TEACHING FIRST-YEAR STUDENTS TO COMMUNICATE PROBLEM ANALYSIS AND INVESTIGATION WITH AN ENGINEERING-SPECIFIC WRITING MODEL

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Abstract – *The ability to communicate problem analysis and investigation is crucial to engineering students' success. The Swales CARS model has generated considerable pedagogical interest because it describes how many engineers communicate in diverse documents. However, research has not yet reached any consensus about how effectively this model improves students' ability to communicate problem analysis and investigation. In previous work, we reported that teaching the Swales CARS model and deploying an engineering case increased the students' confidence to critique their own projects, but that study only focused on student impressions of their ability. To address this gap and expand on previous work, we evaluated students in a first-year engineering-communications course to determine whether teaching the Swales CARS model improved their ability to communicate problem analysis and investigation. Our results show our expanded approach generates considerable gains in these skills, which has far-reaching implications for the design of communications instruction in engineering programs.*

Keywords: engineering communication, problem analysis, investigation, engineering cases, Swales CARS model.

1. INTRODUCTION

After knowledge base for engineering, the Canadian Engineering Accreditation Board (CEAB) names the second engineering graduate attribute as problem analysis and the third as investigation [1]. The CEAB mandates that students develop “the ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems.” The American Board of Engineering and Technology (ABET), in very similar language, names “an ability to identify, formulate, and solve complex engineering problems” first among student outcomes [2]. Both bodies emphasize the ability to communicate engineering problems and investigations to multiple types of stakeholders, “within the profession and with society at large,” including “reports and design documentation” in the CEAB guidelines [1], and an

“ability to communicate effectively with a range of audiences,” often “involving diverse groups of stakeholders” in the ABET guidelines [2]. At its very core, engineering education values the ability to communicate problems in ways that demonstrate the relevance and urgency of those problems to audiences that might not immediately recognize them. A growing body of research confirms that engineers in industry agree that communication is essential to their success [8, 15, 20].

Engineering programs address this need in various ways, especially because the CEAB and ABET accreditation criteria do not prescribe exact methods to teach engineering communications. In Canada, programs must include 225 accreditation units for “complementary studies,” which must include some combination of “humanities, social sciences, arts, languages, management, engineering economics and communications” [1]. The ABET criteria only mention the word “communications” in descriptions of individual program criteria [2]. Further adding to ambiguity here, many students entering engineering programs receive most of their previous communications education in secondary-school English classes, which often focus on a literature-centric approach to composition. Somewhere in this space, programs attempt to build on transferable skills learned in secondary school and help students learn how to “communicate like engineers.”

However, there is considerable evidence that traditional methods of teaching composition do not reflect how engineers communicate their problem analysis and investigation [8]. Engineering-communications textbooks often devote several chapters to grammar and stylistics before delving into the production of specific document types, but generally do not address engineering-specific modes of argument [22]. Researchers have focused on the potential to create connections between professional or industrial guidelines and communications courses [16]. Further, engineering students do not always recognize that they are using models of communication [21]; however, communities including engineers use specific conventions to communicate messages [14], which some

communications researchers have argued can be effectively taught with discipline-specific artifacts and tasks [3, 5].

Working from examples of engineering articles, John Swales starting in the 1980s provided a model that effectively describes many of the conventions that engineers use in diverse communications. Swales revealed that engineers use a combination of three phases or “moves” [19] to demonstrate the motivation for their work and excite audiences about the relevance and credibility of their objectives. Swales termed the model “CARS” for “Create a Research Space,” termed “Swales CARS” in this paper. Move 1 is to “establish a territory,” in which engineers first present facts to demonstrate that the engineering issue is relevant to significant groups and has serious impacts on those groups, and second give a brief explanation of the technical background for diverse readers. Move 2 is to “reveal a niche,” in which engineers argue that a critical problem exists in knowledge or technology, and that engineers and researchers have attempted to develop solutions, but that existing solutions present significant limitations. Move 3 is to “occupy the niche,” in which engineers present a credible and relevant response to the problem and preview the essential stages of their work. The Swales CARS model is widely acknowledged to describe scientific communication [10, 17] and engineering communication [6, 7, 9, 12], with some attention to its suitability for use in teaching engineering communication [4].

In our 2019 work, we reported that teaching students to communicate engineering problems benefited from the use of the Swales CARS model, because it improved students’ ability to understand engineering documents. In that work, we used a concise engineering case that also presents elements of the Swales CARS model, surveyed the students, and observed that a single case lesson helped students recognize specific engineering problems and critique their plans to develop solutions. However, that work only measured the effect of the case on students’ impressions of their ability to identify and resolve an engineering problem. The project did not measure students’ improvement across the course or evaluate whether students could use the Swales CARS model to generate authentic and persuasive engineering documents in their own projects.

In this pedagogical reflection, we address these limitations, measure students’ learning of the Swales CARS model, and assess their ability to write persuasive engineering-specific documents about their own real engineering projects in an engineering-communications course. We assessed students’ existing skills in a baseline reflection, taught the model with various exercises, created a multi-assignment scaffolded engineering project, evaluated students’ impressions of their project-management abilities, and then assessed how students were able to use the model to communicate the motivation,

logic, and credibility of their work to diverse audiences in a final engineering proposal. Our results suggest that this scaffolded approach elicits extensive improvements in students’ abilities to write in engineering-specific ways about problem analysis and investigation. These outcomes have far-reaching implications for how engineering programs may design communications curricula to prepare students to meet the demands of the engineering industry.

2. METHODS: COURSE, SURVEY DESIGN

This pedagogical reflection assesses the progress made by 70 students in three sections (one civil engineering, two electrical and computer engineering) of an engineering-communications course, all taught by the same instructor. To train students to communicate problem analysis and investigation in engineering-specific ways, the course requires students to begin by identifying an engineering topic of interest and finish by submitting an engineering project proposal to address a problem in that topic area. Students model their proposals on the structures and criteria used by the local regional government, which partners with the course to generate an immersive and authentic environment for engineering students to develop these skills.

The course scaffolds the students’ projects into several stages, in which students in later work refine earlier work and add new elements in an iterative writing process. This iteration allows students to approach these projects in manageable phases, reflect on their work, receive feedback from peers and the instructor, and improve their work before they submit the final proposal. The course begins by assessing students’ existing skills in communicating projects and assessing information for credibility. An engineering librarian then trains students in techniques to assess information for credibility, which addresses the problem that the information-seeking behaviour of first-year engineering students is not well understood [13]. Students then learn the Swales CARS model, work in groups and then individually to analyze diverse engineering documents to learn to read with the model, and complete quizzes to ensure they remember the model. As the course progresses, students learn to write with the Swales CARS model and complete increasingly sophisticated documents to report their progress: a pitch memo, a progress report, a project presentation, and the final proposal.

To assess the students’ learning, rubrics and grading guidelines were used for all assignments and aligned to evaluate how well the students were developing the three major moves of the Swales CARS model. The objective in this reflection was to track whether students could not only remember the structure, but actually write and speak with it persuasively in their own engineering communications. We designed five metrics to evaluate the students’ progress:

1. Baseline task: In the first class, students were given 20 minutes to respond to the prompt, “Based on your high-school education, tell me how to write the introduction to an article or essay.” The purpose here was to appraise the students’ existing understanding of how to communicate projects to audiences. These reflections were then assessed to determine whether the students recognized the need to (1) establish a territory with specific facts, (2) present a problem with existing knowledge that calls for intervention, and (3) offer an objective that is a credible and relevant response to that problem.
 2. Pitch e-mail: After roughly three weeks, students submitted an e-mail message in formal direct-request format, as if they were requesting permission from a supervisor, to use company time and resources to investigate an engineering problem of interest that could have ethical or business potential. The instructor provided detailed feedback to help students evolve their projects and improve their communications skills. These e-mails were then assessed to determine whether students had enhanced their use of the three moves of the Swales CARS model.
 3. Case analysis and surveys: Students were first given a survey to determine the students’ impressions of their project progress. Three questions asked (1) whether students were finding it difficult to recognize a real engineering problem that required a specific solution, (2) whether students believed that their project idea at that time lacked specific evidence or a clear plan to solve the problem, and (3) whether students believed they would be able to produce a proposal that finds an engineering problem and proposes a specific solution [11]. Students answered on a five-point Likert scale, with the following values: (1) very positive, (2) generally positive, (3) neutral in context, (4) mildly negative, and (5) strongly negative. The instructor then used the Swales CARS model to lead students through the analysis of an engineering case from our institution’s case collection. Civil-engineering students read a case about persistent flood-control problems and dike construction in the local region, while electrical and computer-engineering students read a case about a projector component that will become obsolete and must be replaced with a part meeting size, power, and operational requirements. Students completed a form in which they confirmed their understanding of the motivation of the case, the problem that it addressed, and how they might develop a credible and relevant solution for it. Students were then given a follow-up survey to assess whether their answers to the pre-case survey questions had changed. Students answered surveys without indicating their identity, and the instructors collected surveys face-down.
 4. Project presentation: Students presented their individual engineering projects to their peers and the instructor in the class. Presentation guidelines directed students to demonstrate persuasive motivation for the project, clear evidence of a problem requiring intervention, specific examples of real progress made in developing knowledge about potential solutions, and a credible plan to investigate solutions further or develop the skills to do so. Peers asked questions about the motivation for the project and the credibility and relevance of the response, and the instructor gave feedback about the project’s evolution and the student’s presentation skills. The presentations were then assessed for how persuasively each student employed the three moves of the Swales CARS model.
 5. Final proposal: Students collected their project work throughout the course and incorporated it into their final project proposals, which required revision of their previous communications, refinement of their project plans, budgeting of early project stages, and formatting according to the criteria set out in the requests for proposals (RFPs) of the local regional government. The instructor provided feedback about the proposal’s persuasiveness and written communication. The proposals were then assessed to determine each student’s use of the three moves of the Swales CARS model.
- None of the teaching methods or grading practices were adjusted to accommodate the reflection, and no control groups or experiments were used. All analysis of the students’ work for the purposes of this reflection began only after all grades were submitted, the course was closed, and there was no indication of any student petitions. This reflection is an extension of our previous work, about which we consulted the Office of Research Ethics at our institution to learn whether this work required ethics approval. The Office determined that this is a reflective practice, not requiring further review.

3. RESULTS

Teaching engineering students to communicate problem analysis and investigation in engineering-specific ways remains a challenging problem because of the lack of consensus about how to teach engineering communications, and the relative novelty of the Swales CARS model as a teaching method. The assessment of the students’ use of the three Swales CARS moves was tabulated in a single spreadsheet and analyzed for global and individual trends. Our findings suggest that students can make considerable progress within a one-term course and use the Swales CARS model not only to read engineering documents, but also to generate documents consistent with how engineers often think and communicate.

We assessed the students' use of each Swales CARS move on a five-point scale: (1) not present: the student shows no awareness of the move in the task, (2) limited: the student makes vague use of the move but it is not persuasive and presents no fact, (3) adequate: the student makes direct use of the move but uses only general details to support it, (4) significant: the student uses the move persuasively with at least one credible, specific detail, and (5) thorough: the student uses the move very persuasively with a body of credible, specific details.

As a whole sample, students in the baseline task showed only limited awareness (2.01) of the importance of establishing a territory, a general lack of awareness (1.19) of the importance of stating a problem that calls for intervention or an solution, and limited evidence (2.03) that an objective should be a credible and relevant response to a need. Though with some exceptions, students widely reported (with strikingly similar language) that it was important to "catch the attention of the reader," but very few students could suggest the kinds of content that would do so, and nearly none discussed identifying specific groups or using specific facts to show the relevance of an issue to such groups, or suggest the impact of an issue on them. Students generally reported the importance of presenting a "thesis," but very few even implied that such a thesis was a response to something that needed to be investigated. Most notably, only two students reported that an essay or article responds to a problem that calls for some kind of solution or intervention. Most students did not suggest that a project must communicate some kind of motivation, but rather only a response to a prompt.

The students then learned the Swales CARS model, performed group analysis of engineering articles to find the model in use, and wrote quizzes to confirm their retention of the model. In the pitch e-mail, which followed this teaching and was submitted roughly three weeks after the baseline task, students showed adequate use of establishing a territory (3.33), presenting evidence of a problem (2.93), and offering a credible and relevant response (2.74). In the presentations, students showed significant use of establishing a specific territory (4.39), presenting a clear problem (4.31), and offering a credible and relevant solution (4.01). In the proposals, average student scores were 4.42, 4.13, and 3.99. These numbers show a transition from vague or even absent uses of the moves common among professional engineers to persuasive and specific use of these essential messages about engineering projects.

Table 1: Global trends in Swales CARS move use

Move	Baseline	Pitch	Presentation	Proposal
1	2.01	3.33	4.39	4.42
2	1.19	2.93	4.31	4.13
3	2.03	2.74	4.01	3.99

The engineering case lesson exemplified a real engineering problem, and was written by engineers and senior engineering students following the widely practiced conventions of writing about engineering processes. The authors were independent from our course, and their cases were selected only for relevance, not for their structure. The case surveys assessed the students' impressions of three key elements of their ability to design and manage engineering projects.

In the pre-case survey, Question 1 asked students to report whether they were finding it difficult to recognize a real engineering problem that required a specific solution. Answers ranged as follows: 1 (no difficulty), 2 (minor difficulty), 3 (moderate difficulty), 4 (considerable difficulty), and 5 (extreme difficulty). Students reported an average score of 3.26: moderate difficulty. However, after studying the case, students reported that the case demonstrated between a generally clear example and a very clear example of a specific problem (1.54).

Question 2 in the pre-case survey asked students to report whether their current projects showed specific evidence of a clear problem and a credible plan to respond to it. Students reported an average score of 3.00: they believed their problems and plans were only moderately specific. After studying the case, students reported that the case had generally helped them (2.04) see how their own projects should be more specific.

Question 3 in the pre-case survey asked whether students felt confident that they could recognize a specific engineering problem and present a clear plan to address it. Students reported an average score of 2.87: they were only moderately confident. After studying the case, students reported that they were closer to confident in their ability to do so, though with minor questions (2.36).

All three outcomes suggest that leading students through a single, real engineering case and using the Swales CARS structure to read the case improved the students' perception of their ability to recognize a real engineering problem, and produce a plan to address it.

Table 2: Likert-scale survey results

Q.	Topic	Before case	After case
1	Recognize problems	3.26	1.54
2	Focusing the project	3.00	2.04
3	Confidence in project	2.87	2.36

The global data for the sample only presented a picture of how the class was progressing on average, but we also examined how individual students progressed in their use of the three moves of the Swales CARS model to write authentic engineering documents. If only a minority of students made enough progress to produce the results above, the teaching approach would not meet our objectives or the purpose of the course. To assess how many students had made progress, we compared individual student use of each of the three moves to determine

whether later assignments showed improvement over the baseline and earlier assignments. We present five key comparisons here:

1. Pitch e-mail vs. baseline (PE>BL)
2. Presentation vs. baseline (PS>BL)
3. Proposal vs. baseline (PP>BL)
4. Proposal vs. presentation (PP>PS)
5. Decline in proposal vs. presentation (PP<PS)

Move 1: establishing a territory. Students learned the importance of using specific facts to demonstrate the relevance of an engineering issue to large but specific groups, and to show the serious impact of this issue on those groups. The results demonstrate that a large majority of students showed improvements in the pitch e-mail (77%) compared to their baseline. 96% of students' presentations and 94% of students' proposals showed improvement over the baseline. 27% showed slight improvement in the final proposal over the presentation, and 26% showed a slight decline.

Table 3: Student use of Swales CARS move 1

Change	PE>BL	PS>BL	PP>BL	PP>PS
Improved	54	67	66	19
Not improved	16	3	4	51
% improved	77.14%	95.71%	94.29%	27.14%

Move 2: revealing a niche. Students learned that engineers demonstrate evidence of a clear problem that calls for a solution or intervention, not merely a topic of the author's interest. The results demonstrate that a very large majority of students showed improvements in the pitch e-mail (94%) compared to the baseline. Nearly 99% of students' presentations and 97% of students' proposals showed improvement over the baseline. 17% showed slight improvement in the final proposal over the presentation, and over 33% showed a slight decline.

Table 4: Student use of Swales CARS move 2

Change	PE>BL	PS>BL	PP>BL	PP>PS
Improved	66	69	68	12
Not improved	4	1	2	58
% improved	94.29%	98.57%	97.14%	17.14%

Move 3: occupying the niche. Students learned that engineers offer highly credible and relevant responses to problems, which includes specificity and logic in their planning. The results demonstrate that a majority of students showed improvement in the pitch e-mail (63%) compared to the baseline. 94% of students' presentations and 90% of students' proposals showed improvement over the baseline. 23% showed slight improvement in the final proposal over the presentation, and just under 22% showed a slight decline.

Table 5: Student use of Swales CARS move 3

Change	PE>BL	PS>BL	PP>BL	PP>PS
Improved	44	66	63	16
Not improved	26	4	7	54
% improved	62.86%	94.29%	90.00%	22.86%

We expected that later comparisons such as PP>PS would present less improvement, as significant improvements over the baseline in earlier steps helped students develop the intended skills. As a whole, these numbers demonstrate a strongly positive trend towards actually writing with the Swales CARS model, and that the extent of change is considerable, and not merely observable.

4. DISCUSSION

Our objective was to assess whether the students in this course were able to evolve their ability to communicate problem analysis and investigation with the engineering-specific Swales CARS model. We have found that teaching this model in a scaffolded multi-phase iterative assignment design enables students not only to understand engineering articles, white papers, requests for proposals, and proposals, but also to generate their own documents and presentations with this model, as engineering researchers and industry professionals do.

Question 1: How did the students' use of the three moves of Swales CARS evolve throughout the course? Our investigation of the students' baseline communication skills revealed extremely important insight into what incoming students think a project does, and therefore what students attempt to communicate about a project. Most students recognized that it was important to "catch a reader's attention" (Move 1: establish a territory), but did not know how to go about doing so. We found that students changed from showing limited awareness (2.01) of how to establish the territory of a project to significantly or thoroughly doing so in presentations (4.39) and proposals (4.42). In the baseline reflections, students showed nearly no awareness (1.19) of the value of stating a critical problem in need of a solution or intervention. We found that students significantly presented clear evidence of a problem in need of intervention in their presentations (4.31) and their engineering proposals (4.13). In the baseline reflections, most students described the need to state a "thesis," but showed limited understanding (2.03) that the thesis should be a relevant and credible response to a problem, but did so significantly in their presentations (4.01) and proposals (3.99). These outcomes are valuable evidence that a one-term communications course can train students to communicate problem analysis and investigation with the engineering-specific Swales CARS model.

Question 2: Does an engineering case help students shape engineering projects? We observed from the surveys

that connecting the Swales CARS model with a real engineering case, and then requiring the students to use the model to report the contents of the case, not only helps them understand the case but also helps them understand how to design their own projects. Students reported that just the one engineering case considerably enhanced their ability to recognize specific engineering problems. Students also reported that the case improved their ability to critique their own projects for specificity and relevance: they believed they could distinguish between a general project idea and a project with a specific problem that could generate a tangible solution. Students also reported that reading an engineering case with the Swales CARS model made them more confident that they could formulate and present a clear plan to address an engineering problem. As such, we suggest that this method is an effective way to train students to find projects, demonstrate persuasive motivation for those projects, and develop credible plans to address them.

Question 3: How many individual students demonstrated progress or stagnation in this course? We were highly motivated to learn how many individual students were contributing to the overall trend of apparent progress in this learning. If the methods only succeeded with a small majority or large minority of students, this would raise questions about whether this pedagogical approach is accessible and practical in an engineering-communications course. We found that, in the final presentations and proposals, at least 90% of students showed better performance in all three Swales CARS moves than they did in the baseline reflections. Approximately 95% showed improvement in their ability to establish a territory, such as by identifying specific stakeholder groups and presenting facts to show both relevance to and serious impact on those groups. More dramatically, more than 97% of students showed improvement in their ability to present evidence of a clear problem that calls for a solution, rather than merely proceeding with a topic of their personal interest. While only 90% of students' proposals showed improvement over the baseline for the ability to frame a credible and relevant response to a problem, 94% did so in their presentations. These outcomes indicate that using Swales CARS as the central communications model and teaching engineering communication through a scaffolded engineering project facilitate learning among a very large majority of students.

Two minor discrepancies invite further consideration. The first discrepancy is that some students showed slightly weaker performance with the three moves in their proposals than they did in the presentations. 26% did so for establishing a territory (Move 1), 33% for revealing a niche (Move 2), and 21% for occupying the niche (Move 3). Many of these were variations between "thorough" and "significant." However, a smaller minority failed to score as at least "significant." For Move 1, four students (5%) scored a "3" (adequate), and only one student (1.5%)

scored "2" (limited). For Move 2, eight students (10%) scored "3" (adequate), and three students (4.2%) scored "2" (limited). For Move 3, twelve students (17%) scored "3" (adequate), and only three students (4.2%) scored "2" (limited). We did not ascertain the reason for this decline in some students' performance on the proposals. The final proposals did require further revision, which may have been impacted by impending exams. Also, students may have perceived more need to persuade their peers during presentations than the instructor in written submissions. A second discrepancy is that eight students failed to improve over their baseline in at least one of the three moves, in either their presentation or their proposal. Future work should investigate how to detect situations in which students stagnate and intervene earlier in the course, in order to improve student outcomes. The Swales CARS model and the methods reported in this pedagogical reflection provide ideas for a framework to do so.

5. CONCLUSION

In addition to the discrepancies reported in our discussion, this pedagogical reflection does present limitations that create opportunities for future pedagogical development and research. First, this work is still a pedagogical reflection, so there may be some inherent instructor bias in grading the work and measuring whether student progress meets objectives. Second, although our sample size has grown from 45 to 70, larger sample sizes run in more sections, and with more instructors, could provide a more representative understanding of this method, but that would require more course alignments, which were not possible in the current program. Instituting a control would further test these outcomes if it is possible to evaluate a class that does not explicitly teach the CARS model, even if the class still trains the students in the key attributes of engineering-specific writing.

Despite these limitations, this project has also dramatically expanded on our previous work by tracking students throughout the course, gathering baselines and evidence of progress, and aligning several scaffolded assignments to assess student learning with the Swales CARS model. Emerging pedagogical research is demonstrating the value of exposing engineering students to authentic, discipline-specific documents. Further research has revealed the potential of the Swales CARS model to describe the structures used by engineers to create documents and presentations. Our findings demonstrate that organizing a communications course around the Swales CARS model, using the model as a heuristic to enable students to understand and compose authentic engineering communications, and measuring the students' learning by evaluating their use of the model can produce extremely valuable learning gains that connect with the essential graduate learning outcomes of communicating problem analysis and investigation. These findings can

have wide-ranging implications for how engineering programs may re-design communications curricula to focus on engineering-specific communications models with authentic engineering documents.

Future pedagogical design can build upon our work first by seeking ways to overcome instructor bias, perhaps by establishing partnerships between communications instructors and engineering professionals, who could independently review student outcomes and compare them to current engineering practice. This would necessitate ethics review, which would in turn potentially facilitate tracking students after the communications course, and possibly experimental methods to evaluate students receiving different methods of teaching.

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References

- [1] 2019 Accreditation Criteria and Procedures. Ottawa, ON: Canadian Engineering Accreditation Board, 2019, 122 pp. Available as of Feb 10, 2020, from <https://engineerscanada.ca/accreditation/accreditation-resources>
- [2] ABET. *Criteria for Accrediting Engineering Programs, 2019 – 2020*. Baltimore, MD: Accreditation Board for Education and Technology, 2017, 45 pp. Available as of Feb 10, 2020, from <https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/> (accessed February 1, 2020).
- [3] John Bean, *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*. (2nd ed.), San Francisco, CA: Jossey-Bass, 2011. {ISBN: 978-0470532904}
- [4] Lynne Flowerdew, "A Combined Corpus and Systemic-Functional Analysis of the Problem-Solution Pattern in a Student and Professional Corpus of Technical Writing," *TESOL Quarterly* vol. 37, no. 3, pp. 489-511, 2003.
- [5] Aviva Freedman and Natasha Artemeva, "Learning to Teach Writing to Engineers," *Technostyle*, vol. 14, no. 1, pp. 1-20, 1998.
- [6] Budsaba Kanoksilapatham, "Distinguishing textual features characterizing structural variation in research articles across three engineering sub-discipline corpora," *English for Specific Purposes*, vol. 37, pp. 74–86, 2015.
- [7] Budsaba Kanoksilapatham, "Structure of Research Article Introductions in Three Engineering Subdisciplines," *IEEE Transactions on Professional Communications*, vol. 55, no. 4, pp. 294-309, 2012.
- [8] Anne Keane and Ivan Gibson, "Communication Trends in Engineering Firms: Implications for Undergraduate Engineering Courses," *International Journal of Engineering Education*, vol. 15, no. 2, pp. 115-121, 1999.
- [9] Li Lian Khaw and Wei Wu Tan, "Establishing a Territory in the Introductions of Engineering Research Articles Using a Problem-Solution Patterns Approach," *IEEE Transactions on Professional Communications*, vol. 61, no. 2, pp. 133-150, 2018.
- [10] Becky S.C. Kwan, Hang Chan, and Colin Lam, "Evaluating prior scholarship in literature reviews of research articles: A comparative study of practices in two research paradigms," *English for Specific Purposes*, vol. 21, pp. 1-17, 2002.
- [11] George Lamont and Stephan Lambert, "Deploying engineering cases to facilitate problem-based thinking in engineering communications" 2019: *Proceedings of the Canadian Engineering Education Association (CEEA-ACEG) Conference June 8 - 12 Ottawa Ontario*. 2019.
- [12] Sayako Maswanaa, Toshiyuki Kanamarub, and Akira Tajino, "Move analysis of research articles across five engineering fields: What they share and what they do not," *Ampersand*, vol. 2, pp. 1-11, 2015.
- [13] Kathryn Mercer, Kari Weaver and J.A. Stables-Kennedy, "Understanding undergraduate engineering student information access and needs: Results from a scoping review," 2019 *ASEE Annual Conference & Exposition Proceedings*, Tampa, FL, 2019.
- [14] Carolyn R. Miller, "Genre as Social Action," *Quarterly Journal of Speech* vol. 70, no. 2, pp. 151-167, 1984.
- [15] Carolyn R. Miller, *Communication in the Workplace: What Can NCSU Students Expect?* 1996, 40 pp. Available as of March 3, 2019, from https://repository.lib.ncsu.edu/bitstream/handle/1840.2/2294/MillerLarsenGaitensComm_Workplace1996.pdf?sequence=1&isAllowed=y
- [16] Traci Nathans-Kelly, Rick Evans, and Ashim Dalta, "Meshing goals: Bringing a Computer-Aided Engineering course with Biomedical Applications, Engineering Communications, and FDA Reporting guidelines into alignment towards stronger student outcomes," 2017 *IEEE International Professional Communication Conference (Procomm)*, Madison, WI, pp. 1-7, 2017.
- [17] B. Samraj, "Introductions in Research Articles: Variations across Disciplines," *English for Specific Purposes*, vol. 31, pp. 188-201, 2012.
- [18] Pat Strauss and Lynn Grant, "'We Mainly Deal with Maths': New Zealand Engineering Lecturers' and Students' Perceptions of 'Engineering Writing'," *New Zealand Studies in Applied Linguistics*, vol. 24 no. 2, pp. 1-11, 2018.
- [19] John Swales, *Genre Analysis: English in Academic and Research Settings*. New York, NY: Cambridge, 1990. 274 pp. {ISBN: 978-0521338134}
- [20] Jason Swarts, Stacey Pigg, Jamie Larsen, Julia Helo Gonzalez, Rebecca De Haas, and Elizabeth Wagner, *Communication in the Workplace: What Can NC State Students Expect?* 2018, 70pp.

- [21] Winsor, Dorothy, *Writing Like an Engineer: A Rhetorical Education*. New York and London, Routledge, 1996 (Rpt. 2009), 120 pp. {ISBN: 0-8058-1958-4}
- [22] Wolfe, Joanna, "How Technical Communication Textbooks Fail Engineering Students," *Technical Communication Quarterly*, vol. 18, no. 4, pp. 351–375, 2009.
- [23] Pavel Zemliansky and Landon Berry, "A Writing-Across-the-Curriculum Faculty Development Program: An Experience Report," *IEEE Transactions on Professional Communications*, vol. 60, no. 3, pp. 306-316, 2017.