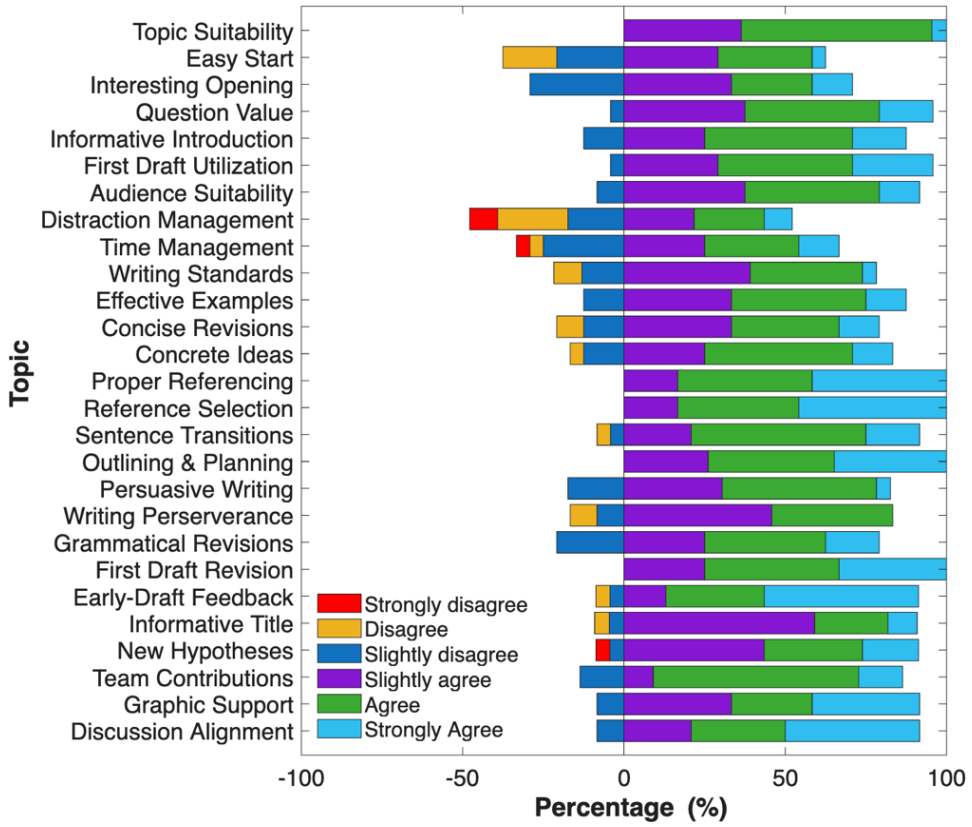


Figure 6 *Survey responses measuring writing self-efficacy. The plot shows percentages of each response for a specific question on the WSRES. The total of each bar is 100%. Negative percentages represent responses with negative connotation, e.g. variations of disagree.*

When it comes to mid-writing adjustments, the data suggest that pedagogical interventions should shift away from focusing solely on content-based writing rules and also include explicit instruction on environmental and process-based self-regulation. Some of the strengths to leverage include that students are already proficient at monitoring for content alignment, but areas for improvement include environmental control, metacognitive awareness, and managing writing related stress.

For post-intervention adoption, the data suggests that pedagogical interventions are effective at fostering key writing behaviors, particularly those related to peer engagement and ensuring that claims are logically sound and well supported. Some suggestions for future interventions are to leverage peer interactions and to focus on integrating writing into the research workflow. Regarding peer interactions, the high adoption rate of peer feedback validates the use of structured peer review activities. The lower adoption of intermittent editing reveals the opportunity for targeted instruction. Interventions should explicitly teach and model strategies for breaking down writing to manageable concurrent tasks.

The majority of respondents participated in the writing courses, so we infer that the writing courses were most impactful. This intervention offers the students the largest number of strategies over an extended period during which they make significant progress on their writing projects. Because it is a graded course, students are more accountable for their writing

throughout the semester. However, it is the opinion of the lead author that the peer writing groups could be more effective if they were more sustainable and if students fully committed to the groups. These groups create accountability amongst students, help students in managing physical and digital distractions, and promote consistent writing throughout the research cycle. The peer writing groups have potential to strongly address the four factors influencing self-efficacy in writing [18]: (1) the ability to practice and draw on previous successful experiences, (2) the ability to compare others to oneself, (3) positive and negative feedback from the community, and (4) the ability to use healthy emotional and psychological strategies to approach new challenges.

A common theme across all the results is the need to integrate iterative writing processes as part of the research workflow. This would result in students using writing as a way of synthesizing knowledge rather than as a culminating method targeted at reporting results. This along with the high adoption rate for peer feedback suggests that peer-writing groups could significantly enhance the writing experience for students.

6. Conclusion

Herein, we describe the implementation of a systematic approach to technical writing education for graduate students in engineering. This approach utilizes four instructional interventions (writing workshops, writing courses, peer writing groups, and an OER) implemented at a "research intensive" university. The effect of these interventions on student self-efficacy and self-regulation was evaluated using the MSKT survey, an adapted version of the WSRES survey, and semi-structured interviews.

The results of the surveys and interviews were divided into pre-writing strategies, mid-writing adjustments, post-intervention adoption, and writing self-efficacy. The results indicate that engineering graduate students possess a generally high sense of writing self-efficacy. It was observed that students were proficient at identifying gaps in the literature and monitoring their writing for content alignment (e.g., hypothesis, methods, and literature). Opportunities exist for targeted instruction on managing digital and physical distractions and for integrating writing processes as a discovery tool into the research workflow.

7. Acknowledgements

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