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Learning the language of academic engineering: Sociocognitive writing in graduate students

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LEARNING THE LANGUAGE OF ACADEMIC ENGINEERING:

SOCIOCOGNITIVE WRITING IN GRADUATE STUDENTS

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For our amazing baby, Jacob, who has had the (mis)fortune of entering the worlds of engineering, research, and writing very early in life!

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ABSTRACT

Berdanier, Catherine G. P. Ph.D., Purdue University, May 2016. Learning the Language of Academic Engineering: Sociocognitive Writing in Graduate Students. Major Professors: Monica Cox and Joyce Main.

Although engineering graduate programs rarely require academic writing courses, the indicators of merit in academic engineering, such as journal publications, successful grants, and doctoral milestones (e.g. theses, dissertations) are based in effective written argumentation and disciplinary discourse. Further, graduate student attrition averages 57% across all disciplines, with some studies classifying up to 50% of these students as "ABD" (All But Dissertation.) In engineering disciplines specifically, graduate attrition rates across the U.S. average 36% (both Master's and PhD students), according to the Council of Graduate Schools. The lack of socialization is generally noted as a main reason for graduate attrition, one of the primary elements of which is the development of disciplinary identity and membership within a discourse community. To this end, this research presents findings from a mixed methods study that maps the writing attitudes, processes and dispositions of engineering graduate students with enacted writing patterns in research proposals. Statistical survey data and the research proposals from 50 winners of the National Science Foundation's Graduate Research Fellowship Program (NSF GRFP) were analyzed through statistical methods, genre analysis, and content analysis methods. Interpreted through Role Identity Theory and

Academic Literacies Theory, the findings from this research indicate that engineering writers may approach writing differently from students in other disciplines, and as such, the instruction of engineering writing should be taught in ways that encourage sociocognitive enculturation of graduate students into the engineering discourse community.

CHAPTER 1. INTRODUCTION

1.1 Motivation for a Discussion of Writing in Doctoral Education

The role of traditional graduate programs lies in the socialization of graduate students into the disciplinary norms required by future academic careers (Austin, 2002, 2009) and many scholars have noted the importance of graduate students' development of an academic identity in graduate school (Austin & McDaniels, 2006; Colbeck, 2008; Gardner, 2008b; Sweitzer, 2006). Jazvac-Martek (2009) emphasizes the importance of understanding how students come to form an identity in academia as a contributing scholar, noting that, "[t]he academic identity that develops through the doctoral journey represents a dynamic configuration of elements that are simultaneously internal, or psychological and developmental, and external, involving the social and the disciplinary" (p. 253). Even for students pursuing careers in industry, many responsibilities in industry for graduate degree-holding engineers require strong written and verbal communication skills (Berdanier, Tally, Branch, Ahn & Cox, in press), and many engineers still publish research papers in conference and journal publications.

The results of ineffective socialization can lead to attrition from doctoral programs (Gardner, 2010). Across all disciplines and institutions in the United States, doctoral attrition rates range from 24% to 68% by departments (Gardner, 2009): attrition rates are estimated at 57% overall (Council of Graduate Schools, 2008). In engineering disciplines, the Council of Graduate Schools (2008) calculates the attrition rate to be 36% overall, but this figure varies when disaggregated by student gender (women have a 44% attrition rate; men,35%), citizenship status (international students, 30% attrition; domestic students, 41%) , and ethnicity (White, 39% attrition; Hispanic, 45% attrition; Asian, 47% attrition; and African American, 53% attrition).

The structure of graduate programs in engineering may be the cause of the lower overall attrition rates than other disciplines (especially in the humanities), Science, technology, engineering and mathematics (STEM) doctoral programs differ from those in the humanities or social sciences. Although both stress knowledge creation and publication, STEM coursework tends to be based in knowledge acquisition and problem-solving, providing students with the technical tools with which to complete their research. Assessments are generally based in problem-solving and analytical methods, with very little emphasis placed in written or verbal communication as a means to assess knowledge (Jenkins, Jordan, & Weiland, 1993). Little or no formal attention is paid to the theory-based teaching and learning of academic, disciplinary writing—which is misaligned given the ‘publish or perish’ mentality correlating writing productivity with career advancement, tenure, and promotion (Kamler, 2008). There are other differences between graduate programs in science and engineering disciplines that affect the ways in which graduate students are educated: First, the research group structure of science and engineering research groups promotes community of practice (Lave, 1991) mechanisms for students completing research degrees, which may aid in retention. In addition, engineering research tends to be funded externally through research grants or industry sponsorship, yielding funding for research students and decreased time-to-degree than in the humanities, where doctoral degrees can require over ten years to complete. In addition, many graduate students seek to obtain a master's degree in engineering in order to pursue careers in industry, and may not be required to conduct research as part of the degree curriculum. In these ways, the socialization mechanisms for engineering students may differ from those for the humanities, social sciences, or natural sciences.

In any field, engineering or otherwise, attrition is a significant problem for students themselves, as well as the faculty and sponsoring agencies that support these students financially. Scholars who study the doctoral education process as a means of socialization often work to investigate both the social and the psychological factors that are necessary for doctoral student persistence (Hesli, Fink, & Duffy, 2003; Mansson & Myers, 2012; Most, 2008; Vaquera, 2007). In one study of attrition in graduate school, Lovitts (2001) noted that faculty rarely described academic inability as a reason for attrition, but rather, under-preparation for expectations of graduate school, whereas graduate students themselves noted an overlapping range of personal reasons (70%), academic reasons (42%), and financial reasons (23%) for leaving academia. These findings indicate that understanding and conforming to expectations, or "fitting the mold" (Gardner, 2008) is an enormous part of doctoral success. The discrepancy in perceived causes for attrition between faculty and non-completing students, has provoked conversations around best practices for doctoral programs for the mentoring practices, fostering collegiality, and structuring scholarly activities have been suggested in order to narrow the gap (Boyle & Boice, 1998; Brown, Davis, & McClendon, 1999; Chesler & Chesler, 2002).

In all fields, graduate students advancing in their degrees often report feeling unprepared to complete preliminary dissertation proposals and dissertations, and students preparing to be faculty report under-preparation in grant- and proposal-writing skills (Austin, 2002). This is problematic since "currency" at research universities in academia, even in engineering and other highly technical fields, continues to be based on journal authorship and grant-writing. However, writing resources for graduate students are often sparse. Academic literacy programs and writing centers offered to undergraduate students are available for graduate students in general; however, with disciplinary differences in argumentation, rhetoric, standards, and style, it can be ineffective for a general writing center to try to help graduate students to learn to write for a specific academic, disciplinary audience (Catterall, Ross, Aitchison, & Bergin, 2011). Advisors are quick to delegate the teaching of writing to English departments or writing centers, as they feel "the development of student writing [is] beyond their province" (Catterall et al., 2011, p. 7).

Some students do develop satisfactory disciplinary writing skills, despite these barriers. Aitchison (2009) proposes that "lucky" graduate students may pick up writing style from peers, past personal writing experience, or "cultural capital" related to background, good mentoring, or a supportive advisor (p. 907), but these are not tools that are universally guaranteed to all graduate students (Catterall et al., 2011). The results of this gap can be catastrophic to graduate student success: Supervisors in STEM fields have critiqued students' lack of writing proficiency, claiming it can add years onto a dissertation process, costing students valuable research and career opportunities (Catterall et al., 2011). This situation is paradoxical: While lamenting underpreparation of their students in writing abilities, the design of the engineering curriculum and engineering faculty overall chose not to teach engineering writing.

It is difficult to directly link attrition solely to a student's lack of writing proficiency, and, to date has not been correlated statistically. However, in qualitative research, attrition has been found to involve many different aspects related to the lack of a student's socialization, including supportive mentoring and advisor issues (Boyle & Boice, 1998; Belcher, 1994; Tenenbaum, Crosby & Gliner, 2001; Thomas, Willis, & Davis, 2007), university "climate" issues (Ceci, Williams & Barnett, 2009; Bilimoria & Stewart, 2009; Beddoes, 2011; Marandet & Wanwright, 2010; Springer, Parker, & Leviten-Reid, 2008; Weststar, 2012), and "fit" issues (Golde, 1998; Lovitts, 2001). This "fit" issue is often linked with issues of a scholarly identity, and writing researchers argue that the ability to write and converse in a discipline's discourse is a part of "fitting" into a university, department, and disciplinary community (Gardner, 2008b). A lack of scholarly identity or "fit," may factor into a graduate student's decision to leave the university when she or he reaches the research stage: Most non-completers, according to Lovitts, "feel inadequately prepared to do this type of research and find themselves unprepared to cope with writing in the style required for a dissertation" (2001, p. 72). Writing experts also connect affective factors such as writing anxiety and apprehension to decreased disciplinary self-esteem, self-perceptions, and motivation at the undergraduate (Daly & Wilson, 1983) and graduate levels (Onwuegbuzie, 1999; Bloom, 1985). Although these issues can manifest from sources other than writing, these same factors have been correlated with causes of attrition in engineering graduate students (Austin, 2002).

The overarching purpose of this dissertation is to investigate the social and cognitive processes involved in writing by doctoral students in engineering. With this research, it is hoped that engineering curricula and resources can be developed and adapted to better prepare graduate students to write in the engineering academic genre early in their graduate career, and therefore more efficiently socialize into their discipline and their new identities as disciplinary experts. The context of focus for studying graduate engineering academic writing in this study will be applications for the National Science Foundation's (NSF) Graduate Research Fellowship Program (GRFP). The NSF GRFP will now be introduced in order to provide context for the literature review, theoretical frameworks, and research decisions.

1.2 Introduction to NSF GRFP

The National Science Foundation sponsors an annual Graduate Research Fellowship Program award as a means for supporting promising early career graduate students through advanced degrees. This prestigious national fellowship is granted to 2,000 graduate students in science and engineering disciplines each year. As of 2014, the prestigious award provides generous academic funding and stipend monies (tuition, fees, and a $35,000 annual living allowance) for three years of a student's graduate career. The award is recognized among science and engineering communities as an indicator of both academic and research potential merit. Eligibility requirements insist that students have completed no more than 12 months of doctoral study (e.g. seniors in college, first-year graduate students, and second-year students are eligible to apply) if they do not have prior advanced degrees or are not working toward professional degrees (e.g., MBAs, MDs, DVMs). Exceptions exist for individuals with extenuating circumstances, such as military or veteran status. Lastly, since the fellowship is federally funded by the United States, only U.S. citizens, U.S. nationals, or permanent residents are eligible to apply.

Although the limitations of the NSF GRFP inherently limit the population that can be studied, the constraints also offer particular advantages to be used to benefit this research. One main advantage is that the experience limit (no more advanced than second-year graduate students) focuses the sample population to early career graduate who may be experiencing the enormous transitions that often occur between undergraduate and graduate degrees, as well as new encounters with unfamiliar expectations, academic work, introduction to research, and academic writing (Golde, 1998). Because of the narrow experience range of the eligibility criteria, this kind of purposeful sampling (Creswell, 2012) allows the research to focus the study on early-career graduate students, who may be still developing academic identities. Additionally, the NSF GRFP offers an ideal study context because the application requirements of all graduate students are identical. Demographic data, transcripts, Graduate Record Examination (GRE) scores, and reference letters are required in the application packages, but the most intensive part of the application packages is the composition of two essays that are judged by panels of disciplinary experts. The application packages are ultimately judged as a whole in order to determine the student’s aptitude and worthiness for the award.

The first of these essays is the "Personal, Relevant Background, and Future Goals Statement," which will now be referred to as the "Personal Statement" is prompted for students online (https://www.nsfgrfp.org/applicants/application_components) which presents the task and the expected components:

"Please outline your educational and professional development plans and career goals. How do you envision graduate school preparing you for a career that allows you to contribute to expanding scientific understanding as well as broadly benefit society? [...]Describe your personal, educational and/or professional experiences that motivate your decision to pursue advanced study in science, technology, engineering or mathematics (STEM). Include specific examples of any research and/or professional activities in which you have participated. Present a concise description of the activities, highlight the results and discuss how these activities have prepared you to seek a graduate degree. Specify your role in the activity including the extent to which you worked independently and/or as part of a team. Describe the contributions of your activity to advancing knowledge in STEM fields as well as the potential for broader societal impacts (See Solicitation, Section VI, for more information about Broader Impacts) (NSF, 2016).

This written task requires students to blend their academic identity with their personal reflections on their career goals in order to prove to an academic audience that they have the "potential to satisfy" the goal of NSF to support students who will become "globally engaged knowledge experts and leaders who can contribute significantly to research, education, and innovations in science and engineering" (NSF, 2016). Personal reflection on one's own development as an engineer and researcher, while highly affective and psychological, is presented to the academic community to judged, and therefore, the way in which the psychological content is argued has sociological components. While the statement is "personal," the audience and context of the fellowship implies a sociological component in terms of the applicant's responsibility to justify the acceptability or legitimacy of their personal experiences to the wider academic community—represented by the panel of disciplinary judges. In other words, while the writer's relationship with the content is psychological, the process of presentation and argumentation in the context of NSF GRFP is sociological.

Similarly, the second essay, the "Graduate Research Plan Statement," which will from now on be referred to as the "Research Statement," is also prompted as follows.

> *Present an original research topic that you would like to pursue in graduate school. Describe the research idea, your general approach, as well as any unique resources that may be needed for accomplishing the research goal (i.e., access to national facilities or collections, collaborations, overseas work, etc.) You may choose to include important literature citations. Address the potential of the research to advance knowledge and understanding within science as well as the potential for broader impacts on society. The research discussed must be in a field listed in the Solicitation (Section X, Fields of Study (NSF, 2016).*

This essay asks students to prepare an original research plan, something that likely novice graduate students have not been required to perform before in their careers, especially if they are first-time NSF GRFP applicants. Many students choose to ask their research advisor for help in planning the research statement because of this. The role of disciplinary discourse is important in this task, since students are asked to be aware of the academic merit of their proposed research, as well as be familiar with the intricacies of the research process—something that is enculturated into students through experience rather than traditionally taught in undergraduate classes. This learning of discourse is a connection between the sociological aspects and the cognitive aspects of the writing process.

1.3 Research Purpose and Goals

The vision for this study is to demystify the engineering academic writing process and experience in graduate students. This is a novel topic with implications in cognitive and social writing research, engineering education research, and practice in teaching engineering communication. In light of the under-exposure that graduate engineering students have to authentic, disciplinary writing and the misalignment of this fact with the idea that doctoral success, tenure, and promotion are contingent upon publishing and acquiring grant monies through written language, the goal of the proposed research is to study graduate engineering students in their involvement with the National Science Foundation Graduate Research Fellowship Program. The proposed research is a mixed methods study. First, successful (winning) NSF GRFP essays will be analyzed via document and genre analysis methods in order to answer the following research questions:

1. *What argumentation strategies do engineering graduate students employ in research proposals that have been awarded the NSF GRFP?*
2. *How do these strategies confirm or modify existing theories of genre analysis, composition theory, and argumentation logic for an engineering doctoral context?*
3. *How do a writer's affective perceptions about writing influence the strategies for argumentation that have been employed in essays winning NSF GRFP?*

The following chapters of the dissertation are arranged in order to present a comprehensive literature review on the state of engineering writing and writing research and a chapter on methods outlining the research design, methods, and methodological decisions. The results chapters are then presented in four parts. Chapter Four presents quantitative results of the study, correlating statistical results across multiple surveys to understand the ways in which NSF GRFP winners conceptualize and engage with the writing process. Chapter Five presents a genre analysis of the research statements in order to map these cognitive statistical results with enacted writing and argumentation patterns. Chapters Six and Seven present results from a thematic analysis characterizing the Intellectual Merits and Broader Impacts criteria within the research statements, describing patterns between disciplinary lines and between participant gender. Each of these results chapters (Chapters Four through Seven) includes both the results and a discussion and recommendations sections within them. As a final chapter, Chapter Eight discusses the overall conclusions from the dissertation as a whole.

CHAPTER 2. LITERATURE REVIEW

In this literature review, the role of writing in the STEM doctoral education system will be examined closely. Through the task of academic writing, graduate students learn to communicate effectively with an established scholarly community through accepted modes of writing styles and argumentation, in order to build an identity and understand the implicit expectations of an engineering career. This literature review will present advances in the area of academic writing, first understanding recent relevant literature in writing research at the graduate level for STEM students to further motivate the literature review. This will lead to a more theoretical discussion of writing education research and theory, presenting the process both as a cognitive activity and a social activity, informed from a variety of disciplines (communication, rhetoric, English, philosophy, psychology, social psychology, sociology). Combined, these areas offer tools through which to study, understand, and address the lack of academic and writing competencies for graduate STEM students.

In an effort to understand how graduate engineering students become socialized into disciplinary norms and expectations through academic writing experiences, this literature review will begin with a brief discussion on the state of writing research in STEM and engineering disciplines, specifically. Then, a brief discussion of paradigms will provide context to the theoretical and research communities that study social and cognitive writing. Lastly, literature will be reviewed presenting engineering writing as a social activity and as a cognitive activity.

2.1 The State of Writing Exposure in STEM Graduate Programs

Very few authentic writing activities (representing real-world tasks, motivated by performance outside a classroom context) are introduced at either the undergraduate or graduate levels in STEM disciplines in the United States. At the undergraduate level, academic requirements of universities require that a certain level of competency be reached through "general education" coursework, which includes composition classes taught usually through English or communications departments. Departments are beginning to understand the need for integration of writing into the technical curriculum. At the undergraduate level, movements such as the "Writing to Learn" (Tynjälä, Mason, & Lonka, 2001) and "Writing across the Curriculum" initiatives have sought to introduce more writing into all curricula: Several engineering educators discuss these efforts in engineering courses and other technical curricula (Olds, Dyrud, Held, & Sharp, 1993; Olds, 1998). Often, the literature that results from these is practice-oriented rather than research oriented. Engineering writing curriculum literature that reports on these initiatives offers much in the way of best practices for developing collaborative relationships between engineering faculty and technical writing experts in English, working together to determine the necessary skills for engineering writers, which offer guidelines for the types of skills that should be taught in such courses and strategies to employ them (Kuhn & Vogt-Alexander, 1994). Most agree that for undergraduates, without this type of collaboration between English and engineering faculty, engineering students will not be able to successfully learn to write for an engineering audience (Clayton, 1996). Even though this agreement has been reached regarding the importance of engineering writing, many engineering programs chose not to devote disciplinary resources to the teaching of engineering writing.

Undergraduate engineering students without these integrated disciplinary writing experiences may actually be able to progress through their bachelor’s degrees without taking any composition classes—potentially progressing to graduate school with little more than a high-school level background in composition, and no formal disciplinary writing education. Ackerman, Kanfer, and Calderwood (2013) noted that nearly 20% of entering STEM students at a research-intensive university received college credit for high school Advanced Placement English coursework, therefore lessening the time to degree completion. However, if these statistics are generalizable to other strong engineering colleges, and these students (as Ackerman et al. show) receive higher grade point averages, it is entirely possible for undergraduate STEM students to enter graduate school without taking any composition courses past high school, especially not those related to disciplinary discourse.

At the graduate level, fewer discussions on implemented engineering writing curricula are reported. The needs for formal disciplinary engineering writing are well noted in literature, calling attention to the discrepancy in engineering fields between the importance of writing and literacy and the time spent teaching this to students (Jenkins, Jordan, & Weiland, 1993; Ding, 2008). Much of graduate level literature studies the needs of graduate students in general (Rose & McClafferty, 2001; Castello, Iñesta, &

Moñereo, 2009; Granello, 2001) and tends to be aimed at the needs of international graduate students in STEM fields who are labeled as English as a Second Language (ESL) students, second language (L2), or non-native speaker (NNS) in literature (Jenkins, Jordan, & Weiland, 1993; Allison, Cooley, Lewkowicz, and Nunan, 1998; Abasi, Akbari & Graves, 2006). Although the situated language needs of foreign graduate students are very important, the graduate-level writing literature (both in general and engineering or STEM-specific) ignores the fact that even domestic engineering graduate students are under-prepared to undertake publication and dissertation writing.

In order to meet the needs of engineering communication preparation, some universities offer fellowship and proposal-writing courses or seminars to graduate students, which may help them in application processes to national fellowships or in their future careers. In literature, U.S.-located researchers have described a few courses for STEM graduate students to practice academic writing and publishing (Leydens & Olds, 2007), and in writing grant proposals (Fang, 2012; Ding, 2008), but rarely do these course descriptions explicitly recognize both social and cognitive composition theory. Leydens and Olds' 2007 tutorial on a "publishing in science and engineering contexts" course is exemplary in its references to teaching literature-based rhetorical strategies and basing the course in writing research. If other studies and reports are based in theory, most of them refer to sociological theory behind the teaching of writing (cognitive apprenticeship, identity theory, situated learning cognition, and communities of practice) as their theoretical framework, rather than referring explicitly to composition research (Ding, 2008; Castello, Iñesta, & Moñereo, 2009; Hyland, 2002; Artemeva, Logie, & St-Martin, 1999). Some interdisciplinary efforts such as National Science Foundation-funded Integrative Graduate Education Research Traineeship (IGERT) programs offer modules or seminars related to grant-working and writing skill-building (Gamse, Espinosa, & Roy, 2013), but the records in literature also fail to report on writing pedagogies or connect their work to writing research.

Since the state of STEM writing instruction at the graduate level has been proven to be scarce, it motivates an in-depth study on the composition and argumentation patterns of engineering graduate students, such as this study. The remainder of this literature review will discuss literature and theory probing writing as a cognitive activity and writing as a social activity in order to more fully understand the history of the field and gaps in the literature that can be filled through the proposed research. First, though, I will briefly deviate to discuss research movements and paradigms through which writing theory and research is placed, as they have motivated and continue to motivate the generation of ideas and methods.

2.2 Writing Research Paradigms

Literature that will be discussed in this review results from several different paradigms in research. Paralleling the movement of learning paradigms from behaviorism, to cognitivism, to situated cognition (sociocognitivism), so too have writing theories moved from current-traditionalism, to process movements, to the post-process movement, a disciplinary subcategory of the new social science paradigm (Petraglia, 1999). Each movement offers different critiques of writing as an activity, and each offers different benefits. Current-traditionalism proposes that writing is an act that people do simply in order to achieve a product, with the focus being on the product itself. Due to its simplistic and problematic assumptions, current-traditionalism is considered rather antiquated. The process movement is more recent, and lends itself well to pedagogical advances and ways that teachers can try to "teach" writing. Petraglia (1999) summarizes that "writing was less a single behavior than a series of procedures and strategic choices that formed a complex system of text production: in short, a process" (p. 51). In this way, the emphasis of the process model of writing evolved. Most literature from this era neglects writing and composition theory, except for a brief mention in the foreword. Instead, they are aimed at pedagogies and methods for studying the composition process, which is useful, but, as many scholars have pointed out, is not a substitute for a theory of writing, composition, or revision (Hayes, 2012; McCutchen, 2000; Sommers, 1979).

The post-process theory of writing leans on the ideas that writing is public, interpretive, and situated. It is public in the fact that writers always write for an audience, and/or we use the language of the public to communicate. It is interpretive in that writers interpret their own thoughts, and writers interpret their readers, who in turn re-interpret the writer's words given their experiences. Post-process theorists would say this is the flaw with a process model—if it's interpretive, then it cannot have a process, because "writing cannot begin nowhere" (Kent, 1999, p. 3). It is situated amongst knowledge-based communities, but is not limited to them. Olson (1999) rejects the need to have a Capital T "Theory" of writing because it assumes a process that can be taught, and post-process theories suggest that "writing—indeed all communication—is entirely situational. Consequently, efforts to pin down some version of 'the writing process' are misguided, unproductive, and misleading" (Kent, 1999, pp. 8–9). They challenge "rhetoric of assertion" on which objective rhetoric (especially in academia) is based (Olson, 1999, p. 9). Post-process theorists emphasize that theorization should answer interesting questions about the socially situated activities involved in the creation of a text. In writing and communicating with an audience, Blyler explains that "writers engage in a hermeneutic guessing game, attempting to suit their interpretations and their writing to the interpretations of those with whom they wish to communicate" (1999, p. 67). This is not the place for a discussion of the minutia in arguments between the camps of paradigm theorists, but it is important to understand that these paradigms frame the research that is conducted in writing, composition, and rhetoric. The theories and research that will be covered in this literature review mostly fall within the process theorists, but some might edge—even if subtly—to a more situated paradigm, where genre and context begin to play a much larger role in studying writing.

2.3 Theoretical Frameworks for Writing Research

Several social and cognitive theories support, inform, and frame STEM graduate students' writing processes and experiences. The conception and interpretation of this research relies on academic literacies theory, role identity theory, and genre analysis theory. These theories are just a few of the sociological frameworks through which writing can be considered: Many researchers also talk about learning and performing writing in terms of broader learning theories: cognitive apprenticeship and communities of practice (Lave, 1991) and situated learning and cognition (Brown, Collins, & Duguid, 1989; Bandura, 1989). Although the action of composition may happen individually, the purpose of writing is ultimately to communicate with other people.

2.3.1 Academic Literacies Theory

Through the lens of academic-literacies theory (Lea & Street, 1999, 2006), writing is not a task or set of skills, but a situated social practice: "Navigating the disciplinary differences requires an understanding of context, including how knowledge is constructed in the field and how writers adopt and critically defend positions. An academic-literacies perspective is concerned with how teaching and learning about writing occur within a complex social system that incorporates issues of epistemology, power, and identity" (Catterall et al., 2011, p. 1). Writing for audiences in particular genres or disciplines each carry social implications at the graduate level: Journet (1999) confronts this issue for communication within disciplines, as well as writing for interdisciplinary audiences and their expectations. Part of developing academic literacy involves learning to communicate with and anticipate values of validity with other members of the academic community. Rosenblatt (1988) discusses this development as an awareness of "the responsibility for providing verbal means that will help readers gain required facts, share relevant sensations or attitudes, or make logical transitions" (p. 13).

This "responsibility" in academic and disciplinary writing is usually judged or validated by the acceptance of the argument or communication in a journal or a publication (Duff, 2007; Duff, 2010). Each discipline, field, and community has unwritten standards for the content and structure of communication, which is then considered to be a component of the rigor of the communication (Ahamad & Yusof, 2012; Bremner, 2011; Ibrahim & Nambiar, 2012; Li & Ge, 2009; Wingate, 2012). The field of

English for specific purposes (ESP) has evolved from the fields of sociology and linguistics to better understand the discursive practices of communities of people, understanding that the process of learning how to communicate appropriately in a group of people is one main aspect of socialization into a group. Discourse analysis methods are regularly employed to study these areas, with the more specific practice of genre analysis used to better understand the necessary components of legitimate communication in a discipline. This has been clearly studied in the venues of higher education and academia (Bremner, 2011; Ibrahim & Nambiar, 2012; Morton, 2009; Preiss, Castillo, Grigorenko, & Manzi, 2013), and the field of engineering has been studied for explicit practices in sociotechnical communication and rhetoric (Dannels, 2002; Darling & Dannels, 2003; Darling, 2005; Leydens, 2012; Leydens & Olds, 2007). This is a highly relevant field of study for engineering written communication research: Associated methods and analyses will be discussed further in the methods discussion.

2.3.2 Role Identity Theory

The act of learning a discipline's specific language, rhetoric, and argumentation through a disciplinary lens corresponds with social theories of learning that also hold an identity component, such as cognitive apprenticeship models and legitimate peripheral participation theories in community of practice frameworks (Andrews, 2000; Austin, 2009; Lave, 1991). More specifically, role identity theory (Labianca, Fairbank, Thomas, Gioia, & Umphress, 2014; Stryker & Burke, 2014) seeks to understand how people come to adopt a role as an identity in a field, discipline, or community, encompassing the ideas included in these other theories. In a complex academic social system, several different levels of epistemology, power, and identity are often confusing to developing scholars: A graduate student struggles with a changing identity from being a consumer of knowledge to a producer of knowledge for an entire research community (Jazvac-Martek, 2009). The issue of identity development in this sense is much more social than psychological, related to becoming a member of a community, and adopting the accepted discourse patterns to be recognized as a scholar in a discipline. Aitchison and Lee (2006) studied the importance of writing groups to the development of academic identities and the feeling of belonging, where the writing group helped students develop identities as students practice writing, arguing, and critiquing others' writing as scholars, finding a voice in a writing group setting and in a discourse community. Bartholomae (1985) also discussed the problems of identity development and language usage for students learning to write in disciplinary contexts, and the potential for problems to arise.

> "The student has to be appropriate (or be appropriated by) a specialized discourse, and he has to do this as though he were easily and comfortably one with his audience, as though he were a member of the academy or an historian or an anthropologist or an economist; he has to invent the university by assembling and mimicking its language while finding some compromise between idiosyncrasy, a personal history, on the one hand and the requirements of convention, the history of a discipline, on the other. He must learn to speak our language. Or he must dare to speak it or to carry off the bluff, since speaking and writing will most certainly be required long before the skill is 'learned.' And this, understandably, causes problems." (Bartholomae, 1985, p. 135)

The issue of development of a written style or voice is as much an issue of identity development within a community as it is the learning of the expectations or rhetoric patterns of a discipline.

Discussion of writing as a social and situated activity as well as a cognitive and psychological theory lends insight into the complexities of studying advanced disciplinary academic writing. Since theorists emphasize the importance of disciplinary writing and studying writing in a context-specific area, the need for emphasis on writing research and teaching within STEM graduate programs is evident.

2.4 Cognitive Writing

Many scholars have sought to understand psychological processes of writing: For the sake of this literature review, theories that are focused on development of writing processes and written language abilities, especially in young children (for example, Bereiter and Scardamalia's (1987) knowledge-telling vs. knowledge transforming model) will remain uncovered, instead focusing on the most influential theories for studying writing practices of experienced writers based in cognitive theory. The development of Hayes and Flower's (1980, 1996) hierarchical cognitive process model and the theories of working memory in cognitive writing, supported through the work of Baddeley, (1979, 1994), Kellogg (1996), and McCutchen (2000) are especially illuminating when seeking to understand the cognitive writing processes of experienced writers.

2.4.1 Hierarchical Process Models of Writing

Flower and Hayes' hierarchical process structure of writing confronted decades of work modeling the writing process as a linear stage process models (brainstorm, write, re-write) (Flower & Hayes, 1980, 1981; Hayes & Flower, 1980). Flower and Hayes' model is broken into three main units: (1) the task environment (the problem/task, and includes all written work as it happens), (2) the writer's long-term memory (storage of plans and goals, audience, and topic), and (3) the writing process (planning, translating, and reviewing). Flower and Hayes also discuss the importance of goal formation within the writing process, and the idea that "…writers not only create a hierarchical network of guiding goals, but, as they compose, they continually return or 'pop' back up to their higher-level goals. And these higher-level goals give direction and coherence to their next move" (Flower & Hayes, 1981, p. 379). This model is shown in Figure 2.1(a).

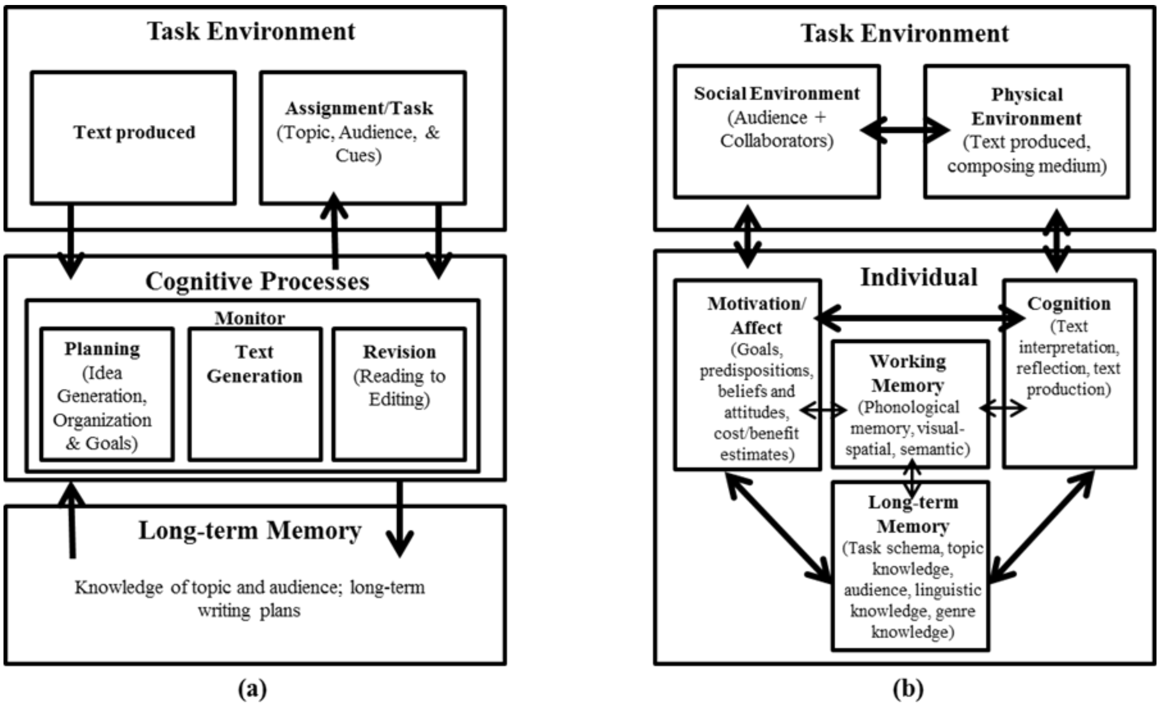


Figure 2.1 Hierarchical Model of Writing. (a) Adapted Flower and Hayes' 1981 Hierarchical Model of Writing and (b) Adapted Hayes 1996 model (revised from 1981)

2.4.2 Working Memory Theories of Writing

The 1980s provided researchers with many new technologies enabling new methods and emphasis across the world in uncovering psychological writing processes: Pockets of writing researchers in northern Europe, France, and the United States contributed to theories of memory in writing. In the 1990s, however, socially-situated theories became fashionable, and cognitive theories yielded to the incorporation of affective and social dimensions, at the same time that psychological theories of working memory were being developed: For example, Hayes updated the 1980 hierarchical process model to be more encompassing of the affective domain and the interactions that are juggled in writer's short-term and long-term memories (Hayes, 1996). Many scholars have since accepted this model of "working memory" in composition, through which a writer holds necessary short-term and/or long-term memories in his or her attention. General psychological theories of memory capacity based on the work of Miller (1956) estimate that the average human working memory can hold seven (+/- two) bits of information; experts can hold more information by combining it into memorable patterns or "chunks". Hayes' revision to the influential hierarchical cognitive process model emulated more recent developments in cognitive writing research, which had been proposed by Kellogg. This model proposes that the writing process is governed by a central executive system, which parcels out memory and attention to various formulation, execution, and monitoring branches (Kellogg, 1996). A simple diagram of the 1996 revised cognitive process model is shown in Figure 1(b).

Many writing process models, however, argue that more than seven processes and pieces of information are juggled during the writing process. Ericsson and Kintsch (1995) overcame the psychological capacity of working memory by proposing a theory of "long-term working memory" in addition to "short-term working memory," where long-term working memory (LT-WM) results in text-generation fluency results from, keeping writers in touch with the writing assignment, audience, writing and argumentation plans, and content knowledge or experience. Short-term working memory (ST-WM) is the working memory that allows writers to exhibit sentence fluency, keeping one sentence in line with the next sentence in a logical sequence of thoughts.

Writing theorists arguing for a LT-WM theory of writing propose that expert writers encode information more effectively into long-term working memory, which allows them to store their subject-matter expertise as well as information regarding the task and plans indefinitely while working on sentence generation, which is the contribution that McCutchen made in her Capacity Theory of working memory in writing (2000). The ability to efficiently encode information and expertise to long-term working memory allows writers to remain unconstrained by short-term working memory capacity constraints as typically defined. Typically, theories of LT- and ST-working memory refer to the various procedures that go into the planning, translating, and monitoring functions when a writer is working on a manuscript. However, these processes also allow writers to come back to a paper or an assignment after a break without needing to re-plan an argument, the purpose, or previous decisions. Long-term working memory also allows for longer documents and more complex arguments to be developed in academic writing. Although the working memory models of writing have augmented the older hierarchical cognitive process model of writing, there are several areas which still need further research (McCutchen, 1996, 2000; Olive, 2012). McCutchen specifically lists issues related to the methods and testing of LT-WM theories, specifically questions related to method development in order to isolate writers' long-term and short-term working memory to "induce" more novice or expert writing strategies (McCutchen, 2000, p. 21). An in-depth discussion of methods used for writing research and future research questions for methods will be discussed at length later in this literature review chapter.

2.4.3 Affective Dimensions of Writing

Research into other cognitive processes related to the affective factors of writing can also be of use when discussing writing as a psychological or cognitive activity. Here, issues related to problem-framing, decision-making, iteration and revision; overcoming writers' block and fixation, as well as the role of metacognition and reflection in writing are addressed, using research from writing research as well as research from other fields. One area of cognitive research involving a subcomponent of the writing process involves writing apprehension and writing anxiety.

Writing anxiety "is a label for one of a combination feelings, beliefs, or behaviors that interfere with a person's ability to start, work on, or finish a given writing task that he or she is intellectually capable of doing" (Bloom, 1985, p. 121). Bloom conducted two case studies of graduate students, who "out of context, may be neither anxious nor a writer," determining that underlying barriers to writing fluency might be due to artistic (creativity-based), temperamental (motivational), biological (energy-based), and emotional factors (1985, p. 119). Other researchers in psychology and in composition fields have further researched these phenomena applied to the writing process, constructing a variety of scales, correlating high levels of writing anxiety and apprehension to factors such as sex differences and self-esteem constructs, to name a few (Bloom, 1985; Daly, 1985; Onwuegbuzie & Collins, 2001).

Writing attitudes have been the topics of several quantitative studies, investigating the effects of constructs such as writing anxiety, writing apprehension, and writing attitudes. According to Bloom (1985), the "significance or intensity [of writing apprehension] may be powerful enough to overwhelm the writer's whole life, especially if finishing a dissertation or writing articles or books is crucial to the writer's career" (p. 121). Writing apprehension, although sharing the multifaceted nature of writing anxiety, is more related to the "enduring tendencies" of a writer "to like or dislike, approach or avoid, enjoy or fear writing" combined with whether or not the writer recognizes "some value in the activity […] For no matter how skillful the individual may be as a writer, without a willingness to engage in writing one can expect little more than the atrophying of composing skills" (Daly, 1985, p. 44).

The Daly-Miller Writing Apprehension Scale has been used in many statistical analyses which show correlations between high levels of writing apprehension and lower performance, writing aversion, weaker arguments, shorter compositions, and lower disciplinary self-esteem (Daly & Miller, 1975a, b; Daly, 1978; Daly, 1985; Daly & Wilson, 1983). These measures have also been used to correlate writing apprehension with undergraduate students' choice of major, where students with high writing apprehension tend to select majors in which they perceive very little writing to be done, especially engineering, physics, and mathematics disciplines (Daly & Shamo, 1976; Daly & Shamo, 1978).

A recently-published survey instrument developed by Lonka, Chow, Keskinen, Hakkarainen, Sandtröm, and Pyhältö (2014) probes the writing attitudes of graduate students based on six graduate-student-specific constructs: blocks, procrastination, perfectionism, ideas on innate ability, knowledge transformation, and productivity. The survey, because of its recent release, is less widely employed than the Daly-Miller Writing Apprehension scale, but is grounded in the same sociological academic literacies theory and identity theory discussed above, which are also the grounding theoretical frameworks for the study. This new study might offer future insight into the affective domain in graduate students as their scores correlate with patterns discovered in qualitative research.

In these ways, it is easy to understand the effect of the affective domain in issues related to getting starting, planning, and procrastination. However, these issues are present during all parts of the writing process. In process theories of writing, the sub-components of revision are often related to the affective domain, involving how writers learn to self-question, evaluate, and revise their own documents. These themes are inseparable from themes of metacognition and reflection in the writing process. Matsuhashi and Gordon (1985) recall the differences in “knowing that” and “knowing how” in the writing process. Several models of revision have been proposed, from the taxonomic, which separate surface edits from text (or meaning-based) edits (Witte, 1985), to a hierarchical model of revising theory (Sommers, 1979). Sommers ultimately urges writing theorists and educators to situate the revising part of writing within all the other parts of the writing process: “Instead of thinking of revision as an activity at the end of the process, what if we thought of revision as a process of making a work congruent with what a writer intends---a process that occurs throughout the writing of a work?” (p. 48). This constant process of reflection and evaluation within the writing process is advocated by other research as well. Daiute proposes engaging in conversation to stimulate inner dialogue: “Mature writers, in short, talk to themselves about their writing and their writing talks to them as well” (1985, p. 138).

Since writing is such a complex activity, there are a variety of methods available in research that have been used to study different facets of the writing process. These deserve attention, and bring attention to areas where the methods can be advanced. These are discussed presently.

2.5 Advances in Writing Research Methods

The techniques for monitoring and studying writing presented in this section will move along a continuum of sorts, moving from traditional and static techniques of cognitive writing research, to more recent, novel, and dynamic methods, beginning with retrospective static methods. Retrospective methods such as surveys and interviews have been used to study writing and writing sub-processes. Survey-based techniques have generally been used to understand issues such as writing anxiety, which help instructors and researchers to identify or overcome about cognitive barriers to fluent text production (Daly, 1985; Lonka, Chow, Keskinen, Hakkarainen, Sandström & Pyhältö, 2014). Reflection on the writing process has also been used as data, as a retrospective and introspective view of the writing process (Fang, 2012), study of writing anxiety (Bloom, 1985; Kamler, 2008; Onwuegbuzie & Collins, 2001) and writing support programs after the task has been finished (Aitchison, 2009; Blair & Mader, 2013; Johnson, 2014). Although students are engaged in reflective practice about their own personal writing styles and behaviors, which is important for growth and development, introspective and retrospective analyses and reflections are inherently biased by the work a writer has completed, and gives a less-than-adequate understanding of what happens in the writing process interviews and introspective analysis of the writing process (Negretti, 2012). Flower and Hayes (1981) advocate against using retrospective reflections about cognitive writing processes, since “people rapidly forget many of their own local working goals once those goals have been satisfied” (p. 377).

Document analysis, a qualitative method employing thematic and content analysis within documents specifically, has also been shown to be an incomplete, yet useful tool for identifying argumentation and writing processes. Although analysis of a completed, edited, revised, and submitted document does not give insight into the procedure or path it took to get to that stage, and may reinforce an emphasis on writing as a product-oriented (rather than process oriented activity) (Bereiter, 1980; Rosenblatt, 1988), a piece of writing as an “end product” can expose patterns in the usage of argumentation strategies and information organization within a document (Fang, 2012). Final products also demonstrate disciplinary discourse and values through the use of visual representations, outlining of arguments, use of technical terms, and style (Collins & Gentner, 1980). Such assessments, of course, are biased toward personal preferences and disciplinary discourse; therefore, the development of a reliable rubric from which several people can reliably and fairly analyze final written documents is necessary (Hayes & Flower, 1980; Moskal & Leydens, 2000).

The main drawback of these retrospective or “static” forms of data and analysis lie in the inability of these methods to show process, progress, learning, or development over the course of the writing process. Flower and Hayes have studied cognitive writing processes over the last three decades through real-time think-aloud methods, which are transcribed and analyzed as a protocol (Flower & Hayes, 1981; Flower & Hayes, 1980; Hayes, 2012; Hayes & Flower, 1980; Hayes & Nash, 1996; Hayes, 1996). Several other researchers also use protocol analysis hoping to gain insight into cognitive writing processes of writers in many different contexts (Olive, 2004; Storch, 2005; Wong, 2005). A major drawback to this is the inauthenticity that this situation sets up—rarely, in practice, do writers talk aloud and justify their decisions during the composition process. It also presents the issue of reactivity of the method on the assessed task—that is, the idea that the method of analysis will disturb the cognitive activity that is trying to be studied, which is a problematic limitation (Janssen, van Waes, & van den Bergh, 1996). Additionally, if a researcher intends to study the most authentic writing experience, or a writing experience that occurs over a long period of time, think-aloud methods and protocol analyses are inconvenient.

Metacognitive studies in writing have been studied to collect developmental data, using journals that students keep regarding their writing processes in order to study how students develop in terms of approaching writing in a variety of contexts (Negretti, 2012; Storch, 2005). Negretti's study of declarative, procedural, and conditional metacognition indicated that journaling was a superior method to prior think-aloud protocols because "it allowed complete integration into the coursework" as students recorded their reflections on writing, strategies, progress, and final performance over the course of essay-based assignments (2012, p. 148). This longitudinal observation of development of self-regulation in writing may be a helpful compromise to gain insight on process, pairing metacognitive data collection with retrospective document analysis or reflection. Use of periodic metacognitive reflections also helps to integrate the focuses "product" and "process" in student writing (Rosenblatt, 1988). Journals and metacognitive studies can probe the development of students over time, despite the limited capacity to measure real-time cognitive processes.

With advances in computing and technologies over the last two decades, cognitive writing researchers have used technology-based forms of quasi-"real-time" data to study cognitive writing and composing practices. Some researchers track "pause times"—that is, times when students are not actively or fluently writing, which can be used to understand syntactical and linguistic process, as well as idea fluency processes (Bourdin & Fayol, 2002; Fayol, Hupet, & Largy, 1999; Fayol, 2012; Maggio, Lété, Chenu, Jisa, & Fayol, 2011). Others focus on studying the writing process through keystroke logging (Dragsted & Carl, 2013; Leijten & Van Waes, 2013) as a method of studying revision practices and cognitive fluency. Several keystroke logging programs are available (see van Waes, Leijten, Wengelin, and Lindgren (2012) for a complete list), and offer researchers the ability to visualize pause times, keystroke loggings, and replay of the writing for use. Some have also combined keystroke logging and eye-tracking methods to gain further insight on where attention is located during writing activities (Alamargot et al., 2012; Rayner, 2009; van Gog, Kester, Nievelstein, Giesbers, & Paas, 2009; van Waes, Leijten, & Quinlan, 2009; Vandeberg, Bouwmeester, Bocanegra, & Zwaan, 2013), especially as more authentic writing is being done on computers, rather than by hand (a difference from writing research in the 1980s and 1990s). Eye-tracking has been used as a common method for the last decade in cognitive literacy (writing, reading, and listening) research (Rayner, 2009; Reichle, Rayner, & Pollatsek, 2003; van Gog & Scheiter, 2010; van Waes et al., 2009). Some scholars project that eye-tracking software will be the method of the future in cognitive writing research advances (Alamargot & Chanquoy, 2012), while others recommend pairing keystroke logging with eye-tracking or traditional think-aloud techniques, to triangulate data and gain insight on decision-making processes (van Waes, Leijten, Wengelin, & Lingren, 2012).

Further research questions involving current eye-tracking and other digital methods are both practical and theoretically oriented. Practically, eye-tracking methods employ head-mounted cameras, which are inherently obtrusive to writers if researchers would like to study writing processes over a long amount of time. Some scholars have questioned the cognitive reactivity of different digital methods—that is, how the method intrudes upon or changes normal cognitive function (van Waes, Leijten, Wengelin, & Lindgren, 2012). Although these methods for data collection have revolutionized cognitive writing research, most researchers tend to focus on studying the act of writing, which is the translation (brain idea to written word) step of the writing process, using small and inauthentic tasks. These researchers have not expanded this work into looking at the entirety of the writing process, although a few researchers have noted the importance of studying expert writers in a variety of professional contexts and careers in order to more firmly understand working memory theories of writing (Alamargot, Caporossi, Chesnet, & Ros, 2011; Alamargot & Lebrave, 2010; Blyler, 1999).

Another major criticism of using pause times and other markers of writing as activity to study academic writing as a long-term process, however, comes from a practical standpoint. When writing about content (rather than a narrative), often writers—even content experts—take breaks to consult literature, corroborate ideas with other researchers, or take time to think. Murray (1985) even proposes that there is an “essential delay” when writing productively, which limits the use of these metrics for measuring

Table 2.1 Table of Available Writing Research Methods

Method	Writing Processes Captured	Advantages	Disadvantages	Relevant Literature
Surveys	Static	Identify affective constructs and attitudes about writing	Do not study the writing process itself	Lonka, et al (2014) Daly (1985) and other Daly sources
Written reflections on writing	Static	Identify student's evolving thoughts and attitudes on writing throughout and after a project/process	Researcher does not use writer's actual process as data, demonstrated self-report bias	Fang (2012) Bloom (1985) Kamler (2008) Onwuegbuzie & Collins (2001) Aitchison (2009) Blair & Mader (2013) Johnson (2014) Negretti (2012) Storch (2005)
Document and genre analysis	Static	Use final product to expose overall communication patterns and discourse strategies	Final product does not show development or evolution of writing through revision process (product vs. process orientation)	Bereiter (1980) Rosenblatt (1988) Fang (2012) Collins & Gentner (1980) Hayes & Flower (1980)
Think-aloud protocol analysis	Dynamic	Hear writer's musings on the composing process *during* the task	Reactive method may interfere with cognitive processes associated with composing	Hayes & Flower (1980) Flower & Hayes (1980) Flower & Hayes (1981) Hayes & Nash (1996) Hayes (1996) Hayes (2012)
Keystroke logging	Dynamic	Captures all logged keystrokes; can identify editing and revising processes	Require special software in order to capture and analyze keystroke data	Dragsted & Carl (2013) Leijten & van Waes (2013) Van Waes, et al. (2012) Alamargot et al. (2012) Rayner (2009) Van Gog, et al (2009) Van Waes, et al (2009) Vandeberg, et al (2013)
Pause-time tracking	Dynamic	Identification of fluent writing periods and pauses research areas of difficulty in composition	Assumes pauses are indicators of poor writing, rather than essential in authentic tasks	Bourdin & Fayol (2012) Fayol, Hupet, & Largy (1999) Fayol (2012) Maggio et al. (2011)
Eye-tracking methods	Dynamic	Accurately tracks where attention is spent on the page during composing process	Advanced computing technology necessary; writer wears headgear during entire writing task	Rayner, (2009) Reichle, et al. (2003) van Gog & Scheiter, (2010) Van Waes et al., (2009)

writing competency. Additionally, the pause-time measurements are not valid for studying deep revision or editing processes, because, likely during these times there will be long pauses for reading or thinking. Table 2.1 indicates the advantages and disadvantages of all these previously-employed writing research methods.

Researchers in the on-line (meaning, "real-time," not necessarily internet-related) cognitive writing research community have seen great advances with the ubiquity of personal computers and the advances in technology development and availability. Short of brain-imaging during a writer's long-term writing processes (fascinating, although not practical with current technologies) (Bazerman, 2012), non-obtrusive digital techniques are the most accessible way to mark cognition patterns in writing.

2.6 Gaps in the Literature

Through this literature review, the governing theories of cognitive writing theory, especially Flower and Hayes' modified hierarchical process model and the working memory and capacity theories of writing were discussed, which will frame my proposed research in the area of engineering writing. More recent research has been motivated by the development of new methods, especially including eye-tracking and key-stroke logging practices, usually in addition to think aloud methods. There are several gaps in the literature that should be identified before proceeding with the research questions and design. Although this proposed dissertation will most thoroughly address gaps in cognitive and social writing research in engineering graduate students, likely, findings can be used to improve research-to-practice literature in order to advance writing resources available to graduate engineering students.

2.6.1 Graduate Engineering Writing Gaps

The STEM and engineering literature explored above demonstrated the general lack of rigorous writing research done in disciplinary research in engineering overall, and more important, at the graduate level. I expect that this proposed research will offer a renewed look at the importance of studying engineering writing processes in order to better assist engineering graduate students in developing effective writing curriculum housed within engineering disciplines.

2.6.2 Social Writing Research Gaps

The field of English for Specific Purposes is beginning to unveil the importance of understanding difference in disciplinary discourse. This study would be the first of its kind to explore the ways in which graduate engineering students embody their identity change (from a consumer of knowledge to a producer of knowledge) through their established argumentation patterns. Using the NSF GRFP as an authentic academic engineering writing task will offer a close look at writing practice in early graduate years, when this identity may be most in flux. By addressing the “process” part of developing disciplinary and sociological processes, the proposed research may be able to lend insight into how people develop disciplinary discourse patterns.

2.6.3 Cognitive Writing Research Gaps

The biggest area where research is lacking in the cognitive writing space is in the development of new methods to investigate cognitive writing, given the prevalence of personal laptops and readily available software. The proposed research will examine currently available technologies in order to extend the writing research that was popular in the 1980s. This is a timely area to expand upon, since few researchers have employed screen-capture methods using readily available computer software. Only one study, from 1996, implemented this method (Levy & Ransdell, 1996), but also implemented think-aloud protocol, which has been critiqued in the literature to load different cognitive functions in working memory, "competing" with the space that would normally be used for writing processes (van Waes, Leijten, Wengelin, & Lindgren, 2012). In light of available screen capture software and prevalence of personal computers for student writing, it is important to review this method for studying engineering writing cognition. Additionally, cognitive writing research is rarely situated in a discipline or authentic writing activity. A genre-specific lens could lend insight into the areas of cognitive writing research as well as disciplinary genre research.

2.7 Theoretical Frameworks and Research Questions

The theoretical frameworks that will guide the study overall are Academic Literacies Theory and Role Identity Theory. These sociological theories involve individual psychological and cognitive components, which can be applied well in both the social and cognitive writing research. These two theories were selected since they incorporate a sociological view of identity and identity development specifically in an academic setting, which is important to the context of this research. Analysis of the cognitive phase of the research relies on Flowers and Hayes' Hierarchical Process Model of writing, as well as the Working Memory theories of writing. Table 2.2 demonstrates each theory's usefulness in this research study.

Table 2.2 Theoretical Frameworks for the Study

Framework	**Usefulness in Answering Research Questions**
Academic Literacies Theory (Lea & Street, 1998)	Graduate student experiences are grounded the overall goal of learning to be literate in the spoken and written discourse of an academic community. This socialization framework will be used in document and genre analysis in order to describe the ways that students are practicing appropriate disciplinary argumentation patterns in cognitive writing phases.
Role Identity Theory (Labianca, Fairbank, Thomas, Gioia, & Umphress, 2014; Stryker & Burke, 2014)	Posits that as a student develops through a doctoral program, scholarly identity is in flux. Students are still learning, but in some contexts need to communicate as technical experts simultaneously. This theory can explain juggling of various roles and "voices" in writing, lending insight to argumentation patterns in the social parts of the research, and explain peculiarities in voice, uncertainty, and revision processes during the actual writing process.
Hierarchical Process Theory of Writing & Working Memory Theories of Writing (McCutchen, 2000; Flower & Hayes, 1980; Hayes, 1996)	Identifies multiple constraints that writers balance when writing and strategies that writers use to mitigate the multiple constraints. This theory is relied upon in the cognitive research, to analyze real-time writing processes.

Based on the gaps in the literature on engineering writing and graduate-level writing, this research is guided by several research questions:

1. *What argumentation strategies do engineering graduate students employ in research proposals that have been awarded the NSF GRFP?*
2. *How do these strategies confirm or modify existing theories of genre analysis, composition theory, and argumentation logic for an engineering doctoral context?*
3. *How do a writer's affective perceptions about writing influence the strategies for argumentation that have been employed in essays winning NSF GRFP?*

2.7.1 Strategy of Inquiry

The strategy of inquiry used in this study is abductive analysis, which can be an alternative to grounded theory, inductive, and deductive analysis. Deductive analysis is useful for classifying instances of phenomena into pre-existing knowledge as a form of theory testing, while inductive analysis, conversely, seeks to organize pieces of data into cohesive themes and categories, in order to abstract into a new theory (Elo & Kyngäs, 2008).

In contrast to both of these, however, abductive analysis is meant to work among multiple existing theories that relate to a phenomenon at hand, letting the “suprising” parts of the data emerge as modifications of existing theories, and may combine elements of both inductive and deductive analysis in order to uncover explanatory relationships between data and theory. Rather than either creating a new theory through emergent open and axial coding, or potentially forcing data to fit within *a priori* codes from a pre-selected framework or theory, coding, classification, and grouping of data during abductive analysis may be informed by many diverse theories (Timmermans & Tavory, 2012). And, as Timmermans and Tavory note,“[r]ather than engaging with the scholarly literature at the end of the research project, as inductivity approaches have often advised, abduction assumes extensive familiarity with existing theories at the outset and throughout every research step” (2012, p. 173).

In general, the aims of abductive analysis are to find the commonalities out of empirical examples: “[… Theory allows us to move between instances within the same study and between studies as well to expect certain things to happen and explain how and why certain events have happened. Abductive analysis specifically aims at generating novel theoretical insights that reframe empirical findings in contrast to existing theories” (2012, p. 174). One of the primary assumptions of abductive analysis is that the phenomena being studied may be similar to other phenomena observed in other research studies, which may be governed by unseen cause/effect relationships which can be uncovered by finding the parts of the phenomena that do not fit within existing theories.

Ontologically and epistemologically, the views of abductive analysis are similar to those of grounded theory. I seek to understand the cognitive and identity-building processes involved for graduate students applying for the NSF GRFP. These experiences will be varied for all participants, and the study is not meant to identify a truth or a single correct way of writing. Through the use of abductive analysis, themes can emerge from several different writing theories, which serve as *a priori* codes and as ways to arrange or organize emergent themes. Past studies of writing, whether they be within an engineering context or in other disciplines, can lend insight into the particular commonalities or differences between cognitive and sociological writing patterns and processes. I seek to uncover "surprising" ways in which academic engineering writing in graduate students may differ from previously reported research in order to understand how and why to better teach writing to engineering students.

CHAPTER 3. SOCIOCOGNITIVE WRITING RESEARCH METHODS

3.1 Research Design

This research is designed to study disciplinary and sociocognitive aspects of writing using a simultaneous mixed methods design. Both the quantitative and qualitative data were collected simultaneously from the same 50 winners of NSF GRFP that were recruited to be participants in this project from the 2015 NSF GRFP Awards. The survey instruments that were used to collect the quantitative data were selected to lend insight into the writing attitudes and apprehensions of the writer in order to contextualize writing and argumentation patterns found in document and genre analysis as qualitative methods. The data were collected and analyzed simultaneously, and even though the quantitative and qualitative findings can stand alone, the “mixing” occurs in both the analysis and the interpretation phases of the research project (Creswell & Clark, 2007). Triangulation and crystallization of results happens by considering the findings between the quantitative methods and the two qualitative methods (content analysis and genre analysis) employed in this study as a part of a whole system.

3.1.1 Recruitment and Sampling

Participants were purposively sampled using the outcomes of the 2014 NSF GRFP application cycle. Awards were announced in early April 2015. After Institutional

Review Board approval for this research was obtained, eligible participants were identified using the NSF FastLane (online award submission) website (https://www.fastlane.nsf.gov/grfp/AwardeeList.do?method=loadAwardeeList). This cycle, 510 NSF GRFP fellowships were awarded to engineering students in 18 engineering disciplines at U.S. universities. STEM and Engineering Education were not considered in this sample because of their subject matter focused on human learning rather than on technological and scientific advances. NSF GRFP awardees and honorable mention awardees (although Honorable Mention recipients were not recruited for this study) are listed on the NSF website along with their baccalaureate institution, graduate institution, and discipline to which they applied for NSF GRFP. Although new fellow email addresses are not listed on the website, most academic institutions list directory contact information (including university-affiliated email addresses) on their websites. Email addresses were then obtained manually by searching university webpages for student email addresses. Some universities limit access to non-affiliated parties (i.e., require an institutional login) in order to access student email addresses, and therefore, these potential participants could not be recruited. A total of 330 email addresses for NSF GRFP winners were acquired, 65% of total awardees.

A recruitment email was sent to NSF GRFP winners in May 2015 shortly after the NSF GRFP award winners were announced. The recruitment email included the link to the Qualtrics online survey which contained informed consent, demographic questions, asked them to upload winning NSF GRFP documents, and then contained five independent writing and research-related surveys dealing with writing attitudes, apprehensions, and self-efficacy. These scales will be described in depth later. Since

NSF Research Proposals and Personal Statements may contain identifiable information, I specifically noted that any identifying information would be blinded before data analysis. Additionally, if students did not want excerpts of their writings to be used in any data reporting, they were instructed to answer a survey question as such. This would be applicable for students who have sensitive preliminary results or intellectual property in their documents. Students were also not required to upload their documents: If they felt uncomfortable, they were still able to participate in the survey probing writing attitudes without uploading their documents.

NSF GRFP winners from all disciplines of engineering were sampled. No efforts were made to quota sampling by participant gender or by discipline. The sample was not intended to be representative of all engineering students and their writing styles but was meant to understand composition and genre mechanisms in application packages that experts in the community have deemed worthwhile, laudable, and high-quality. Sampling through NSF GRFP allowed nationwide sampling from across United States research institutions. This stratified sampling (Marshall & Rossman, 2011) was intended to investigate the practices of graduate students in order to understand engineering writing and the development of disciplinary discourse as both a sociological and cognitive process that is critical to the socialization of engineering graduate students.

The format of NSF GRFP is an interesting case of one way in which graduate engineering students may write in an authentic disciplinary setting. However, the format does present limitations on the interpretation of results. Firstly, the results will be representative of only NSF GRFP engineering winners, not extendable to all graduate engineering students. Further, the award is highly competitive, and students have the ability to use multiple resources to complete the task to the best of their ability, including edits from research advisors or older students. Lastly, the NSF GRFP competition, although judged according to the NSF GRFP criterion, is largely subjective according to the preferences of the judging panel. Although “honorable mentions” are awarded, that are likely just as high quality as the winners, I did not sample for honorable mentions in this study. Therefore, interpretation of the findings will continually take these factors into account.

59 of the 330 (17.8%) recruited participants responded to the survey. Fifty of the 59 gave complete sets of data, including the completion of all the surveys and uploaded both their personal statement and research statement, for a final response rate of 15.2%. Total times spent on the survey averaged approximately 39 minutes.

The attainment of 50 application packages met the intended numbers of proposals to sample. Fifty was chosen as an appropriate number for this qualitative method based on estimations given for needed number of interview participants in studies comprised of similar participants (20-40 interviews is average for a study, according to Vogt, Gardner, & Haeffele (2012)). Although this study is not an interview method, I expected a similar estimation of participants to achieve saturation of qualitative data.

In addition, an N=50 for quantitative studies can be assumed to follow a normal distribution, albeit still a small value for quantitative work. The Central Limit Theory states that for large samples ($N \geq 30$), the sampling distribution of variable means will be normal, in combination with the fact that, skew tests for my sample of N=50 indicate acceptable symmetries of the means of the variables (Tebbs & Bower, 2013). In addition, I conducted Shapiro-Wilks tests for normality for the continuous variables.

3.2 Participant Demographics

23 of the 50 participants identified as women, which is disproportionate representation for engineering. (According to the 2012 NSF Science and Engineering Indicators report, percentages of earned doctorates and earned master's degrees in engineering awarded to women as of 2009 were calculated to be 21.6% and 22.5%, respectively (NSF, 2012)). Other participant demographic characteristics of interest are shown in Table 3.1.

Table 3.1 Participant Demographic Information

Racial/Ethnic Demographics	**Number**	**Percentage**
White/Caucasian	39	78%
Asian/Pacific Islander	4	8%
Black/African American	2	4%
Hispanic/Latin American	3	6%
Multiple		
White/Asian	1	2%
White/Hispanic	1	2%
First Language	**Number**	**Percentage**
English	46	92%
Spanish	3	6%
Other	1	2%

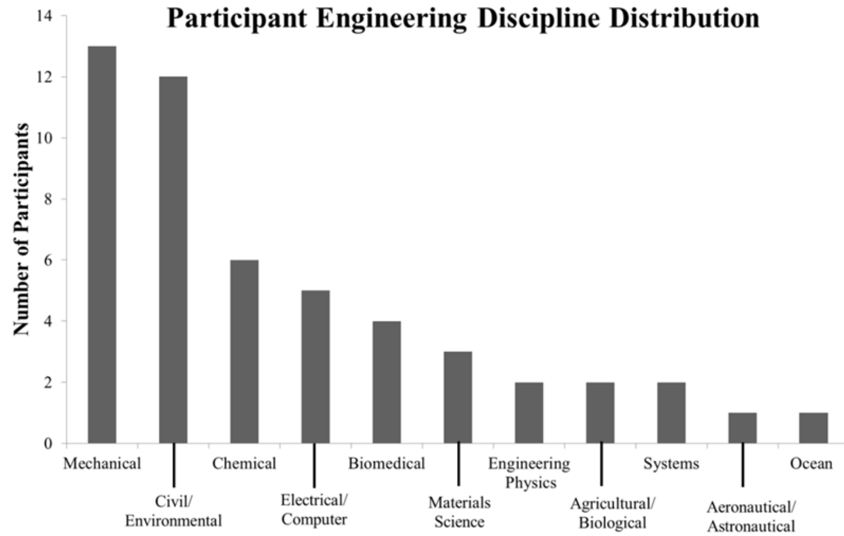
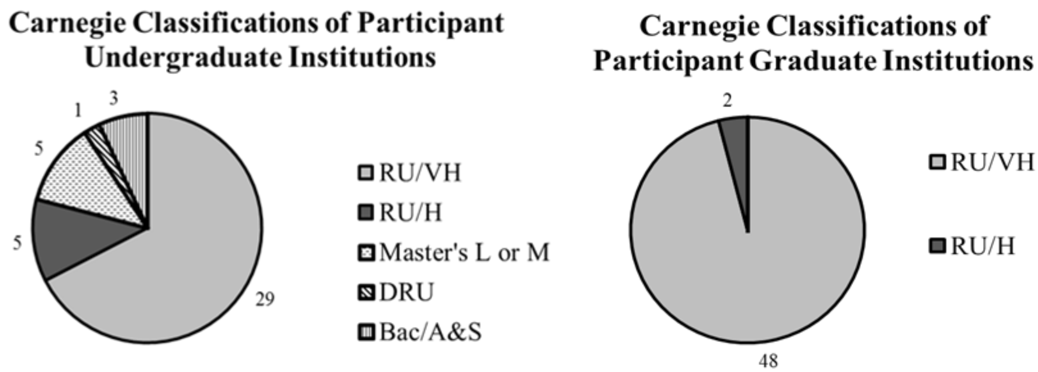


Figure 3.1 Participant Engineering Discipline Distribution

As shown in Figure 3.2, the 50 participants represent 11 engineering disciplines. For the purposes of data analysis, the one participant identifying as Aeronautical and Astronautical was grouped with Mechanical Engineering, and the one Ocean Engineer was grouped with the Civil and Environmental Engineers for the subsequent phases of data analysis.

The educational background questions in the survey revealed that 10 students won the NSF GRFP as senior undergraduate students, 24 as first-year graduate students, and 15 as second-year graduate students. One participant selected “other,” which is indicative of a participant who falls into the exempt criteria because of a nontraditional background or time out of school as per the NSF GRFP guidelines. Other questions in the survey provided insight on the types of institutions at which students were completing their graduate work. The data in Figure 3.3 show that while the participants completed



Doctorate-granting Universities:
RU/VH: Research University, Very High Research Activity
RU/H: Research University, High Research Activity
DRU: Doctoral/Research University
Master’s Colleges and Universities:
Master’s L: Master’s College/University, Larger Program
Master’s M: Master’s College/University, Medium Program
Baccalaureate Colleges:
Bac/A&S: Baccalaureate Colleges—Arts & Science

Figure 3.2 Educational Background of Participants

their undergraduate degrees at a variety of institutional types, the graduate institutions of the participants were all at either Research Universities with Very High (RU/VH) or High (RU/H) levels of research activity. The demographic survey also asked students their formal writing coursework background: 76% reported taking no writing-intensive courses (in any department) within the last two years. Participant numbers were assigned to the data before incomplete survey responses were deleted and the data were cleaned. Therefore, in the results sections, participant numbers extend beyond “Participant 50”.

3.3 Survey Design

The survey deployed to the participants was based on five separate writing and research scales that have been reported and validated in literature. Rather than develop a new instrument (requiring additional levels of validation and reliability testing) it was decided that several different scales previously published would be used as vehicles to study engineering writing attitudes. Reliability and validity for the present study were calculated in order to justify the use of the surveys on the population of engineering graduate students. The arrangement of the survey completion process was as follows: Informed consent; demographic data and uploading of Personal Statements and Research Proposals; Inventory of Graduate Writing Processes (Lavelle & Bushrow, 2007); Self-Regulatory Efficacy for Writing (Zimmerman & Bandura, 1994); Graduate Concepts of Academic Writing (Lonka et al., 2014); Daly-Miller Writing Apprehension Scale (Daly & Miller, 1975); and the Research Self-Efficacy Scale (Bieschke, Bishop & Garcia, 1996).

The survey display and arrangement of the survey were intended to reduce survey fatigue and to put the most "useful" data for researchers toward the beginning of the survey. For example, the purpose of putting the demographic data and the uploading of documents at the beginning was to maximize the number of documents available to analyze; if the participants didn't complete the rest of the survey, the documents would still be available saved as data. Similarly, the writing-specific scales were put first in order to capture that data, with the general Research Self-Efficacy Scale (Bieschke, Bishop, & Garcia, 1996) at the end of the survey. The formatting of the scale items in Qualtrics online survey software was also intended to help participants take the survey and reduce fatigue: The scales varied in length from twenty-five to seventy-five items. In order to make this more palatable, a format for the questions was selected that visibly broke up the questions into groups of four or five, with white space in between to reduce cognitive load. The Research Self-Efficacy scale asks participants to rate their confidence at various tasks from 0 to 100, with 100 being completely confident: For this question, an interactive slider bar was used to keep participants engaged and reduce repetition and fatigue.

The following sections introduce the five validated scales from other researchers used in this portion of the research study. These scales are briefly presented in Table 3.2.

Table 3.2 Brief description of writing surveys employed

Scale and Source	Attributes
Inventory of Graduate Writing Processes Lavelle, E. & Bushrow, K. (2007).	Delineates "styles" of writers, which assumes that every individual has different writing strategies, but the stylistic patterns are consistent and "largely not modifiable by instruction" (p. 808): Elaborative, Low Self-Efficacy, No Revision, Intuitive, Scientist, Task, and Sculptor
Self-Regulatory Efficacy for Writing Zimmerman, B.J. & Bandura, A. (1994).	Measures writing self-efficacy with relation to the rest of the sample
Graduate Concepts of Academic Writing Lonka et al., (2014).	Maps different graduate attitudes about writing to six factors that influence graduate writing processes: Blocks, procrastination, perfectionism, belief in innate ability, knowledge transforming, and productivity.
Daly-Miller Writing Apprehension Scale Daly & Miller (1975)	Measures high,- moderate,- and low-apprehensive writers with relation to the rest of the sample
Research Self-Efficacy Scale Bieschke, K.J., Bishop, R.M., & Garcia, V.L. (1996).	Developed for graduate students to measure their self-efficacy in conducting normal research tasks, validated using a STEM population.

To date, this research is unique in that it employs several different scales to observe patterns and interactions between the scale results on the same population. Some of the scales have been designed for graduate students (Lavelle & Bushrow, 2007; Lonka et al. 2014; Bieschke, Bishop, & Garcia, 1996), but the others (Zimmerman & Bandura, 1994; Daly & Miller, 1975) have been mainly employed with general undergraduate populations. These scales were still deemed useful since they characterize apprehension and efficacy relative to the sample mean and standard deviation, therefore basing the characteristic among the sample at hand. In addition, these scales have been used on a variety of populations, and therefore extension to the present study's context was logical. Four of the five scales are focused on writing attitudes, processes, self-efficacy, and apprehension. The fifth scale, the Research Self Efficacy Scale (Bieschke, Bishop, & Garcia), probes the knowledge and skills necessary for research success as a graduate student. Though some of the survey items focus on writing and communication of results, it was important to study the situated nature of writing as a part of a holistic graduate career. For example, students may have strong research self-efficacy and high writing apprehension, and might fare well in an engineering graduate program despite the writing apprehension. Thinking about the social nature of graduate school and the purpose of engineering writing to be a part of the entire socialization process means that these research components, which are normally of focus in graduate engineering education, should not be ignored.

The entirety of the survey deployed to participants is included in Appendix A. Some items were modified slightly in order to better fit the context of graduate engineering academic writing, especially from the surveys that were for a more general or undergraduate audience. The modified items are denoted with a footnote that shows the original item from the literature source.

3.3.1 Inventory of Graduate Writing Processes

Lavelle and Bushrow (2007) developed and validated the Inventory of Graduate Writing Processes scale in order to more fully understand the approaches that graduate students take while writing. This extended prior work by Lavelle and Zuercher (2001), which developed a similar scale for undergraduate writers. However, since graduate students use writing in different ways, they re-developed and validated the scale using factor analysis. Seven factors were determined to be indicators of graduate writing processes, separated into “deep” writing processes (those that engage with the subjects on which the writing focuses, theses, audience, and revision during writing), and “surface” approaches, which often rely primarily on rules and simply reporting information instead of synthesizing knowledge in new ways.

Four factors (Elaborative, Low-Self Efficacy, No Revision, and Intuitive) correspond with “deep” features of writing. The remaining three factors, Scientist, Task-oriented, and Sculptor, were align with the demonstration of “surface”-level approaches to writing. Table 3.2 shows the seven factors within the Inventory of Graduate Writing Process along with definitions.

In this study, the Inventory of Graduate Writing Processes will be used to determine the approaches that graduate engineering students use when approaching authentic writing tasks.

Table 3.3 Inventory of Graduate Writing Processes

The Inventory of Graduate Writing Processes (Lavelle & Bushrow, 2007)		
	Factor	**Definitions and Characteristics**
Deep Writing Characteristics	Elaborative	• Writing as a personal investment • Affective orientation toward writing • Writing is part of learning
	Low Self-Efficacy	• Low confidence in writing abilities
	No Revision	• Hesitant toward revision either conceptually or procedurally
	Intuitive	• Relationship with writing as a "sense" • "Hear" the writing or "see" the argument
Surface Writing Characteristics	Scientist	• Structured and disciplined approach to writing; little flexibility in approach
	Task-oriented	• Strong adherence to "rules" of writing • Little self-expression or personal connection to writing
	Sculptor	• Very fluent—pours all thoughts into the writing before heavy revision and editing

The original study was validated with master's students in educational psychology, so the differences in mean factor scores and variance will be interesting to note as a way to distinguish engineering writers from social science writers.

3.3.2 Self-Regulatory Efficacy for Writing

Self-efficacy is defined as one's sustained confidence in their ability to succeed and to have agency in meeting desired goals (Bandura, 1977). Although self-efficacy in general is correlated with student success, self-efficacy is specific to the task at hand. By using a scale developed specifically to understand writing self-efficacy, it is possible to then notice any enacted differences in writing and argumentation patterns between low, moderate, and high self-efficacy writers. Further, low self-efficacy scores may correlate with other dimensions of writing concepts and processes.

To meet this need Zimmerman and Bandura (1994) created the Self-Regulatory Self-Efficacy scale for writing. The 25-item survey assesses "students' perceived capability (a) to execute strategic aspects of the writing process such as planning, organizing and revising compositions; (b) to realize the creating aspects of writing such as generating good topics, writing interesting introductions and overviews; and (c) to execute behavioral self-management of time, motivation, and competing alternative activities" (p. 849). Once the mean writing self-efficacy score is calculated, high- and low- self-efficacy categories are calculated based on the scores that are above and below one standard deviation from the mean. Therefore, the self-efficacy scale is relative to the sample population surveyed.

3.3.3 Graduate Concepts of Academic Writing

This scale is a recent development by Lonka et al (2014), which assesses various concepts that graduate students hold with relationship to writing tasks. The initial survey was conducted using Ph.D. students in social science and medicine, and the results of the writing concepts were correlated with other psychological measures of well-being for graduate students.

For this study, the writing scale developed through this work is interesting in that it characterizes graduate student "concepts" of writing, capturing behavioral processes that affect the cognitive activities of writing. Table 3.3 designates these concepts and their definitions. Used in this study, these concepts will be correlated with other facets of writing in order to more accurately discuss the interplay of various dimensions of writing.

Table 3.4 Graduate Concepts of Writing

Graduate Concepts of Writing (Lonka et al. 2014)	
Concepts	**Definitions and Characteristics**
Writing Blocks	Suffers from writing “paralysis” or the inability to think of what to write, or what to write next
Procrastination	Puts off working on writing tasks
Perfectionism	Often will not finish writing tasks due to continuous editing and revision
Belief in Innate Ability	Believes writing ability is fixed and cannot be enhanced with practice
Knowledge Producing	Writing is a way to build and test knowledge and arguments
Productivity	Stay on task with writing, make progress on writing tasks

3.3.4 Daly-Miller Writing Apprehension Scale

The Daly-Miller Writing-Apprehension Scale (Daly, 1975) has been validated to uncover writing apprehension and attitudes in high school, college, and adult writers. The Daly-Miller Writing Apprehension Scale has not been deployed in graduate engineering student in a multiple or mixed methods context, but the argumentation patterns of “low apprehensives” and “high apprehensives” --to use the language of Daly—could lend insight into how students falling into either of these categories make argumentations differently in a disciplinary context. Just because a writer exhibits traits of high writing apprehension does not mean that she or he is a bad writer or would not be able to win NSF GRFP: It is an indicator of enduring tendencies and attitudes, which may affect writing performance. Rather than offering specific statistics, the tool shows if students are low, moderate, or high-apprehensives (based on standard deviations from the median scores), which can then be correlated with argumentation patterns to lend insight into writing patterns.

3.3.5 Graduate Research Self-Efficacy Scale

The last scale given to participants was the Graduate Research Self-Effiacy Scale, proposed and validated by Bieschke, Bishop, and Garcia (1996). While this scale is not directly or entirely related to writing, the scale asks students their perceived levels of confidence on a long list (75 survey items) of tasks related to graduate level research. Early tasks (e.g., dealing with problem selection and literature reviews), mid-project tasks (e.g. research design and data collection), and end-process tasks (e.g. data analysis, communicating results in written or verbal capacities) were probed. In this study, the aim of using this scale is to diagnose potential correlations between writing-specific disposition or efficacy factors and research self-efficacy, as the majority of graduate student time and efforts is usually spent in a research environment.

3.4 Statistical Analysis Methods for Survey Data

After collecting and cleaning the data submitted by participants, 50 complete NSF GRFP application packages were available to be analyzed. First, the continuous data were tested for normality using the Shapiro-Wilks and all five scales were assessed for internal reliability and validity. Then, a Student's *t*-test was conducted on the Graduate Concepts of Writing and Inventory of Graduate Writing Processes surveys in order to determine if the engineering graduate students differed significantly in their writing patterns from the original (social science) graduate students on whom the survey was validated. Further, descriptive statistics on the data show evidence of the major writing processes and concepts to which the participants subscribe. Next, a correlation matrix was calculated in order to determine statistically significant correlations between the constructs of different surveys. In this way, a richer analysis of the writing attitudes of engineering graduate students is obtained. Strong correlations were further analyzed through qualitative methods to triangulate findings.

3.5 Document and Genre Analysis Methods

Research Statements and Personal Statements uploaded through the survey were analyzed through genre analysis and content analysis methods. Discourse analysis is the general method by which any types of communications are organized, categorized, and studied. A subcomponent of discourse analysis, genre analysis is a more specific and suitable method for analyzing academic, disciplinary, and text-based data. Genre analysis is "a useful tool in describing and relating the linguistic features of a genre to their function and purpose," where a genre of communication can be defined by recognizable purpose, features, and conventions, which vary by community (Ahamad & Yusof, 2012). This has been used in literature to categorize the content, features, and style of different disciplines: The English for Specific Purposes (ESP) paradigms seek to characterize the similarities and differences in rhetorical organization in discipline specific texts (Bhatia, 1999).

Although several models exist that seek to categorize academic and disciplinary genres, the CARS (Create A Research Space) model is the foundational model of genre analysis in the field of applied linguistics initiated by Swales (1990). In genre analysis, the objective of the research is to understand the reasons and underlying purposes behind each sentence(s) to map how the document progresses through linguistic “moves” and “steps” from idea to idea. The collection of these moves and steps is then generalized to represent the corpus of documents and the genre as a whole, calling attention to particular features within a corpus of documents (Kanoksilapatham, 2005). Many genre analyses also have impacts on academic literacies research, which seeks to understand how people come to understand the written, oral, and unrecorded expectations and norms of academic disciplines (Lea & Street, 1998, 1999, 2006; Lillis & Scott, 2008; Riaza, 1997).The development of a genre analysis codebook that meets the needs of this specific corpus of documents (NSF GRFP research statements, particularly) was developed and will be presented in Chapter Five.

3.6 Limitations

Survey limitations result from the fact that survey data is self-reported, which can alter some participants’ responses. Since the topic of writing dispositions and attitudes is perhaps not as sensitive as other topics (e.g., gender and race), there may be less impetus to be untruthful. In addition, writing is an activity that is tied easily to self-confidence and self-perception (Onwuegbuzie, 1999), so results may be skewed if less-experienced graduate students perceive that they are excellent writers since they just won NSF GRFP. However, by accessing writing attitudes, perceptions, and self-efficacy through several different scales, internal reliability will perhaps be increased. Partnering the survey results with analysis of the discourse patterns will result in triangulation and crystallization of data (Vogt, Gardner, & Haeffele, 2012; Creswell & Clark, 2007; Johnson & Onwuegbuzie, 2007) to draw overarching conclusions.

The major limitation to document analysis methods is that the data is retrospective and static; that is, it is impossible to see the writers' process in the analysis of the documents. Additionally, due to the large-scale data collection methods, random sampling of documents from respondents, and the nature of the study, member checks (Rubin & Rubin, 2012; Creswell, 2012) could not employed to clarify meanings with the writers of the application packages. Some of the survey scales may offer an insight into the writing attitudes behind the respondents' documents; however, it is important to remember that the judging of academic writing (journal review, judging of NSF GRFP essays, etc.) always takes place outside the control of the writer (i.e., the words communicated are open to interpretation by the judge, who is not interested in what the writer meant, only what she or he as the judge of quality and disciplinary excellence actually thought the writer said.)

One major limitation of the study overall concerns the question of whether or not NSF GRFP as a research venue promotes the "self-selecting" process of students who apply. In other words, graduate students applying are likely high performers, confident in their decisions and qualifications to come to graduate school, and may have adopted the disciplinary voice of their research community. This point has merit, and after much reflection, I have compiled two main thoughts regarding the potential limitation as I have planned and conducted this research.

First, a graduate student's research confidence is not equivalent with a graduate student's writing confidence. As Bloom (1985) points out, writing anxiety might plague those who are "neither anxious, nor a writer" (p. 119), and the less crippling effects of writing apprehension are affiliated with the "enduring tendencies" of the writer, but can be overcome with practice and if the writer finds value in her or his work (Daly, 1985, p. 44). Therefore, just because a student is a competent researcher and has developed a healthy confidence in her or his scholarly abilities may not mean that the student is a strong or confident writer.

Second, even if we were to assume that all students applying to NSF GRFP were competent graduate level engineering writers, many aspects of engineering education use "expert vs. novice" studies to inform classroom techniques that promote expert-like habits of mind (for example, see Atman et al., 2007, in the context of engineering design thinking). In this case, studying the argumentation patterns of strong engineering graduate students may help define areas where cognitively, different processes happen with expert disciplinary writers than with novice writers attempting to write in their disciplines. If this is the case, it may be interesting to map the patterns of competent engineering writers, and then perform a follow-up study of novice and un-confident graduate student writers working on similar tasks in order to make this difference known to the research community. This approach has been used many times in engineering design research to point out areas where experts are not only more efficient at problem-scoping and problem-solving, but their mental processes differ entirely from novices performing the same engineering design task (Atman, Chimka, Bursic, & Nachtman, 1999; Mosborg, Adams, Kim, Atman, Turns, & Cardella, 2005; Schön, 1983; Atman, Adams, Mosburg, Cardella, Turns, & Saleem, 2008). Since writing, like design, is both situated and cognitive, I would not expect the same kinds of discrepancies to exist between strong and weak writers, even at the graduate level. Follow-up studies regarding writing practices of underdeveloped writers in engineering will be an excellent complement to this study in order to research the gap that, right now, is theoretical.

A final limitation of the study is that, per the eligibility requirements of NSF GRFP, international students are not eligible for the award. A large percentage of engineering graduate students across the U.S. may fit this category and would not be sampled. Although there are not any international students in the participant pool, three participants noted speaking a language other than English as a first language.

CHAPTER 4. CORRELATION OF STATISTICAL WRITING CONSTRUCTS FOR GRADUATE ENGINEERING STUDENTS

4.1 Introduction

This chapter presents the statistical survey results from the quantitative portion of the study, guiding study on research question three, which seeks to understand statistical patterns in the participants' conceptions of engineering writing in the affective domain. As a reminder, five published surveys studying writing, graduate student writing, and research were deployed to survey participants, who also uploaded their winning NSF GRFP research statements and teaching statements. The remainder of this chapter will be dedicated to survey analysis, findings, discussion, recommendations, and conclusions.

4.2 Results

4.2.1 Reliability and Validity

Reliability for the present data for all five scales was calculated in terms of Cronbach's alpha. Much literature has been devoted to the uses of Cronbach's alpha (or Coefficient alpha) to determine internal reliability of survey constructs (Schmitt, 1996; Litwin, 1995). Although the higher the alpha coefficient, the better indication of homogeneity (unidirectionality) and interrelationship of the survey items, the alpha level can be artificially inflated with a higher redundancy of items (items that measure the same idea in very similar terms) and with the length of the survey. Although Cronbach alpha values are generally considered acceptable if $\alpha \geq 0.60$, Bieschke, Bishop, and Garcia (1996) note that acceptable levels of alpha are dependent on test purposes, and that high values of internal consistency may not be as critical for research scales (rather than decision-making or predictive scales.) The construct reliabilities, means, and standard deviations for the five scales are presented in Table 4.1.

While many of the Cronbach alpha values fall within or close to the acceptable limit for internal reliability, there are a few very low values (Perfectionism, Task-Orientation). The scale items that make up these constructs, while grouped into a single theme, have no repetition in the questions, which may be one of the causes for low levels of internal reliability. In addition, the different populations of survey participants and their pre-existing relationships and conceptions of writing tasks may be different: Academic writing for educational psychology students, or medical students, or social science students may be differently defined than academic writing for engineers, who, in this study, were may have been guided to be thinking about the NSF GRFP as the writing task of interest based on the arrangement of the deployed survey.

Table 4.1: Reliabilities, Means, and Standard Deviations of the Scales Employed

Reliabilities, Means, and Standard Deviations of Scales and Subscales Employed						
	Present Study			Original Study		
	Reliability (Cronbach's alpha)	Mean	SD	Reliability (Cronbach's alpha)	Mean	SD
Graduate Writing Processes (Lavelle & Bushrow)						
Elaborative	0.68	32	2.82	0.82	30.25	5.61
Low Self-Efficacy	0.76	27.75	2.47	0.63	25.72	4.3
No Revision	0.81	21	2.60	0.80	19.78	4.78
Intuitive	0.54	37	3.59	0.77	35.11	4.73
Scientist	0.54	21	2.26	0.43	27.62	2.62
Task-Oriented	0.28	18	2.20	0.56	17.99	2.97
Sculptor	0.46	14.5	2.45	0.42	15.24	2.32
Graduate Concepts of Writing (Lonka et al)						
Blocks	0.57	2.3	0.68	0.60	2.3	0.67
Procrastination	0.61	2.9	0.84	0.81	2.8	0.95
Perfectionism	0.17	2.0	0.45	0.64	2.7	0.79
Innate Ability	0.60	1.5	0.50	0.75	4.4	0.47
Knowledge-Transforming	0.56	4.3	0.39	0.63	2	0.88
Productivity	0.72	2.5	0.78	0.76	2.7	0.83
Research Self-Efficacy Scale (Bieschke, Bishop & Garcia)						
Conceptualization	0.57	74.20	13.81	0.92	84.42	16.12
Implementation	0.92	72.50	11.72	0.96	76.58	14.49
Early Tasks	0.91	75.67	11.47	0.75	67.27	25.39
Presenting the Results	0.78	76.50	11.99	0.91	76.48	18.83
Writing Self-Efficacy Scale (Zimmerman & Bandura)	0.82	5.17	1.19	0.91	4.3	1.35
Writing Apprehension Scale (Daly & Miller)	0.91	57.80	13.4	0.94	79.28	18.86

The validity of the scales can be assessed through both non-rigorous and rigorous methods. Face validity and content validity both verify that the survey items are related to writing and the attitudes and perceptions that may influence writing. More rigorous standards of validity can be approached through the criterion validity between related constructs across multiple surveys and other studies. For example, low self-efficacy has been shown in other studies to be a predictor of procrastination (Haycock, McCarthy, & Skay, 1998), and (as will be shown) the Low Self-Efficacy construct from Lavelle and Bushrow's scale (Graduate Writing Processes) correlates strongly with the Writing Self-

Efficacy scale from Zimmerman and Bandura, and there is a strong negative correlation between writing self-efficacy and writing apprehension, which has been studied qualitatively by researchers such as Wachholz and Etheridge(1996) and Pajares and Johnson (1994). Construct validity can be further assessed by comparing the descriptive statistics of the various constructs (reliability, means, and standard deviations) of the different populations in Table 4.1. The oldest of the scales was developed in 1975, indicating that at the time of the study it was forty years since its conception; the use of these scales across time and various populations also contributes to construct validity measures (Litwin, 1995).

Missing data were accounted for in the following way: In the initial cleaning of the data, any participants who left an entire survey blank were eliminated from the study population. Because of the length of the overall survey (consisting of the five scales), a few participants missed one or two survey items. In order to still use these data, after the data from each scale were sorted into their representative constructs, the average of the other survey items within that construct were used to fill in the missing data value. Because most of the survey constructs had reasonable internal consistency, this method was used.

4.2.2 Homogeneity of Variances and Normality of Data

For the continuous data (N=50), normality was tested using the Shapiro-Wilks test and tests for skew around the mean. The Central Limit Theory states that for large samples ($N \geq 30$), the sampling distribution of variable means will be normal, in combination with the fact that skew tests for N=50 indicate acceptable symmetries of the means of the variables (Tebbs & Bower, 2013). Shapiro-Wilks tests for normality for the continuous variables indicated no reason to reject the null hypothesis that the distribution is normal ($p > 0.42$, greater than $\alpha=0.05$) (Zaiontz, 2016).

Homogeneity of variances between the sample populations in the original studies were calculated through an F-test. With 95% confidence, none of the variances reported in the original sample are significantly different from the variances calculated in the present study.

4.2.3 Comparing Graduate Writing Processes and Concepts

It is most important to compare the writing processes and concepts of the engineering graduate students with the original participants, especially because in both the Graduate Concepts of Writing survey and the Inventory of Graduate Writing Processes, the original samples consisted of graduate students in educational psychology and arts, social science, and medicine, respectively. In order to compare the data, the construct calculations were performed as per the methods in the original reports, and independent samples Student's t-tests (two-tailed) were performed in order to determine if the average responses of engineering students were statistically significant and at what confidence level.

Table 4.2 shows the engineering students' tendencies in comparison to the original social science study participants with reference to the Graduate Concepts of Writing survey (Lonka et al., 2014). The engineering participants did not differ significantly from the original participants in their tendencies toward writer's block or procrastination. However, the engineering students were less likely ($p<0.001$) to struggle with perfectionism, were less likely ($p<0.001$) to believe that writing skills were an innate ability and were therefore unable to be improved or learned. Effect sizes (Cohen's d) values are also included in the table. Effect sizes less than 0.2 are considered small, between 0.2 and 0.5 are considered moderate, and above 0.5 are considered large. For these factors included in the Graduate Concepts of Writing, the Perfectionism and Innate Ability factors had a large effect size.

However, the engineering participants are slightly less likely ($p < 0.1$) to subscribe to the "Knowledge Producing" component of writing—that writing helps to produce new thoughts and ideas—and to feel less productive when they write. This, too, may be an artifact of the engineering curriculum, which has traditionally not focused on writing-centric tasks: Writing in engineering is usually a means by which to transfer information (through a lab report or memo), rather than a way to produce new arguments or thoughts on a particular subjects. This context for writing may also explain the discrepancy in the "productivity" scores, where the original social science students had higher affinities with "productivity" than the present study of engineering participants. The effects (Cohen's d) values for the Knowledge Producing and Productivity factors were moderate (Table 4.2.)

As discussed, Lavelle and Bushrow (2007) proposed a set of seven writing approaches for graduate students in academic writing tasks. Based on a model developed for undergraduate students, the particular difference for the graduate models is in the inclusion of an Intuitive approach to writing, which Lavelle and Bushrow discuss as an implicit understanding of what "sounds" right according to the task and to the discipline and an ability to "see" an argument. For our purposes, this might be considered an indicator of the extent to which graduate students have internalized the discourse patterns of the engineering community. In the original quantitative studies, the Intuitive factor was the only predictor of writing quality. These data are shown in Table 4.3.

Table 4.2 Engineering Graduate Student Concepts of Writing

Engineering Student Responses Compared with Lonka et al. (2014) Survey Validation				
Writing Concepts	**Eng. Student Mean**	**Difference in Mean (Current Eng. Students- Original Arts, Medicine, and Social Science Grad Students)**	**p value**	**Cohen's d**
Blocks	2.32	0.02	0.84	0.00
Procrastination	2.94	0.14	0.26	0.11
Perfectionism	1.96****	**-0.74**	**1.6E-23**	**1.13**
Belief in Innate Ability	1.46****	**-0.54**	**1.7E-11**	**0.72**
Knowledge Producing	4.30*	**-0.10**	**0.07**	**0.23**
Productivity	2.49*	**-0.21**	**0.07**	**0.25**
*p<0.1 **p<0.05 ***p<0.01 ****p<0.001				

Table 4.3 Engineering Graduate Student Writing Approaches

Engineering Student Responses Compared with Lavelle & Bushrow (2007) Survey Validation				
Writing Processes	**Eng. Student Mean**	**Difference in Mean (Current Eng. Grad Students- Original Ed. Psych Grad Students)**	**p value**	**Cohen's d**
Elaborative	**32.20****	**1.95**	**0.02**	**0.46**
Low Self-Efficacy	**27.75*****	**2.48**	**0.002**	**0.60**
No Revision	**21.04***	**1.26**	**0.09**	**0.34**
Intuitive	**36.95****	**1.84**	**0.02**	**0.44**
Scientist	**20.90******	**-6.72**	**1.6E-26**	**2.76**
Task	18.36	0.37	0.46	0.14
Sculptor	**14.47***	**-0.77**	**0.10**	**0.32**
*p<0.1 **p<0.05 ***p<0.01 ****p<0.001				

Significant differences at the $p<0.1$ level were found for the "No Revision" factor, where engineering students were more likely to align with this trait with a moderate effect size. The "No Revision" trait, according to Lavelle and Bushrow, is common in graduate students who are often limited with time for tasks and may not think that extra rounds of revision make their writing significantly better. Potentially, engineering students may more closely align with this facet because of the research and coursework constraints on their time, which are not affiliated with writing tasks. The original population of students (educational psychology) may have had more background in courses that require reading and writing—after all, 76% of the NSF GRFP winning engineering students surveyed responded they had taken no writing-intensive classes in the last two years—and therefore may value the process of revision in writing tasks. At this significance level, the "Sculptor" approach of engineering students was less than that of the educational psychology students in the original survey. This facet describes an "All at once" approach to writing, getting all ideas out on paper and then sorting through them for meaning and organization later. Because engineers are trained to be methodical and process-oriented through their scientific and laboratory training, this finding is expected.

The "Elaborative" and "Intuitive" factors were significantly higher for engineering students than for the original students ($p<0.05$, Cohen's $d = 0.46$ and 0.44 respectively). Students aligning with an elaborative factor approach writing as a personal endeavor, making personal meaning through the words. The "Intuitive" factor, as discussed before, aligns with students who know what "sounds right" and the "right way" to say things for a particular audience. Students ranking high in the "intuitive" approach demonstrate their enculturation into the discourse patterns of their discipline, having an affinity of what is appropriate for a disciplinary audience, a subscription to the literacy norms present in publications. Potentially this is an indication of engineering students' research commitments or identities as engineers developed throughout undergraduate and graduate education.

Although engineers had higher alignments with the "Intuitive" factor of writing (which was correlated with writing achievement by Lavelle and Bushrow in their original study), the engineering graduate students also had a statistically significant ($p<0.01$) higher average of "Low Self-Efficacy" scores, with a large effect size. This implies that although students may be able to identify problematic phrasing or language that does not fit in the discipline, for example, they have much lower confidence in their writing abilities. This would also fit with the data showing that the majority of engineering students studied have not been enrolled in writing intensive classes, which may result in these low efficacy scores.

Finally, at the $p<0.001$ level, the original educational psychology graduate students subscribed much more strongly than the engineering students to the "Scientist" approach with a large effect size (Cohen's $d = 2.76$). Writers aligned with this approach see "good" writing happening in a prescribed and formulaic way and are often process oriented and rigid in their writing thinking. Many exhibit fixation characteristics at the sentence level, refusing to move on to a new sentence before the previous one is "right." This may also align with engineering habits of mind engrained during engineering design or laboratory courses; that failure is part of the process, and that there may not be one singular "right" solution to a given problem.

In general, the writing approaches of the engineering graduate students differed from the average approaches and concepts of the educational psychology students initially studied. Since the average score of many of these factors differed between the engineering samples and the social- and life-science populations on which the initial surveys were validated, that means that engineering writing artefacts themselves (e.g. research proposals for NSF GRFP) may differ in structure and organization than many other disciplines, and therefore merit further attention.

4.2.4 Correlation Matrix across Five Writing Scales

Pearson correlations were calculated across the scale constructs in order to construct a correlation matrix showing positive and negative correlations within the five deployed surveys. The matrix is shown in Figure 4.4. As can be seen, there are no significant correlations between any of the writing attitudes, efficacies, approaches, or concepts with either gender or year of eligibility. The significant values ($p<0.05$ and $p<0.01$) are shown in boldface in the matrix.

There are several significant correlations of notice. Within the Lavelle & Bushrow Writing Approaches survey, significant positive correlations were found between Elaborative and Intuitive, Elaborative and Low Self-Efficacy, and Intuitive and Task. One interpretation of these relationships indicate that engineering writers who invest much personal meaning into their work (Elaborative) may find that their professional engineering identity can help them “feel” what is important within the discipline, while other writers might actually be affected negatively by the “personal” nature of writing in academic writing, especially if they do not feel confident in their academic identity, that would result in low-self efficacy in writing tasks. The “Task” factor as a surface approach to writing correlates positively with the deep approach of “Intuitive” writing, potentially as it applies to disciplinary writers who understand the specific parts of a type of academic writing, why they are important, what information the section is intended to convey, and then can systematically complete those tasks according to their intuitive understanding of the audience and task.

The correlation of constructs within the Lonka et al Writing Concepts found significant positive correlations between Blocks and Procrastination, Blocks and Perfectionism, and Knowledge Forming and Procrastination. Significantly negative correlations were found between Blocks and Productivity, Procrastination and Productivity, and Blocks and Knowledge Transforming.

Many of these relationships may seem rather obvious and validated through anecdotal evidence, such as the correlations between Blocks and Procrastination and Perfectionism, and Productivity. The relationships of Procrastination and Blocks with Knowledge Transforming writing concepts are more interesting. As a reminder, writers who score highly in the knowledge-transforming concept of writing understand that writing is a venue to express and transform ideas from one venue into another venue in a professional setting. One explanation, then, for the negative correlation between blocks and knowledge-transforming is that writers who are working to truly understand, make meaning from their writing may actually experience less block because writing is a learning process rather than an overwhelming task to be accomplished. The positive correlation between Knowledge Forming and Procrastination may be due to engineers’ lack of training in using writing as a tool to produce knowledge, rather than simply communicate findings, as discussed above, which may lead to procrastinative tendencies toward writing.

Strong correlations ($p<0.01$) exist between writing self-efficacy and writing apprehension scores. Thus, the higher one's confidence and efficacy with writing, the lower the apprehension toward a given writing task and vice versa. It is important to remember that high writing apprehension and low writing self-efficacy are not indicators of *poor* writing: Indeed all the writers who took these scales won a national fellowship based at least in part on their ability to communicate a research idea to a panel of disciplinary experts. Therefore, it is possible for students to overcome these dispositions for writing such that they are not prohibitively overwhelming. Strong positive correlations ($p<0.01$) exist between writing apprehension and the tendencies toward writer's block, perfectionism, and procrastination, and are negatively correlated with productivity, as might be intuitively expected. Similarly, strong negative correlations ($p<0.01$) exist between writing self-efficacy and block, perfectionism, and procrastination, with a positive correlation between writing self-efficacy and productivity.

Between the Concepts and Processes surveys, significant positive correlations ($p<0.05$) exist between the Sculptor process and tendency toward block. Since the Sculptor process can be described as a "brain dump," it may be difficult when writers are faced with a task on which they are not comfortable writing or lack expertise. This may lead to writer's block. The positive correlations ($p<0.05$) between the Intuitive approach and Productivity traits demonstrate the antithesis to that dilemma: The intuitive approach

Table 4.4 Correlation Matrix for Writing Scales

Correlation Matrix of Various Writing and Research Scales																		
Variables	Gender	Year	Elaborative	Low Self-Efficacy	No Revision	Intuitive	Scientist	Task	Sculptor	Writing Apprehension	Writing Self-Efficacy	Tendency toward Blocks	Procrastin-ation	Perfection-ism	Perception of Innate Ability	Knowledge Transforming	Productiv-ity	Research Self-Efficacy
Gender	1.0																	
Year	0.1	1.0																
Lavelle & Bushrow (2007)																		
Elaborative	-0.22	0.07	1.00															
Low Self-Efficacy	-0.25	0.10	**0.35***	1.00														
No Revision	-0.01	-0.02	-0.08	-0.01	1.00													
Intuitive	-0.02	-0.06	**0.41****	0.23	-0.04	1.00												
Scientist	-0.11	0.09	0.16	0.30	-0.25	0.18	1.00											
Task	-0.18	0.10	0.15	0.21	0.15	**0.35***	0.09	1.00										
Sculptor	0.08	-0.07	0.03	0.04	-0.03	0.07	0.06	-0.23	1.00									
Daly-Miller (1975)																		
Writing Apprehension	0.01	-0.07	-0.04	0.19	0.21	-0.19	-0.09	**-0.34***	0.10	1.00								
Zimmerman & Bandura (1994)																		
Writing Self-Efficacy	-0.21	0.00	0.01	-0.14	-0.07	0.11	0.17	0.28	-0.04	**-0.51****	1.00							
Lonka et al. (2014)																		
Blocks	0.15	0.09	-0.01	0.18	0.28	-0.18	-0.08	-0.30	**0.36***	**0.69****	**-0.56****	1.00						
Procrastination	0.05	0.29	0.14	0.16	**0.42****	-0.08	-0.01	-0.11	0.18	**0.56****	**-0.48****	**0.70****	1.00					
Perfectionism	0.09	-0.07	0.25	**0.42****	-0.12	0.25	0.11	-0.02	-0.01	**0.42****	**-0.46****	**0.32***	0.26	1.00				
Perception of Innate Ability	0.17	-0.07	0.03	0.01	0.10	0.14	0.03	0.25	-0.13	0.10	-0.11	-0.02	0.15	* 0.32	1.00			
Knowledge Transforming	-0.04	-0.11	**0.42****	0.16	**-0.32***	**0.42****	0.24	0.02	0.06	-0.15	0.14	**-0.34***	**0.33***	0.27	-0.16	1.00		
Productivity	-0.21	-0.21	0.16	0.11	-0.17	**0.32***	0.14	**** 0.40****	0.03	**-0.50****	**0.42****	**-0.55****	**-0.42****	-0.10	0.10	0.25	1.00	
Bieschke, Bishop, & Garcia (1996)																		
Research Self-Efficacy	-0.10	0.23	0.01	0.09	0.03	0.02	-0.03	**0.37***	0.00	**-0.31***	0.13	-0.14	-0.10	0.00	-0.02	-0.13	0.27	1.00
*p<.05 **p<.01																		

demonstrates a writer's familiarity with the language, syntax, and discourse of their academic community, and with that comfort comes fluency and productivity. Very strong positive correlations ($p<0.01$) exist between Task-based writing processes and productivity; Intuitive processes with Knowledge Transforming concepts; Elaborative processes with Knowledge Transforming concepts; and No Revision processes with Procrastination concepts. Therefore, writers who understand what steps are to come next in their personal writing process are more productive.

4.3 Descriptive Statistics for Engineering Survey Outcomes

The survey results were analyzed to determine overall patterns of writing for graduate engineering students. The Daly-Miller measure of writing apprehension and the Zimmerman & Bandura measure for writing self-efficacy are both based on a relative scale, such that participants scoring higher than one standard deviation above the mean are "high apprehensive" or "high self-efficacy" writers, and writers scoring lower than one standard deviation below the mean were considered "low apprehensive" or "low self efficacy" writers according to the survey. These factors provide insight to the rest of the quantitative and qualitative findings.

4.3.1 Engineering Graduate Concepts of Writing

The concepts that graduate engineering participants hold about writing were diagnosed by the Lonka et al. (2014) Graduate Writing Concepts survey. In order to best understand the concepts that participants hold, the frequencies of the two highest scoring categories are reported, and shown in Figure 4.1. By observing the two highest scoring categories, the concepts with which the NSF GRFP engineering winners most affiliate can be better understood.

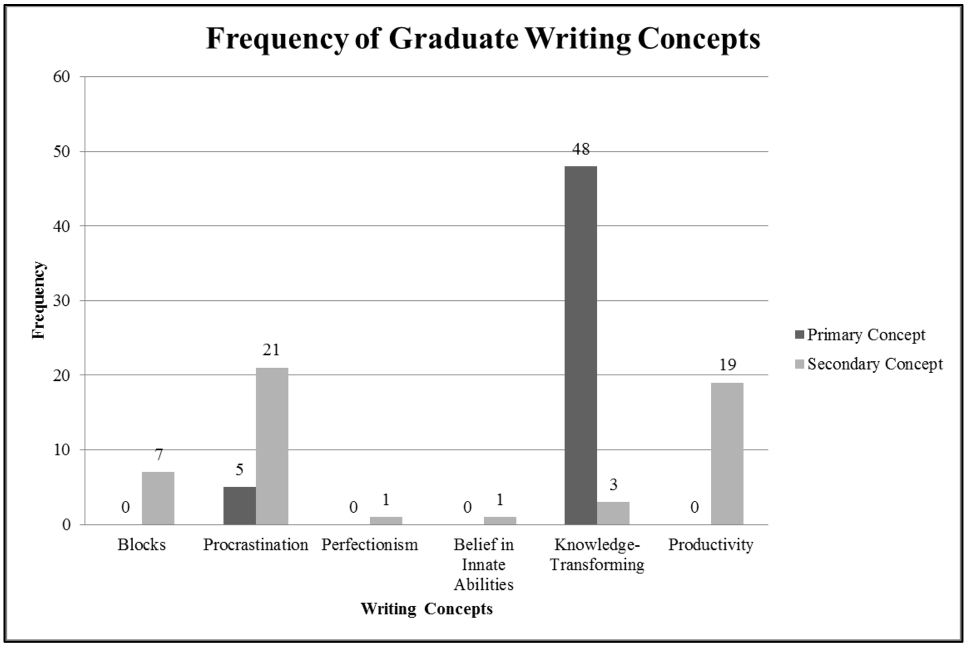


Figure 4.1 Frequency of Graduate Writing Concepts

The Knowledge-Transforming concept of writing is the highest scoring concept, followed by procrastination. The two highest secondary codes are productivity and procrastination. Recalling the statistical correlations discussed earlier, Knowledge-transforming and productivity were significantly correlated. The concept of procrastination as a strong secondary tendency implies that even if the participants do subscribe to the more positive concepts (Knowledge Transforming), they still may struggle with procrastination in their writing.

4.3.2 Engineering Graduate Approaches to Writing

Figure 4.2 shows the frequencies of graduate writing approaches for the primary (highest scoring) and secondary (second-most scoring) approach for the engineering students. As a note, the numbers will not add to 100 (2 times 50 participants' primary and secondary codes) because of ties in the frequencies.

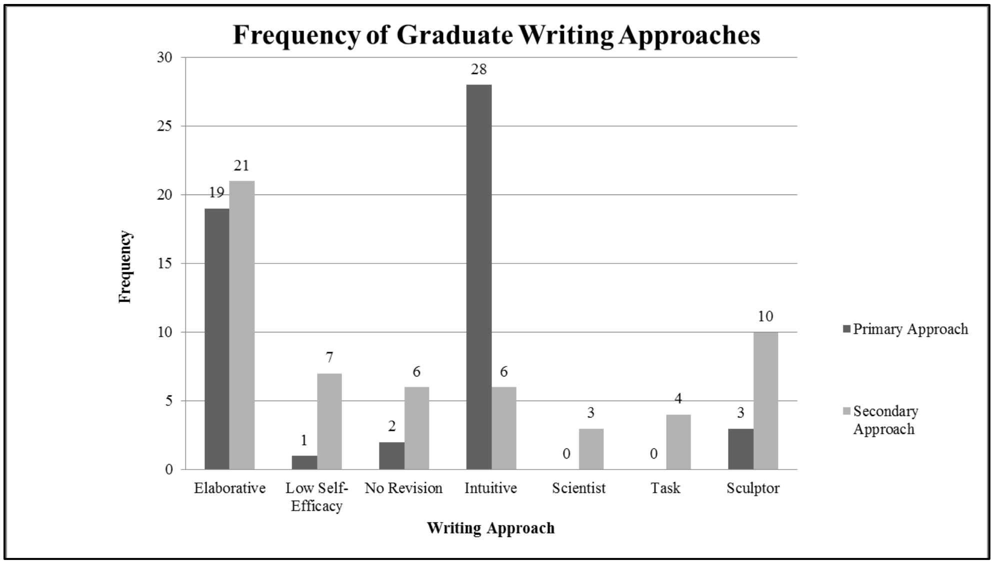


Figure 4.2 Engineering Graduate Writing Approaches

Over half of the participants (28) selected "Intuitive" as their primary approach, and nearly all (47) selected either "Intuitive" or "Elaborative" as their primary approach. These "deep" writing approaches indicate that the graduate engineering students are connecting personally with their writing and understand the disciplinary norms within their discourse because their writing approaches indicate idea fluency, cognizance of the need to elaborate on important topics, and a deeply embedded understanding of what "sounds" right for a disciplinary audience.

The higher values of the secondary approaches in the "surface" approaches ("Scientist", "Task", and "Sculptor") as well as in "Low Self-Efficacy" and "No revision" show that while the engineering students most affiliate with the productive deep approaches of "Intuitive" and "Elaborative," they still have strong tendencies toward approaches that may cause them to struggle with writing tasks overall.

4.3.3 Graduate Research Self-Efficacy

The Graduate Research Self-Efficacy scale divides typical research tasks in science and engineering fields into four categories of research: Early tasks, Conceptualization, Implementation, and Presenting Results. As indicated in the correlation matrix, there is a strong positive correlation ($p<0.05$) between research self-efficacy and task-based conceptions of writing, and a strong negative correlation ($p<0.05$) between research self-efficacy and writing self-efficacy. The latter correlation is particularly interesting in light of a distinct statistical correlation between writing and research. Although correlation cannot be assumed to be causation, engineering students who are confident in their writing abilities may also be more confident researchers, and vice versa. This correlation is (to my knowledge) one of the first in literature to statistically show that writing self-efficacy is linked with research self-efficacy, and the implications for engineering education and the preparation of graduate researchers are that disciplinary and academic writing may lead to better research abilities over all the stages of research. An extension of this logic would lead to a theory that the higher a student's self-efficacy over all the stages of research (beyond simply implementing/conducting research tasks), the more likely they would be to complete their graduate research degree.

Separated by the subcomponents or constructs of research tasks, as proposed by Bieschke, Bishop, and Garcia (1996), descriptive statistics show the variation in scores reported by the study participants in Table 4.5.

Table 4.5 Engineering Research Self-Efficacy Results

Construct of Research Tasks	Mean	SD	Min	Max
Early Tasks	74.20	13.81	30.00	95.00
Conceptualization of Research	72.50	11.72	36.63	89.06
Implementation of Research	75.67	11.47	48.12	93.24
Presenting the Results	76.50	11.99	40.38	96.00
Average Total Research Self-Efficacy Score	**74.71**	**12.24**	**38.78**	**93.33**

Particularly noteworthy is the span from minimum scores to maximum scores in each of the categories. Even though the participants are all deemed promising engineering researchers, by their academic backgrounds, prior success, and their ability to articulate a novel research proposal, they vary widely in their self-efficacy self-ratings in different areas of the research process. The Implementation category has the highest minimum value: One possible explanation of this might be that many undergraduate research experiences or novice graduate engineering projects may focus on a mature project that requires day-to-day laboratory activities, so these participants may be better prepared for those tasks. However, the research process in total starts much earlier, through literature review tasks, conceiving research ideas, proving the ideas, conducting research, analyzing results, and presenting the results to a research group and a wider academic community, which have lower minimum values.

Another noteworthy concept is the relatively high scores provided for the final “stage” of research: Presenting the results. The participants in general have high levels of self-efficacy in presenting research results through oral or written communication.

However, the early-tasks and conceptualization stages include many survey items that are based in academic literacy—the ability to find and synthesize literature, generate effective ideas, and translate them includes elements of writing. It seems as though students are confident with the later stages of research, but in fact, the early stages of independent research (especially in a graduate career, written research proposal milestones) may be more challenging for graduate students. For some students, this part could be debilitating and could lead to attrition.

4.4 Discussion and Recommendations

In total, this portion of research sought to understand how the constructs within the writing process correlate with each other across a variety of surveys meant to analyze writing and research in academic contexts. The two main scales studied (Graduate Concepts of Writing and Graduate Writing Processes) were validated for graduate student populations. The statistical results of this research show that the NSF GRFP engineering winners sampled as part of this research vary in their concepts and processes of writing compared to mostly social science students on whom the surveys were originally validated. Understanding that these writing attitudes and correlations represent the sample of NSF GRFP engineering winners, and because of the small sample size (N = 50), it is not possible to generalize either to all engineering graduate students or all engineers. However, the trends noted are interesting in terms of future work in this area to investigate potential differences between engineering writers. I hypothesize that many potential differences between engineering writers and writers from other disciplines may be attributed to the habits that are encouraged within the engineering undergraduate curriculum, such as positive attitudes toward failure and iteration, optimization instead of perfectionism, and a "growth mindset" for continuous learning of new skills and competencies in writing as a whole (Dweck & Leggett, 1988).

However, the trends and correlations presented in this study indicate that the NSF GRFP engineering students may still struggle with writing apprehension and writer's block, in addition to low writing self-efficacy. This shows that the affective domain is strongly influencing writers, even when the scores for Intuitive and Elaborative processes (which indicate a comfort and fluency with writing and disciplinary discourse) are high.

Only a few recent publications describe quantitative data related to graduate student writing. Currently, Ho (2016) is the one of the only other researchers that currently is studying engineering graduate writing through statistical data: The most recent study found a similar inverse relationship between writing anxiety and writing self-efficacy in English-as-a-Foreign-Language Taiwanese engineering students, backing these statistical correlations with qualitative analyses of writing anxiety in research writing. Another finding from the same study indicated that senior graduate students had higher levels of writing self-efficacy in English research writing tasks than novice and junior students. Since the present study did not research students in the later stages of their graduate careers, we noted no significant correlations between experience in their graduate programs and writing concepts and processes. This is consistent with Ho's findings that there were no differences between Master's students and early-career Ph.D. students, indicating that the large gains in writing self-efficacy do indeed occur in the later stages of a Ph.D., as one is fully enculturated into their engineering discourse community.

To extend these correlations between writing anxiety/apprehension and writing self-efficacy, the present research is the only study to date that combines multiple scales to comprehensively describe the cognitive states of engineering graduate students as they perceive writing tasks and their writing abilities. Although a few of the survey items were modified slightly, they reflected changes in the differing contexts for writing (e.g. changing the words “writing assignment” to “writing task”; see Appendix A for all noted changes), rather than changing the affective relationship with the writing process, maintaining the validity of the results.

Recommendations for engineering writing instructors resulting from this research revolve around the use of personal diagnoses in order to best understand students’ individual cognitive writing conceptions and processes. By using the series of writing surveys presented in this work within writing curricula, writing instructors can better plan their instructional techniques to meet the needs of their students, rather than assuming that all students come with similar prior experiences with and affective relationships to writing. Using these surveys in a formal classroom setting can also help students demystify their own writing processes, promoting metacognitive strategies in writing tasks.

Lavelle and Bushrow (2007) suggest a variety of interventions for graduate student writers based on their affiliations with various writing processes. For example, they suggest that students that strongly subscribe to Intuitive processes of writing may learn writing best through genre studies, studying strong examples of disciplinary writing in order to deconstruct the purposes for and arrangement of arguments, in order to best internalize the genre structures. As another example, students who are exceptionally Task-Oriented on their writing (and indicator of a surface-level relationship with writing) may benefit from writing tasks encouraging timed free writing on a particular subject, practicing the ability of writing to be a "meaning-making" exercise. Conversely, students who are "Sculptors" usually dump their thoughts onto paper, but then often struggle to pull a cohesive argument back out of their writing. These students may benefit from outlining and planning exercises, which encourage a more focused approach to writing.

Although these strategies are strong, especially applied on a case-by-case basis, they may be even more effective when an instructor's understanding of the cognitive writing process is augmented through the student's scores on other writing scales. For example, if an instructor understands that a student is a "Sculptor" who also struggles with writing self-efficacy and is relatively low on the "Intuitive" scores, this student may get "stuck" with an ambiguous and vague first draft, and may not know how to cut most text in order to reveal a single narrative. They may lack the confidence to assert the importance of tackling one underlying story that is affected by multiple other "pieces of the puzzle," and may not want to delete the writing that she or he has worked so hard to put on paper in the first place. In order to meet this student's needs, the appropriate approach may not be to encourage "free writing," but to do exercises related to argument planning through outlining, and then doing a series of timed, focused writing periods in order to "fill in" the outline with relevant thoughts. Too much time, in this circumstance, may permit the student to pursue tangents, or they may get bogged down with finding a citation to meet a certain claim, and this will lead to a further decrease in writing self-efficacy.

In sum, in order to best teach disciplinary writing at the graduate level, instructors may consider learning more about the cognitive writing dispositions and processes of their students, rather than relying on “rules” for “correct writing, and “disparate or reductionist tasks and competitive or normed evaluations which do violence to the nature of writing as a tool of meaning” (Lavelle and Bushrow, 2007, p. 818).

4.5 Conclusions

This chapter reports the statistical findings of five validated writing and research scales that were deployed on a sample of 50 engineering graduate students. The surveys that specifically were designed for graduate writers were compared with the engineering students’ results, finding that graduate NSF GRFP engineering winners differed in their writing concepts and processes than the social science students on which the studies had been validated. A correlation matrix was calculated, comparing the factors influencing writing proficiency across the five studies. Descriptive statistics show that even these highly productive and successful engineering NSF GRFP winners may still struggle with writer’s block, procrastination, and a variety of other affective influences simultaneously. Implications for graduate writing instructors involve using such surveys as a method to diagnose student’s cognitive writing dispositions and tendencies (and to help students diagnose their own), in order to guide structured and tailored interventions to help students achieve high levels of academic literacy in research writing tasks.

CHAPTER 5. GENRE ANALYSIS OF NSF GRFP RESEARCH STATEMENTS

5.1 Introduction

In engineering, the teaching of disciplinary writing is usually outsourced to English or communications departments for undergraduate students, while at the graduate level, academic writing development is likely learned through cognitive apprenticeship under a research advisor to work on journal papers or grants. However, as indicators of merit in academic engineering are based mainly on written deliverables (publications and grant proposals), it is imperative to study how engineering graduate students are learning to write. In addition, proponents of Vygotskian theories of learning posit that the use of language facilitates learning: This sentiment is echoed by social constructivist theories of learning that have inspired “Writing to Learn” and “Writing Across the Curriculum” initiatives in engineering undergraduate curricula. However, despite these efforts, engineering graduate students continue to be guided toward a focus on developing technical skills and knowledge rather than writing skills.

In this way, the purpose of this study is to investigate the linguistic patterns in early-career engineering graduate students in their application packages to a nationally-competitive fellowship program, the National Science Foundation's (NSF) Graduate Research Fellowship Program (GSRP). As most engineering students do not learn disciplinary writing through formal courses in which they can be socialized into the engineering discourse community, the results of this study may inform instructors of technical communication and the broader engineering community of the common patterns for communication upheld in current graduate students. The corpus of NSF GRFP research statements analyzed in the present study are winners of the fellowship, which indicate that these patterns for writing and argumentation have been merited by the panels of disciplinary judges who read the application packages and award the fellowship. Therefore, the results of this study will also show what standards for writing and argumentation are accepted of novice engineering academics by the academic engineering community. This chapter aligns with the research questions regarding the enacted writing strategies for argumentation that graduate students employ in NSF GRFP research proposals.

Genre analysis has been a long-accepted method of systematic analysis of a corpus of documents in order to understand the underlying structure and linguistic features within texts from a discourse community. The most prominent genre analysis work in the field was conducted by Swales (1990, modified in 2004), who proposed that academic research article introductions employ the same four linguistic moves. This model, the Create A Research Space (CARS) model, then inspired generations of applied linguists and English for specific purposes (ESP) scholars to endeavor to understand the structures of other parts of the research article (RA) and other genre-based texts.

Genre analysis of research proposals has been accomplished as it pertains to studying expert writers. The grant proposal or other funding proposals are a unique study in genre, since the genre analysis is actually part of a much larger "genre system" (Moeller and Christensen, 2010), which includes the genre of request for proposals, the social and disciplinary norms and expectations of principal investigators and program officers, and the writing of the grant itself. The texts within proposals are additionally "loaded," as each sentence, though seemingly reporting prior research and proposing new advances, is intended as an element of argumentation, playing to these unspoken norms and expectations from the discourse community.

5.2 Corpus and Method

The corpus analyzed in this study comprises 50 research statements from engineering students who applied for and won the National Science Foundation (NSF) Graduate Research Fellowship Program (GRFP) award. The NSF GRFP is a unique task since the eligibility criteria require that students be in their senior year of their undergraduate education, or a first- or second-year graduate student. The task is limited to a two-page research statement, single spaced (approximately 50 sentences and 1,000 to 1,200 words, depending upon the use of figures and references included in the page limits), and there are several criteria for formatting and requirements in the call for applications, such as font styles and evaluation criteria. Although other scholars have studied the genre of research proposals (Tardy, 2003) and propose genre analyses for CAREER grants (Moeller and Christensen, 2010) and European Union (EU) Grants

(Connor and Mauranen, 1999), this task is different because of a) the two-page limit, b) the limited eligibility for new graduate students, and c) the overarching criteria of broader impact and intellectual merit for review.

5.2.1 Genre Analysis Framework

Preliminary attempts to interpret the consistent trends in language use and argumentation by presence (or omission of) a labelled section of data was first conducted using a rubric-based evaluation method, but this proved to be complex and not a method widely employed by composition and rhetoric scholars to determine document structure. However, these initial inspections of the data were useful in determining a method that was more applicable to the corpus and the intended outcome of the study, which was to determine the language patterns of the participants.

Genre analysis was selected to be the method of evaluation for the NSF GRFP research proposals because the research questions involve mapping recurring argumentation patterns present in the proposal. Frequency analysis of moves and steps and combinations of moves and steps are of interest in the corpus, understanding the variance of these properties with respect to the characteristics of the students who wrote the research proposals. Understanding that the NSF GRFP is nationally competitive for early-career graduate students who are in the process of becoming enculturated into the disciplinary norms and discourse communities of academia and their engineering disciplines, and because of the freedom in structure of the NSF GRFP research statement requirements, there is a wide variance in the research proposals in organization and formatting, just on initial inspection. Genre analysis systematized the evaluation of the recurring patterns of language present in these proposals.

Since this task varies from past work studied, I employed a modified move-step analysis framework based on Swales' (1990) Create a Research Space (CARS) framework for introduction analysis, Kanoksilapatham's (2005) 15-move framework for analyzing biochemistry research articles, and Connor and Mauranen's (1999) framework for European Union Research Grants. These texts provided a strong basis for the characterization of common moves and steps likely found in the NSF GRFP research proposals. Content analysis of the corpus uncovered several additional moves and steps present in this genre because of the specific criteria for the fellowship. Because the research proposal is limited to two pages, including titles, keywords, and any reference citations, figures, or content, many of the sentences, paragraphs, and headings were constructed to meet many argumentation needs simultaneously. In addition, there are no requirements for the sections required for the research proposals, so no limits were placed on the order or placement of specific moves and steps. Although the numerical order of the moves follows a straightforward arrangement based on the previous work of scholars in the ESP field, there were no expectations that all proposals would follow the linear order. Indeed, the various organizational structures of the research proposals provide a wide variety of effective argumentation patterns.

In addition, because of the space limit, linguistic moves were mapped at the sentence level—only a few sentences in all the documents combined did not advance the arguments in deliberate way. The resulting genre analysis framework consists of nine linguistic moves and subcategorical steps which are presented in Table 5.1. The Moves and Steps are noted in terms of ordinal numerical values, following Swales' (1990) tradition.

I employed a reflexive and iterative coding process in order to achieve a consistent coding schema: Preliminary coding rounds were conducted in order to converge upon a coherent set of moves and steps that were “saturated”—no more new linguistic steps were needed in order to code the data. These preliminary coding rounds were tested by coding the research proposals of random participant numbers to test for the need for new codes. The final coding scheme is shown in Table 5.1, which was used to code the entire corpus.

5.2.2 Procedures

Each of the documents in the corpus was coded through the Move-Step schema presented. The unit of analysis was at the sentence level, and moves and steps were assigned based on the functional criteria of the moves that matched the functional value of the sentence in the document, rather than evaluating formal criteria present within a particular sentence. Certainly, an element of subjectivity in the coding of the moves and steps may be present; however, since the author is an engineer and therefore a member of the discourse community of engineering, the coding of the functions of the sentences are likely consistent with the intended and interpreted functions. The qualitative textual data and genre analysis were quantified in order to determine the frequency distribution of the moves and patterns of moves across the corpus. The overall patterns emerging from the genre analysis were sorted by pattern type, and descriptive correlations were noted between the qualitative types of observed structures and student characteristics of writing apprehension, writing self-efficacy, and writing style. Statistical indicators of dependence (Chi-squared tests) could not be performed because of low expected values: A larger sample size would be needed to determine dependence.

5.3 Trustworthiness of Qualitative Methods and Analysis

There are a variety of ways to prove trustworthiness of data. Krefting (1991) articulates practical ways to demonstrate Guba's(1981) model of trustworthiness that is broken into four components: Credibility, Transferability, Dependability, and Confirmability. One of Krefting's (1991) arguments is that not all qualitative research can be assessed with the same strategies, because of the varied nature of qualitative research methods. In this study, there are certain limitations to establishing traditional measures of credibility, for example, since text-based analysis does not lend itself to member checks or interviews to establish credibility. However, I outline here the ways in which I addressed each of Guba and Lincoln's trustworthiness categories for the genre analysis.

First, I establish credibility of my genre analysis coding methods through the multiple iterations of coding of the corpus and the deep genre analysis literature based through which I ground my data analysis scheme. The transferability of my methods and interpretation can be demonstrated from the fact that I outline my sample population, their characteristics, and my sampling method, as well as my reporting of the Moves-Steps coding schema and the examples that I provide in Figures 5.1-5.8 that demonstrate the application of the coding schema and rationale for why the sentences were coded as such. The dependability of the analysis methods and can be assessed through the transparency of my coding scheme development process and the "dense description of research methods" (Krefting, 1991, p. 217). Lastly, the confirmability of the research is not threatened by social desirability toward me as the researcher, since the participants simply uploaded the same documents that they had submitted to NSF GRFP. However, response bias could certainly limit the types of participants who responded. One example of this is the over-response of women participating in the study as compared to the percentage of graduate women in engineering. To posit the confirmability of the study, my discussion section compares this work to other genre analysis work that has been done in the past shows that my findings are reasonable with those from the rest of the writing research community.

5.4 Results

5.4.1 Definitions of Linguistic Moves and Steps

Table 5.1 shows the finalized coding scheme representing the linguistic moves and steps within the document as per a traditional genre analysis schema. In general, the documents in the corpus followed the general moves in numerical order; however, deviations from the order and regressions to past moves were common. This was expected because the moves were based on prior findings from other scientific subgenres. The ordering of the steps within the framework is not meant to indicate a desired order; rather, they stand for elements of each linguistic move without priority or agenda associated with them. This scheme was then used to define the purpose(s) of each sentence of the research proposals. The following sections outline each linguistic move, noting the purposes and an example of how the moves are used and situated within the engineering writers' research proposals. Other genre analysis studies may cite specific sentences that subscribe to each move or step to exemplify the concept; however, in these examples, I provide a larger

Table 5.1 Linguistic Moves and Steps Present in NSF GRFP Research Statements

	# Documents Containing Move/Step	**Percentage of Total**
Move 1: Announcing the Importance of the Study	**49**	**98%**
1.1 Claiming Importance of the Topic	38	76%
1.2 Statement of Context	41	82%
1.3 How Context Affects Humans	17	34%
1.4 Identifying a Problem that Affects Humans	31	62%
1.5 Identify a Technical Problem	29	58%
Move 2: Preparing for the Present Study	**50**	**100%**
2.1 State of the Field/Current Findings	41	82%
2.2 Establish a Gap in Literature	27	54%
2.3 Proposed Solutions to the Problem	41	82%
2.4 Failings of Previously Proposed Solutions	31	62%
2.5 Indicating a Challenge in Efforts/Literature	42	84%
2.6 Raising a Question	8	16%
2.7 Identify Benefits to a New Approach	35	70%
2.8 Familiarizing Readers with Scientific Background	37	74%
Move 3: Introducing the Present Study	**47**	**94%**
3.1 Stating the Global Objective/Hypothesis/Need	44	88%
3.2 Stating the Intended Outcomes	29	58%
3.3 Stating the Impact of the Study	16	32%
3.4 Benefits, Capabilities, or Attributes of the Study	21	42%
3.5 Statement of Novelty	15	30%
Move 4: Describing Specific Procedures and Methods	**50**	**100%**
4.1 Identification of the Sub-aims or Research Questions	44	88%
4.2 Establish Justification, Rationale, Significance related to Methods	43	86%
4.3 List Materials, Specifications or Resources	24	48%
4.4 Citing Established Procedures and Protocols	29	58%
4.5 Detailing Research Tasks, Procedures, Analysis, or Instrumentation Techniques	49	98%
4.6 Statistical Analysis Techniques	12	24%
4.7 Challenges or Limitations	20	40%
4.8 Scientific Background/Mechanisms by which Method Works	37	74%
Move 5: Identifying Expected/Anticipated Results	**49**	**98%**
5.1 Define Anticipated Outcomes	44	88%
5.2 Impact of Achieving Goal	27	54%
5.3 Comparison with Current Technology	17	34%
5.4 Scientific Explanation of Results	5	10%
5.5 Statement of Scope or Project Completion	2	4%
Move 6: Summary of Solution	**49**	**98%**
6.1 Align Solution with Initial Problem	46	92%
6.2 Identify Additional Benefits to Technical Problems	22	44%
6.3 Identify Additional Benefits to Problems Affecting Humans	13	26%
6.4 Solution Includes Scientific Mechanisms	11	22%
6.5 Summary of Novelty	15	30%
6.6 Summary of Impact	37	74%
Move 7: Adherence to NSF Criteria	**45**	**90%**
7.1 Explicitly Address Intellectual Merit Criteria	25	50%
7.2 Explicitly Address Broader Impacts Criteria	45	90%
Move 8: Statement of Personal Ability to Carry Out Project	**40**	**80%**
Move 9: Address NSF GRFP Award or its Benefits	**9**	**18%**

excerpt, usually a paragraph, in order to see how the moves and steps interact in order to form a cohesive argument.

5.4.1.1 Move 1: Motivating the Importance of the Study

"Global mercury contamination results from direct primary atmospheric and secondary legacy emissions. Inputs of inorganic mercury to reducing environments such as wetlands, soils, and sediments can be converted to methyl mercury, a potent neurotoxin that is both bioaccumulative in food chains and biomagnified within fish. The United Nation's Environment Program attributes nearly 40% of 2010 global anthropogenic mercury emissions to artisanal and small-scale gold mining, more than double that of any other sector." (Participant 4)

Paragraph 1 of 10

Sentence 1:
1.2: Statement of Context
1.4: Identify Problem Affecting Humans (mercury contamination)
1.5: Identify Technical Problem (atmospheric and legacy emissions)

Sentence 2:
1.2: Statement of Context
1.3: How Contexts Affects Humans (inorganic mercury converts to methyl mercury, a neurotoxin)
1.4: Identify Problem Affecting Humans (mercury contamination)
1.5: Identify Technical Problem (bioaccumulation in food chains/fish)

Sentence 3:
1.1: Importance of field/topic (40% attributed to gold mining, United Nations number citation)

Figure 5.1 Example of Genre Move 1

In this example (Figure 5.1) from the first paragraph of Participant 4's research proposal, the three sentences cover all five steps of Move 1, which announces the motivation of the entire study, setting the stage for the proposal that is to come.

While not emotionalizing the study, the first sentence is a broad introduction to the problem(s), the second specifies the problems and the mechanisms by which the problems occur, and the third sentence solidifies the importance by framing the importance within cited numbers and figures. It is evident within this example how each sentence does more than one "job" within the paragraph, and also shows an example of how the linguistic steps within a move do not need to exist in a particular order in order to be compelling.

5.4.1.2 Move 2: Preparing for the Present Study

The example in Figure 5.2 shows the interplay of Move 2 as it relates to Moves 1 and 3. Within this paragraph, the sentences mainly work to prepare the reader for the present study, referring briefly back to an "importance" statistic in order to continue to motivate the need for the work immediately before progressing to the beginning of Move 3: Introducing the present study. This "combination" of moves was not uncommon in the research proposals. Rather than each move accommodating its "own" paragraph, with separate paragraphs allocated to separate moves (or "purposes") the paragraphs tend to focus mainly on one purpose, while also continually referring to previous purposes. However, in order to maintain cohesion, these sentences are not explicitly dedicated to a prior move, but they work in tandem with the overall purpose of the paragraph in order to lead the reader to the next move. This often occurred near the beginnings of the proposal right before the global objective of the study was introduced. Just like in this example, the paragraphs that consisted extensively of Move 2 end in the beginnings of Move 3,

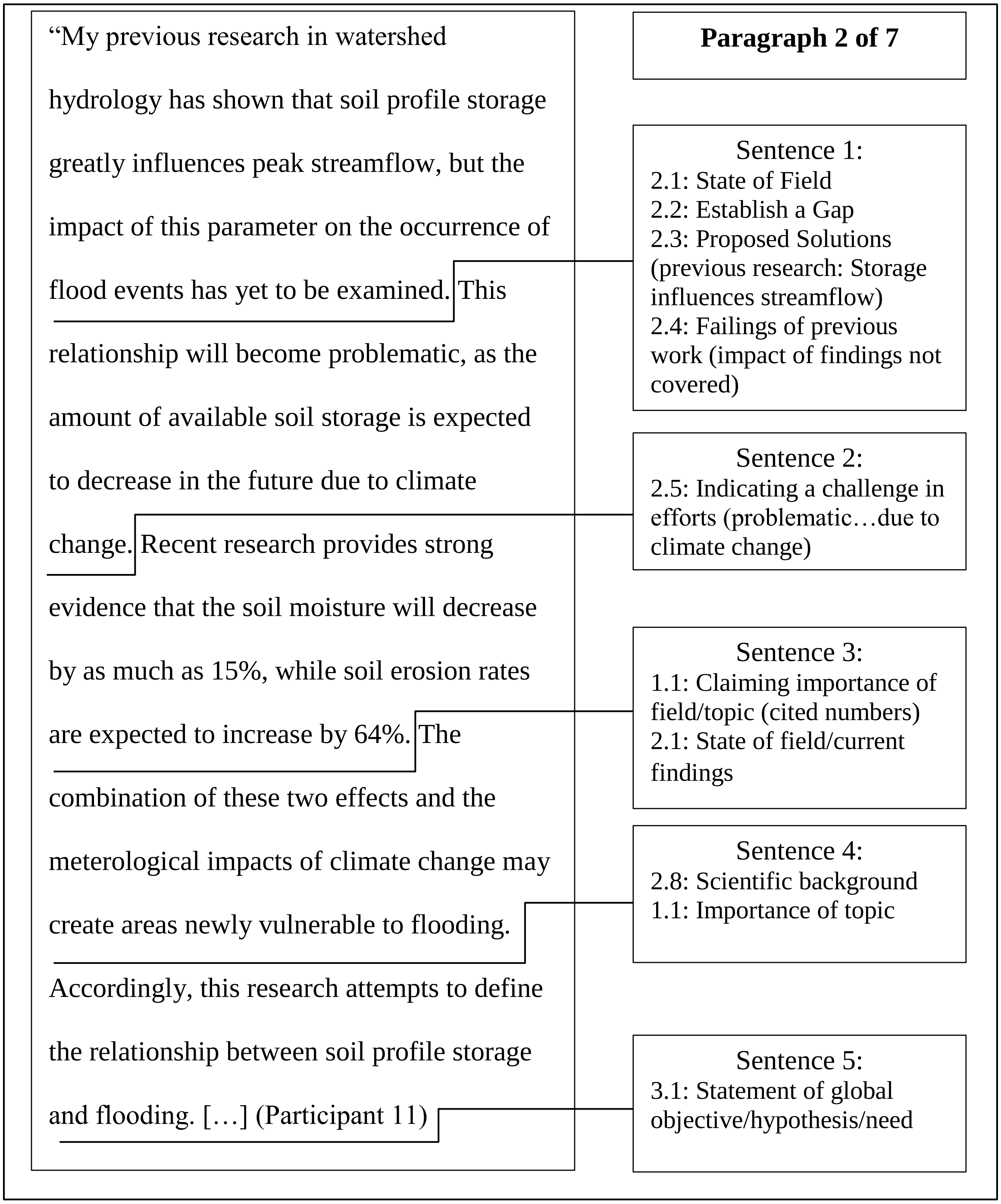


Figure 5.2 Example of Genre Move 2

as a way to strongly introduce the overall objectives, rather than breaking the reader's thought by waiting until the subsequent paragraph for the objective statements to occur.

5.4.1.3 Move 3: Introducing the Present Study

The purpose of Move 3 codes are to give overarching introductions to the forthcoming research steps, potentially including the global objectives, hypotheses, needs, and impacts of the study. Often, participants claim novelty in this code before the minutia of the scientific procedure is discussed. In the excerpt in Figure 5.3, the lead-in from Move 2 (Preparing for the study) is seen, followed by several Move 3 codes stating the global objectives, benefits, and attributes of the study. In this example, each sentence played one specific role within the paragraph, and covered several of the steps within the linguistic move.

5.4.1.4 Move 4: Describing Specific Procedures or Methods

An example of a Move 4 paragraph is shown in Figure 5.4. In the paragraph, the first sentence is complex in terms of its purpose to the argument. Not only is it filling several Move 3 steps, but it introduces Move 4 procedures while alluding to the expected outcomes (Move 5). Similarly, the other sentences play dual roles as well. The pairing of Move 4.5 (A specific task, method, analysis, or instrumentation technique) with Move 4.2 (Rationale or justification) was a common combination of moves present in the

"While recent work shows great promise for the construction of designer glycosylation pathways in *E.coli*, there is still a critical need to bring yield to production scale by tackling bottlenecks in pathway enzyme expression and cell metabolism. Towards this end, an array of new RNA-based tools at the cutting-edge of synthetic biology is being engineered to optimize metabolic pathways by regulating every aspect of gene expression. I propose to use emerging RNA regulators, namely RNA translation control elements and synthetic small RNAs, to optimize a synthetic glycosylation pathway in *E. coli* by tuning pathway enzyme expression and dynamically reducing metabolic bottlenecks. I will focus my efforts on a recently engineered pathway for asparagine-linked (*N*-linked) glycosylation that involves the expression of multiple heterologous enzymes in *E. coli*. This pathway is ideal for optimization because it synthesizes the core glycan structure found on most therapeutic proteins.

Paragraph 2 of 8

Sentence 1:
2.5: Indicating a challenge in previous efforts/literature

Sentence 2:
2.1: State of the field/current findings ("an array of new RNA-based tools at the cutting edge of synthetic biology…")

Sentence 3:
3.4: Benefits, capabilities, and attributes of the study ("dynamically reducing metabolic bottlenecks")

Sentence 4:
3.5: Statement of novelty ("recently engineered")

Sentence 5:
3.4: Benefits, capabilities, and attributes of the study ("ideal for optimization

Figure 5.3 Example of Genre Move 3

"[…]Through the use of real time sampling/analysis on a cutting-edge ultrahigh resolution mass spectrometer (MS), we will produce the first isomer-specific comprehensive data set on oxidized VOCs and I/SVOCs measured in the atmosphere.	**Paragraph 6 of 8** *Sentence 1: Move 2.1* *Sentence 2: Move 2.2:*
Measurements will be made at the [University] Air Monitoring Station, which is uniquely situated to observe air parcels traveling over the ocean undergoing oxidation while isolated from fresh emissions.	Sentence 3: 3.4: Benefits, capabilities, attributes 3.5: Novelty 4.1: Aims/Goals ("we will produce") 4.2: Justification/Rationale (will produce the data set *because* of the real-time sampling abilities) 5.1: Anticipated Results (The overall goal of the project is
This array of data captures the spectrum of oxidation steps needed to decipher the complete picture of chemical pathways.	Sentence 4: 4.5: Analysis and instrumentation techniques 4.2: Justification (for using the Air Monitoring Station)
Source apportionment and factor analyses will allow for the statistical separation of independent processes within a very complex mixture and will allow us to elucidate the array of both emissions and chemical processes impacting the atmosphere.	Sentence 5: 4.2: Rationale/Explanation ("to decipher")
The analysis of the chemical mechanisms and products present in the very powerful data set will require extensive atmospheric chemistry and Bayesian factor analysis for source apportionment calculations; my previous experience as a chemist and mathematician will serve as a boon to these efforts.	Sentence 6: 4.6: Statistical analysis techniques 4.2: Rationale (techniques "allow us to elucidate the array…")
	Sentence 7: 4.5: Detailing analysis techniques 4.6: Statistical techniques ("Bayesian factor analysis") 4.8: Scientific mechanisms ("chemical mechanisms present…will require…")

Figure 5.4 Example of Genre Move 4

methods sections of the documents, as students justified their use of their experimental techniques. As a form of argumentation, this use of justification is not for the use of the writer (participant), but is intended to show an understand the parameters for and reasons to use a specific technique for the judges. This combination of moves similarly bolsters the overall goals and claims within Move 3, as well as make progress toward the realization of Move 5 expected/anticipated results.

5.4.1.5 Move 5: Identifying Expected/Anticipated Results

Examples of Move 5 are shown in Figure 4.5, where the participant is describing a non-physical research output, a model for a particular chemical management process.

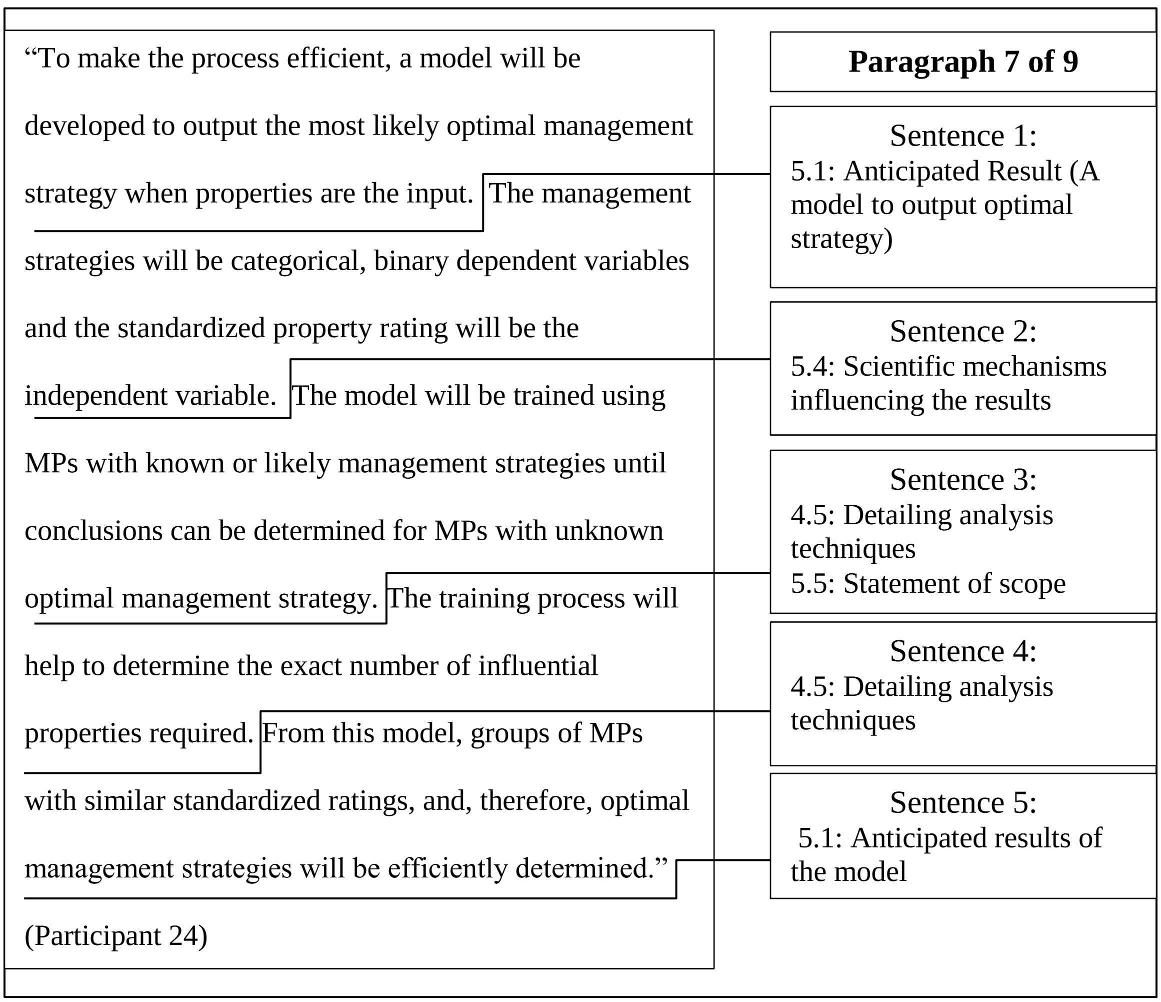


Figure 5.5 Example of Genre Move 5

This example also shows a participant who (in Sentence 3) regresses to Move 4 (methods) in order to clarify a particular process or way in which the "result" of the research would be used.

5.4.1.6 Move 6: Summary of Solution and Move 7: Addressing Criteria of NSF GRFP

The role of linguistic move 6 is to provide a summary of the solution; however, since the task is limited on space, the summary of solutions usually was combined in some aspect with the intellectual merits and/or broader impact of the research, while also aligning with the initial problem posed in the early moves of the document. Most participants kept this "symmetric" format, solving the exact problem they had proposed as a gap or a failing in Move 2.

"**Intellectual Merit**	**Paragraph 7 of 11**
The success of this research will offer new techniques to advance the national health.	Sentence 1: 7.1 Intellectual Merit
A reliable robotic therapy will result in reduced health care costs and novel therapeutic techniques.	Sentence 2: 6.6: Summary of impact
These new techniques will transform the filed of rehabilitation and spur new research into the important aspects of therapy.	Sentence 3: 6.6: Summary of impact
The nature of our proposed controller allows for monitoring of previously unused therapeutic parameters, like the integral of ankle torque during stance.	Sentence 4: 6.6: Summary of impact
" (Participant 44)	Sentence 5: 6.6: Summary of impact

Figure 5.6 Example of Genre Moves 6 and 7

However, some participants had great summaries that were misaligned with the initial problem that they had scoped at the beginnings of the research proposal, and while their solutions via research were still very compelling, they solved a different problem than was originally proposed. Other participants boasted the merits and impacts of their project by not only solving the original problem, but solving additional technical or human problems by way of their research.

5.4.1.7 Move 8: Address Personal Ability to Carry Out Project and Move 9: Address the NSF GRFP and/or its Benefits

Examples of Move 8 are shown in Figure 5.7. This participant chose to have an entire section devoted to their personal potential for success, noting prior research experience, “name-dropping” the prestigious university at which the research is conducted, mentioning access to mentorship, and multidisciplinary educational training. These ways of arguing for personal potentials for success were common in the research proposals, but were not always given their own paragraph. Sometimes they were distributed within methods, or within the anticipated results, or even within the intellectual merit sections of the research statements.

"**Success Potential:** I have been fortunate enough to have a past and present support structure that will allow me to successfully complete the research plan described herein. My three internships at Sandia National Labs' National Solar Thermal Test Facility provided me with a general exposure to CSP technologies and the technical experience needed to perform solar simulator operation, characterization and analysis. Furthermore, the unique facilities at [University], including access to a state-of-the-art HFSS, make it one of the few places worldwide where I can perform this research. My experiences have allowed me to work with researchers with extensive experience in heat transfer, thermochemistry, and CSP design. By drawing on their expertise and my own experience, I can provide a novel and impactful contribution to the field of solar engineering."

(Participant 42)

Paragraph 10 of 10

Sentence 1:
8: Personal ability

Sentence 2:
8: Personal ability

Sentence 3:
8: Personal ability

Sentence 4:
8: Personal ability

Sentence 5:
8: Personal ability

Figure 5.7 Examples of Genre Move 8

The other way in which Move 8 was employed was in terms of the personal abilities that would be gained in doing the proposed research. The Move 9 example, as shown in Figure 5.8, shows one participant who discusses the personal growth that she or he would benefit by conducting the research, opening the opportunities for collaborations across the world.

Paragraph 7 of 10

" I hope to collaborate with energy-sector professionals in cities which have begun to utilize smart grid technologies such as Austin, Texas and Boulder, Colorado in the United States or cities across Europe and Australia.

Sentence 1:
8: Personal Ability/Attributes

Data regarding the cognitive radio networks in these cities would allow me to test the performance of the DSA algorithms under real-world conditions.

Sentence 1:
8: Personal Ability

This collaboration would also allow me to more clearly consider how the algorithms would be implemented with existing software used by grid control centers.

Sentence 1:
8: Personal Ability

Access to the TeraGrid supercomputer network would greatly help with the computational effort involved in running the simulation experiments for this application as well as the initial design of the algorithms.

Sentence 1:
9: Benefits of winning the NSF GRFP (Access to supercomputer)

(Participant 50)

Figure 5.8 Example of Genre Moves 8 and 9

These examples of the linguistic moves and steps employed within the NSF GRFP winners' research proposals illustrate the ways in which the Moves-Steps schema operates in this research context. The excerpts provided, rather than being single-sentence or phrase excerpts, show the dynamic intertwining natures of the roles that each sentence can play in an authentic writing tasks.

5.4.2 Organizational Structures of Research Proposals

Most of the 50 research proposals employed a traditional scientific organizational pattern within the research statements, relying on headers to guide the reader through the separate sections of the research motivation, methods, anticipated findings, and some employed a narrative framework, with few headers or non-traditional headers. Although this component separated the ways in which the research proposals looked on the surface, underlying patterns of linguistic moves and steps proved to be a better indicator of different "styles" of writing in engineering research.

Although it is noted that there is not a "correct order" to either the moves or steps, the general patterns of usage, both from the data and from the genre analyses which based the formation of this analysis show that many research proposals proceed through these common steps overall in these orders. By plotting the Move-Step data as a function of the sentence number (normalized to be a percentage of the document), the characteristic "shape" of each document can be seen visually. Therefore, rather than reading the flow of the document in words, it is possible to see the argumentation structure visually in a plot. Some sentences fulfilled multiple steps within a move, or multiple moves: The data were not assumed to be a technically "mathematical" function of the document, so multiple points on the ordinate (y-axis) could be plotted on a single ordinate (x-axis) point. A visual representation plotting the linguistic moves of each research proposal was generated. These figures are included in Appendix B. After all the figures were generated, they were grouped in terms of the characteristic features of the genre structure, based on the ways in which the author-participants approached the introduction of the motivation, methods, and anticipated results of their proposed projects.

5.4.3 Visual Representations of Argumentation: Characteristic Maps

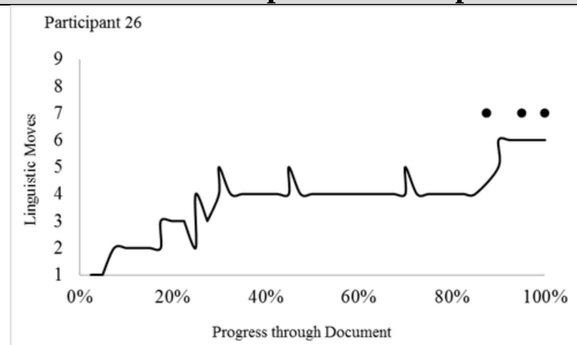
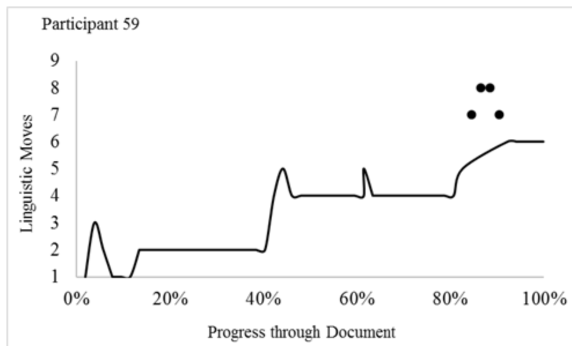
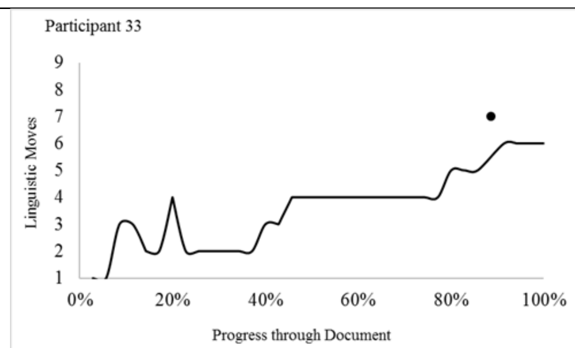
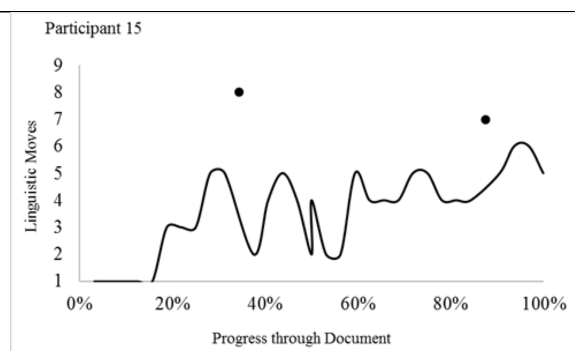
Based on the groupings of the visual characteristic features, the documents in the corpus were sorted into four representative characteristic groups: Process-Oriented, Outcome-oriented, Task-Oriented, and Motivation-Oriented. For each document, the linguistic move of each sentence was plotted as a function of the sentence's position in the document, presented as a normalized percentage representing progression through the document (e.g. sentence number 25 of a 50-sentence document would be plotted at the 50% mark). This resulted in characteristic linguistic maps for all 50 documents in the corpus.

By visual analysis, four categories were determined based on the methods (Move 4) and anticipated results (Move 5) occurrences. Although the visual maps could be sorted according to different linguistic move patterns (for example, the placement of the Moves 7 through 9), it was determined that the relationship between Moves 4 and 5 were responsible for most of the structural variety in the NSF GRFP research statement organization, and therefore would give the most insight to the use of language within the research proposals. The requirements for belonging to a particular characteristic group are listed in Table 5.2, as well as an example of a linguistic map from a document that has that characteristic shape.

The trustworthiness of this analysis and interpretation method can also be considered through Guba and Lincoln's (1981) model for the credibility, transferability, dependability and confirmability of the process. This method is credible because it primarily relies on a coding scheme that was deemed trustworthy in the previous part of the study, my description of the coding and analysis methods, and the consistent reflexivity that I employed when analyzing the data over the course of time through several different methods. The transferability of the data can be demonstrated through the transferability of the initial Moves-Steps coding schema that was demonstrated previously. The dependability of this method can be seen from the examples that will be provided demonstrating the rationale and application of this type of coding scheme, in addition to personal code-recode reliability that was calculated to be 100%. Lastly, the confirmability of this analysis is demonstrated though constant reflexivity and crystallization of methods and findings from the genre analysis and the other quantitative components of the study that come together to interpret the data in light of the contextual factors.

Each of the four overarching characteristics will be described further in the following sections. Each of the four also has particular notable features in terms of the participants' writing beliefs, attitudes, processes and concepts as probed in the quantitative portion of the study.

Table 5.2 Visualization of Argumentation Patterns

Characteristic	Defining Features	Example Genre Map
Process-Oriented (18 Documents)	Argument reaches Move 4 before Move 5; Multiple rounds of Move 4→Move 5 in the heart of the document	
Outcomes-Oriented (11 Documents)	Argument reaches Move 5 before Move 4; Multiple rounds of Move 5→Move 4 in heart of document	
Task-Oriented (12 Documents)	All Move 4 come before Move 5: Usually consists of a large portion of the document centered on methods (Move 4), unbroken by other Moves	
Motivation-Oriented (9 Documents)	Regresses back to Moves 1 and 2 throughout most of the document, resulting in a choppy cyclic visualization	

5.4.3.1 Process-Oriented Characteristics

The characteristic movement of argument for Procedural maps is that move 4 (Methods) is reached before Move 5 (Anticipated results), and that this coupling happens several times throughout the course of the document. Therefore, the focus of the explanation of the research would be to introduce the “steps” and “methods” of the project, in order to reach a summative conclusion. Then, the process is repeated for the next phase of the research project, leading the reader through the process into the anticipated results.

Eighteen of the 50 documents were described as being Process-Oriented. Correlating the writing survey outcomes with the characteristics of participants, the Process-Oriented category also holds the highest percentage of participants with strong affinities to “Productivity” concepts and “Intuitive” approaches. This indicates that the step-wise thought process that is demonstrated in this orientation (moving in small research thrusts, presenting methods and expected results in a cyclic fashion) might indicate how an engineer plans a research design. A high affiliation with the Intuitive writing process was interpreted to mean some level of comfort with disciplinary discourse and thought patterns, so this may be the manifestation of this thought pattern in writing.

5.4.3.2 Outcomes-Oriented Characteristics

Outcomes-Oriented characteristics have the opposite patterns from Process-Oriented Maps: The sections start with the intended outcome, often as an overarching header that serves as an indicator of the intended outcomes of that phase of the project.

Then, the remainder of the paragraph consists of the methods, procedures, and analysis in order to fulfill that sub-aim. In Outcomes-Oriented documents, this cycle occurs several times through the body of the document.

In this study, 11 documents were characterized as Outcomes-Oriented. Interestingly, there were no "high apprehensive" writers in this category, and 40% of the high self-efficacy writers employed this pattern. Also designated by the cyclic, yet methodical approach, this represents an alternative way to present the major anticipated results, and then justify them afterwards with compelling supporting methods/procedures plans.

5.4.3.3 Methods-Oriented Characteristics

Methods-Oriented documents narrate all the methods required for the research plan before discussing anticipated results. A Methods-Oriented map results in a visual majority (around 50%) of the document spent in Move 4 codes. Subsections of task-oriented characteristics exist: Some participants deviate from the Move 4 patterns in order to re-motivate methods through Moves 1, 2, or 3, but do not progress to Move 5 until all Move 4 has been completed, and still has a long plateau of mostly-Move 4 sentences. Only two documents of the 50 were classified as perfectly linear—marching directly from linguistic move to linguistic move without returning to any prior moves throughout the document.

Twelve documents were characterized as being Methods-Oriented. In terms of the participant characteristics, no high self-efficacy writers used this argumentation pattern, and 50% of the low-self efficacy writers employed this pattern. Recalling the statistical correlations between low self-efficacy and “Scientist” and “Task” processes of writing, these writers may be compensating for a lack of writing confidence by following a prescribed format for writing research proposals that may have been taught in a technical writing course. Because of the research design as a document analysis method, no interviews were conducted to confirm or reject this interpretation.

5.4.3.4 Motivation-Oriented Characteristics

The final characteristic is Motivation-Oriented, which describes documents that continually refer to the motivating and preparatory linguistic moves throughout the document. Often, after progressing to Move 3 and introducing the global objectives, these documents return to Moves 1 or 2. Similarly, many of them re-visit these preparatory codes even throughout the methods (Move 4) and results (Move 5). This results in graphs that seem to be very sporadic. In actuality, if the continual returns to motivating moves were to be eliminated, they may show resemblance to another characteristic pattern.

Nine documents were characterized as Motivation-Oriented because of their return to the early linguistic moves. While no low self-efficacy writers used this strategy in their research proposals, this characteristic had the highest amount of participants that affiliated highly with procrastination as a concept of writing. One interpretation of this data is that in writing these documents, the participants knew they could write a decent proposal in a short time, and therefore perhaps did not spend as much time editing and streamlining the argument as some of the other participants. From the statistical data, the procrastination concept correlates strongly with No Revision processes, which would make sense.

However, Procrastination concepts also correlate strongly positive with low Self-Efficacy and strongly negative with Apprehension, which is not seen in this genre pattern. One explanation for this might be that the “low” self-efficacy scores are based on the sample mean, so the survey is comparing strong writers to other strong writers (if the assumption is made that since their research proposals won NSF GRFP, they must be strong enough to deserve the award.)

5.5 Discussion

This research expands the usefulness of genre analysis to not only analyze the specific typology and roles of each sentence within a paragraph, but to see the moves interacting with each other and to visually map the argument progression, which to the best of my knowledge has not been described before in literature. There are several implications for the effect that these findings might have on future writing research and instructional writing interventions for engineering graduate students.

Firstly, one of the easiest ways to teach writing is that paragraphs must progress linearly throughout a document, without reiterating previous ideas in detail. While this is indeed true, this study indicates that in authentic writing contexts, writers can regress to previous sentence *roles* throughout the document, in order to best make a compelling case for the topic being argued. Indeed, the fact that 29 of the 50 documents employed a Process- or Outcomes-Oriented shape, which cycles through miniature research projects, is one effective way to not only present a research plan, but to justify the individual parts of a research plan to a critical disciplinary audience. This step-wise process may convince readers of the feasibility or potential of smaller parts one at a time, rather than introducing the entirety of the study as a whole. This is an element of argumentation that may bolster the author's competency as a researcher in the minds of the reviewers.

Secondly, within the constraints of research proposals, it is also important to help students understand the roles that their sentences play in advancing a greater argument. While it is true that each sentence should capture a single idea, or a short logical progression of ideas, a single sentence can play multiple roles. This perhaps is a case of the adage about "knowing the rules before breaking the rules;" however, at the graduate level, students may not know that they can construct an argumentation structure that is best for their particular argument (as evidenced by the 12 documents that employed the Methods-Oriented pattern, many of which are low self-efficacy writers.)

The genre moves-steps analysis that was conducted through this research shows some interesting features compared with prior genre analyses of scientific and research proposal writing, especially the personal voice that is evidenced especially in Moves 7-9 (the impacts/merit, personal ability to conduct the research, and addressing the NSF GRFP). As discussed, pieces of "extra" information were embedded through these moves that can be classified as rhetorical elements of promotion and legitimacy: The use of citations, references to personal attributes, mention of an advisor or collaborator by name, self-citation of publications or prior results that have already resulted showing the potential of the research, or other elements that "vet" the candidate to the panel of expert judges were often noted in the research proposals. This may be an indication of compliance with the ideas of self-promotion that have been captured in recent literature (Martín and León Pérez, 2014); however, the promotion found in these documents relies on “outside” and indirect promotion, “name-dropping” and pointing out specific attributes in ways that have not been observed within research articles or expert writers in scientific grant proposals.

There are a multitude of confounding factors that limit the “controllability” of using NSF GRFP as a context for graduate writing. Firstly, the application packages are considered as a whole, with the research statement, the personal statement, GPA, GRE scores, and recommendation letters. In addition, the criteria on which the essays are judged can often be subject to a judging panel’s preference, and not ranked on the quality of writing in a rigid way. Lastly, students may have used a variety of other resources in helping them revise, edit, and become successful in the NSF GRFP task. In this way, the NSF GRFP context for this study may not be a way to separate “good” writing from “bad” writing; in fact, only a small percentage of applicants are awarded the fellowship, and many more receive honorable mentions—which were not sampled for this research.

Despite these confounding factors, the genre analysis method presented here is one way to guide an understanding of how some engineering students choose to construct their arguments overall. Rather than evaluating the “goodness” of a research proposal, then, this method is optimal for understanding how the arguments are placed within a document, working toward extending similar strategies into graduate engineering education and engineering communication environments.

5.5.1 Relationship with Existing Literature

Few genre analyses of proposal writing have been conducted in English for Specific Purposes literature: Most genre analyses probing disciplinary discourse analyze research articles within a discipline or between disciplines. Two main studies of genre within proposal writing as a persuasive writing style have been conducted by Connor and Tardy.

In a foundational genre analysis of European Union research proposals, Connor and Mauranen (1999) propose ten recurrent moves from EU research proposals (Territory, Gap, Goal, Means, Reporting Previous Research, Achievements (Anticipated Results), Benefits, Competence, Importance and Compliance.) In reporting their results, they often compared some of their moves with Swales moves (for example, the Means is equivalent to Swales' Move 2.) In addition, they note that the ordering of moves "is not a canonical order, but is one that was common, and one that roughly follows those given in the various guidelines" (p. 53). Similarly, the results from this research also posit that the formatting and specific requirements of the task may guide writers to presenting linguistic moves in various areas of the document. However, Connor and Mauranen do not pursue this by noting the varied placement or arrangement of the various linguistic moves. Additionally, the coding unit for the present study was conducted at the sentence level, whereas Connor and Mauranen's coding was at the "idea" level, usually exemplifying a linguistic move with an entire paragraph rather than understanding any internal structure of the moves. This may have been because they only classified linguistic moves, not steps within the move. Later, Connor (2000) also discussed a continuation of this work, interviewing the writers of the proposals for their interpretations of the moves which were intended in order to validate the moves analysis. Ultimately, this was the first set of work that implied that proposal writing was a specific genre rather than a simple artifact, that disciplinary discourse formed the social rules for disciplinary genre.

In a second study of research proposals, Tardy (2003) studied the proposals for seven NSF CAREER grants as an "investigation of the genre system of grant-proposal writing and the development of genre knowledge of that system" working through activity theory as a theoretical framework (p. 12-13). Through a complex research design employing expert-informant interviews, participant observation of the grant process for two grants, and seven NSF CAREER Grant proposals across a variety of engineering and science fields, as well as observation of a variety of available online and campus-based resources, Tardy noted the importance of citations (and self-citations), as well as the use of visuals and figures within the grant documents. However, this study was not a traditional genre analysis study, and worked to understand the development of genre knowledge. Therefore, the analysis and interpretation of the results was not focused on the development of linguistic moves or steps, so these facets cannot be directly compared. However, she notes that her analysis of multiple sources "suggests that grant writing is fundamentally a social practice that is inextricably linked to a network of other genres" and that "[t]he social aspect of grant writing is clearly seen through the extensive and obligatory social interactions that grant writers engage in over time, in multiple, overlapping discourse communities, and in various roles and discursive activities, such as school, professional conferences, discussions with [Program Officers] and meetings with various university staff and administrators" (p. 32, 33). In relationship with Tardy's work, the present study of NSF GRFP proposals represents a smaller, shorter, student version of the NSF grant, because it is evaluated on the same criteria and similar engagement in disciplinary discourse and priorities are noted. In addition, although the participants were not asked specifically if their research advisors or senior graduate students helped to consult, revise, organize, or edit the research statements, many students applying for NSF GRFP do use a variety of resources in their completion of the task. Tardy's analysis of the role that communication with a variety of resources play in learning a genre can scaffold this discussion: In the context of the NSF GRFP study, I analyze the end product of the social interactions, understanding that many students may have been influenced by a variety of resources (albeit probably not contacting NSF program officers or to the depth that professors writing CAREER grants might access.) An extension of my work as it relates to Tardy's is that the graduate students applying for NSF GRFP are—in a student role—learning the genre knowledge they may need if they pursue academic careers.

5.6 Conclusion

This study analyzed a corpus of 50 NSF GRFP research proposals through a moves-steps genre analysis. A nine-move schema for the genre was proposed and used to map the argumentation patterns within the documents. Findings indicate that many sentences in the restrictive engineering writing task negotiated multiple steps within a single move or even multiple moves at a time. In addition, the linguistic moves were plotted as a function of progression through the document, in order to create visual representations of the genre patterns. These maps were categorized into four characteristics: Outcomes-Oriented, Process-Oriented, Methods-Oriented, and Motivation-Oriented. Each of these patterns aligns with some of the participant characteristics probed in earlier parts of the research projects. Recommendations stemming from this work include encouraging graduate students to understand the purposes of argumentation and arrangement of thoughts, even in a traditional research proposal, as a strictly linear progression of thought may not be the most compelling.

CHAPTER 6. CATEGORIZATION OF THE INTELLECTUAL MERIT AND BROADER IMPACTS CRITERIA FOR NSF GRFP RESEARCH PROPOSALS: DISCIPLINARY ORIENTATIONS

6.1 Introduction

In this chapter, I seek to capture the ways in which NSF GRFP engineering award winners argue for the intellectual merit and broader impacts of their research proposals, as a way of understanding the values with which novice graduate students are aligning. Furthermore, in this particular study, disciplinary differences in these characterizations are noted as they pertain to the development of students' engineering disciplinary identity. This chapter answers the research question about the ways in which graduate students employ argumentation patterns, in this context, thinking about the ways that they argue how their proposals meet the intellectual merit and broader impact criteria of the NSF GRFP, addressing the following sub-questions:

(1) How do engineering graduate students describe and argue for the "intellectual merit" and "broader impact" of NSF GRFP research proposals?

(2) What is the distribution of these themes across disciplines? Do the narratives and argumentation patterns regarding the Merit or Impacts criteria vary according to the discipline

(3) How do these findings describe how students may be developing a disciplinary identity and "narrative of self" through the NSF GRFP research proposal task?

6.2 Literature Review and Theoretical Frameworks

The development of and enactment of engineering identity is a concept that is becoming of interest to engineering education researchers, mostly because of its implications in attracting and retaining a diverse body of students, and therefore, of future engineers (Danielak, Gupta, & Elby, 2014; Capobianco, 2006; Gill, Sharp, Mills, & Franzway, 2008). Formative experiences within engineering can help students (especially those with an ambivalent engineering identity or those at risk of attrition) gain the experiences to help them see themselves as engineers (Litzler & Young, 2012).

Some identity researchers theorize that identity construction is a manifestation of a "narrative of self," which is a fluid and malleable vision of one's own personhood. Winberg (2008) discusses the practices involved in changing identities as "ventriloquation" (citing Bakhtin (1981)) as students learning within a community of practice embody different narratives. In other words, as students first enact a new identity as an expert researcher, they may need to personify (like a ventriloquist—thus, the "ventriloquization") the attitudes, communication patterns, and expectations of their new role. Dannels (2000) suggests that for engineers, identity development occurs "through experiencing disciplinary genres, engaging in disciplinary research, and interpreting disciplinary texts" (p. 7) citing scientific writing and speaking as tied to engineering identity. In fact, the production of engineering rhetoric is important in knowledge construction, socialization, and negotiation of disciplinary tensions within the development of an engineering identity (Dannels, 2002). Engineering and technical communications researchers also argue that a part of this success is that within such verbal-based activities, students are practicing the authentic engineering discourse needed to consider oneself "an engineer" (Dannels, 2002).

At the graduate level, some level of professional or academic identity has been achieved through bachelor's level education. However, the expectations for disciplinary socialization are much stronger within the apprenticeship model of graduate education in the U.S. As graduate students work under a particular member of an academic discipline, they are able to participate more fully in the activities, the expertise, and the communication patterns of the discipline (Allie et al., 2009; Abasi, Akbari & Braves, 2006). Subsequently, the development of an engineering and research identity as a member of a disciplinary community is important for persistence of engineering graduate students: Graduate research advisors cite the lack of socialization into disciplinary norms and practices as one of the main causes for doctoral student attrition over all fields (Artemeva, Logi, & St-Martin, 1999; Austin, 2002).

The importance of developing an engineering disciplinary identity is well studied as it relates to professionalism, skill development, and retention/persistence; the epistemological differences *between* engineering departments have not been covered. That is, scholars generally have not studied what makes mechanical engineers different from civil engineers, or biomedical engineers, or environmental engineers. Most studies involving epistemological change or identity development either focus on engineering students generally (see Adams, Mann, Forin, and Jordan (2009) studying interdisciplinary communication and design thinking and Turner (2000) defining interdisciplinarity), engineering students in various demographic groups (see Capobianco (2006) and Dryburgh (1999)) studying identity development in women engineers) or focus on a population of a homogenous group of engineers from the same subdiscipline: (see Frye, Montfort, Brown, and Adesope (2012) studying civil engineering students, and Dukhan, Schumack, and Daniels (2008) studying mechanical engineering students). Developing a cohesive "definition" of engineering disciplines is becoming increasingly complex as newer "specialty" engineering disciplines are formed in order to meet interdisciplinary technical challenges. For example, Johnson and Schreuders (2003) discuss this very issue in bioengineering undergraduate and graduate degree programs as they seek to "overcome [a] tendency for fragmentation" to achieve a cohesive identity as a discipline (p. 39), identifying a common essence that bridges a variety of research interests in faculty and graduate studies.

In an ever-more interdisciplinary world, with engineering being a "boundary-spanning" (Jesiek, Mazzurco, Trellinger, & Ramane, 2015) profession that crosses disciplinary boundaries to design processes and products solve global issues, some may argue that the lines between disciplines fade. Certainly, there is more boundary work happening, for example, between mechanical engineering and biomedical engineering, chemical engineering and environmental engineering. However, if "fit" into engineering is such a pivotal component to attracting and retaining diverse groups in engineering, then educators may consider the importance of defining and highlighting disciplinary cultures. More "human"-centered engineering subdisciplines, such as biomedical engineering, have capitalized on the impacts of their particular engineering work as they relate to women who seek careers that have a broader impact on human lives: Indeed, biomedical engineering is often cited as a benchmark for women in engineering fields (Etzkowitz, Kemelgor, & Uzzi, 2000), as their demographics tend to reach critical mass at the student and faculty levels, although there is still work to be done in retaining women across all levels in engineering fields (Chesler, Barabino, Bhatia, & Richards-Kortum, 2010).

In this chapter, I seek to investigate disciplinary values and messages through analysis of indicators of research merit and impact within graduate student research proposals awarded the National Science Foundation Graduate Research Fellowship Program (GRFP). Analysis of the discourse within the research proposals shows what the graduate students identify to be the values and impacts of their discipline, and how they envision their future graduate work fitting into the ideals. Rather than seeking to "define" each discipline, this research provides insight into the trends in emphasis which different disciplines in engineering across the U.S. place on various indicators of merit or impact.

This work subscribes to Academic Literacies Theory (Lea & Street, 1998) as a theoretical framework, which posits that for graduate students, "academic literacy" is much more extensive than understanding what specific words or terms mean. Rather, in becoming a member of a discipline, students learn to convey appropriate information, and appropriate amounts of information in the appropriate syntax and context, subscribing to the values of their academic disciplines. For example, engineering faculty in biomedical disciplines may subliminally promote human-centered design or concern for "soft" components of research differently than engineers that deal with human factors in industrial engineering, which may be different than the ways in which designers consider the needs of their users in aerospace disciplines (see Coso & Pritchett, 2015 for an interesting study of cross-disciplinary communication on human factors that highlights these issues.)Therefore, the disciplinary norms, expectations, and rewards systems promote reproduction of disciplinary rhetoric and values: In addition, learning to write for a disciplinary audience encourages graduate students to embody a new narrative which itself promotes the development of disciplinary identity.

6.3 Methods

Summative content analysis methods (Hsieh & Shannon, 2005) were used to describe the categories in which participants argued for intellectual merit and broader impact criteria. Elements of academic merit and broader impact were open coded through a post-positivist lens (Strauss & Corbin, 1998). This paradigm was selected since there is no positivist “correct” answer for how the proposal as a whole demonstrates intellectual merit or broader impact, but the disciplinary panels of reviewers decide the value of the research proposal and the application as a whole in accordance with these criteria. At the end of the coding process, a comprehensive codebook was established that encompassed the elements of broader impact and intellectual merit using both *a priori* codes (examples of criteria elements provided through NSF resources) and emergent codes repeated by multiple participants in their research statements, and through axial coding methods a total of five Intellectual Merit themes and 15 thematic elements were established. At the end, the themes were sorted into the overarching “Intellectual Merit” and “Broader Impacts” themes as defined by the NSF, understanding that there are elements of both that overlap, and that NSF holistically considers the benefits to the research communities and to broader stakeholders to evaluate all proposals including the NSF GRFP.

The theoretical basis of content analysis methods assume that all human artifacts—written work, visual items, various modes of communication—inherently show the priorities and values of the communicator and the groups who are receiving the message (Krippendorf, 1989). Observational inferences can be made by quantifying the occurrences of a particular manifestation of a phenomenon, which can lend insight into the ways in which graduate students show elements of Broader Impact and Intellectual Merit. Although these are the explicit criteria by which the NSF GRFP is judged, the types of activities that students classify within each group unveil the attitudes and perceived importance of academic engineering activities and what the students believe is valued by the disciplinary community. Since these participants did indeed win the competitive national fellowship, it can logically follow that the disciplinary community (via a panel of expert reviewers) confirms these values as being important.

6.4 Results

6.4.1 Themes for Intellectual Merit and Broader Impacts Criteria

Table 1 presents a chart of the themes, or indicators of merit/impact, that were present in the 50 research statements. Many of the impact markers are traditional indicators of academic success, such as the opportunity to publish at conferences or in journals, a statement of impact on the immediate community or extension of results, findings, or tools to other research communities. In the table, it should be noted that many of the examples were coded as multiple categories across both the Intellectual Merit and Broader Impacts criteria. This is an effect of the condensed format of the NSF GRFP research statement being two pages, which requires applicants to be concise and use their sentences to function for multiple purposes. The features of the examples that comply with a particular theme are in boldface. The italics are in the original texts.

Table 6.1 Intellectual Merit Themes, Definitions, and Participant Examples

Evaluation Criteria: Intellectual Merit		
Theme	**Definition**	**Example**
Conferences	Mention conferences generally or specifically	"Once I have determined the effectiveness of my improvements, I plan to continue **presenting the results of my research at conferences such as the International Workshop on MPI.** This will allow others with an interest in the field to learn about or incorporate my ideas and further their own research."(Participant 36).
Journal Publications	Mention disseminating scholarly knowledge through journals and publications, generally or specifically	"I will disseminate my findings to professional and academic communities through presentations at conferences and **publications in journals, such as *Earthquake Engineering and Structural Dynamics, ASCE Journal of Engineering Mechanics,* and *Engineering Structures.*"** (Participant 9)
Extends Body of Knowledge	States how the research extends the body of knowledge: Explicit or implicit in summary statement	"This proposed project will **advance the field of biomaterials by providing comprehensive insight into the total effects and consequences of polyethylene treatments to its mechanical and electrochemical properties.**" (Participant 52).
Extend Findings to Other Fields/ Applications	Discuss other fields or applications that can use advances, generally or specifically	"These models will be made available for use in a **broad range of applications in fields such as aerospace, automotive, heavy industrial equipment, turbomachinery, and structural engineering.**" (Participant 33).
Novelty	*Explicitly* address novelty, innovation, new technologies, etc.	"This specific investigation of plasma deactivation in desalination membranes will **pioneer a novel and potentially crucial method for combatting what may be the biggest challenge in desalination**. Efficient desalination is essential in addressing the world water crisis." (Participant 59).

Participants varied in their levels of precision in these themes: Some participants discussed in great detail the types of findings they expected and to what journals and conferences to which their work would be submitted. Each of these explicit mentions was counted individually in the frequency counts. Other participants mentioned participating in conferences or publishing in peer-reviewed journals more generally, and these were still coded into the respective theme, but only one "count" was given, rather than if the participant discussed specific plans.

Some indicators of intellectual merit blur with the broader impacts criteria, especially for projects that resolve or study technical problems that affect large populations of people. For these projects, participant research statements noted impacts on affected populations, the environment, society as a whole, or the US economy, markets, or energy independence being both markers of broader impact, but indicators of intellectual merit as well, especially when paired with a convincing research gap in the introductory sections of the documents. Table 2 shows the themes designated as Broader Impacts. These were determined by the NSF definition of Broader Impacts, which was included in the Introduction, as well as open coding from the activities that the participant described as contributing to the broader impact.

Table 6.2 Broader Impacts Themes, Definitions, and Participant Examples

Evaluation Criteria: Broader Impacts		
Theme (Total Counts over all Participants)	**Definition**	**Example(s)**
K-12 Education and Outreach (20)	Mention of outreach to school-aged children, generally or specifically	"As I did as an undergrad during **Engineering for Kids**, I will expose **basic aspects of my research to kids to inspire them to pursue technology**—as an example, I could demonstrate how their headphones work through cancellation of sound waves." (Participant 36).
Higher Education (10)	Outcomes related to undergraduate or graduate-level education and involvement	"Since so few opportunities exist for young engineers to work on cross-cultural topics, upon completion of my surveys, **I plan to work with local faculty to create a learning module for the undergraduate "Water Resources Engineering" course about the challenges of water management in the developing world**." (Participant 46).

Table 6.2 Continued

General/Public Education (15)	General education and/or inclusion of the Public in Technological Literacy	"AM [Advanced Manufacturing] is gaining **wide audiences**, and a reduction in 3D printer prices allows large and small high schools, "**maker spaces" (community driven and operated workspaces), and even rural libraries** and schools to purchase these devices. Thus typically underrepresented groups and **people of all ages continue to gain opportunities to dynamically interact with this emerging technology**." (Participant 2)
Broaden Participation in STEM (14)	Mention of accessing populations traditionally underrepresented in Engineering	"I would actively seek out more opportunities to disseminate this research and to make it accessible and interesting to a younger generation future rehabilitation engineers, **hopefully inspiring young girls with no exposure to engineering, like I once was, to explore scientific and engineering fields**." (Participant 44).
Technological Benefits to Disadvantaged Populations (7)	Benefits of research outcomes specifically reach disadvantaged populations in the US or globally	"There is a definite need for cheaper and more effective therapy to reach a broader population. Stroke, which affects a large percentage of the United States, requires therapy that is sometimes prohibitively expensive. This technique, if deemed as effective as traditional therapy, would reduce health care costs and provide more consistent and longer duration therapy to a broader population." (Participant 44)
Outreach to /Involvement of Affected Populations (3)	Plans to involve or educate the populations which the research impacts	"Finally, I plan to **involve local Senegalese in the research, including the sample collection and communication of the findings**; they live on the land, rely on its resources for their livelihood, and are the ones who must ultimately protect it. (…)**This will require environmental education programming in local languages for women's groups, schools and community leaders**, which I plan to carry out in collaboration with Peace Corps Volunteers in the region." (Participant 4).
Benefits to Affected Populations (31)	Research outcomes better the lives of the affected populations	"**Batteries for electric vehicles must be safe** and have a high energy density. Unfortunately, achieving these properties simultaneously remains a challenge. This study will clarify the phenomena linking reactivity and energy density, leading to **safer and longer lasting battery technologies**." (Participant 7)
Environment and Climate (11)	Research outcomes influence the environment and/or climate change	"By laying the groundwork for renewable energy technologies, DR will **lower the barriers to an energy future with lower CO_2 emissions and reduced global climate impact.**" (Participant 1)
Societal Benefits (8)	Explicit mention of *"society"* or *"societal"* impacts	"My project has the potential to simultaneously advance the fundamental science governing remote sensing while also improving existing technologies that **have broad societal impacts**, and being awarded the NSF-GRF would provide me the freedom to extend this research in ways such that it may reach its full potential." (Participant 29).
Economic Benefits (18)	Mention of money-related benefits such as economy, market, industrial, or cost-reduction	"Biomaterials are key in **the $200-bilion-per-year medical device industry**, improving the quality of life for millions around the world." (Participant 48).
General Safety or Health (9)	Health and Safety of the Public, or General Welfare	"By advancing research in mitigation techniques of extreme structural loads, **I hope to contribute to increasing the accessibility of safe structures around the world**." (Participant 9)

Table 6.2 Continued

United States Interests (4)	Domestic Interests, U.S. economy, competitiveness, energy independence, etc.	"The advancement of AM has the potential to be **transformative within the manufacturing industry**, spurring the development of new jobs, encouraging investment in the US, and positioning the US in the **forefront of advanced manufacturing**." (Participant 2).
Energy and Power (18)	Topics affect advances in energy and power generation, or efficiency	As a result of the proposed work, the overall **energy consumption for the U.S. can be reduced**, smart grid performance can be enhanced, and individual **residential building energy use can be decreased**. If **electrical consumption is reduced**, greenhouse gas emissions related to electricity production will also decrease." (Participant 30).
Collaborations (27)	Collaborations with other researchers, universities, non-profits, institutions, or industry	"By **partnering with Ford and the University of Michigan**, this research has the potential to advance the science of energy storage while accelerating the adoption of electrified vehicles." (Participant 7).
Policy and Regulations (12)	Impact, involvement, or collaboration with politicians or decision-makers for maximum benefit of research findings	"To ensure that this research leads to action, I will consult people studying the **policy-making process** throughout the development of the mode. Their knowledge will help to determine the level of the **policy-making process** on which this model would make the most impact." (Participant 24).

Characterization of the Broader Impact themes resulted in a total of 15 categories, as shown in Table 6.2. Categories were created to provide an accurate understanding of the ways in which participants argued for the broader impacts of their research. For example, rather than a broad "Education" theme, categories were defined for those referring to K-12 education, to higher education (college or graduate school levels), and to public education and outreach. In addition, prior versions of the coding schema combined the themes of "Benefits to disadvantaged populations," "Benefits to affected populations," and "Outreach to affected populations." However, the distinctions were made to distinguish between groups of stakeholders who participants noted as particularly disadvantaged (due to socioeconomic status, populations living in areas affected by natural disasters, etc.), and a few participants discussed how they would conduct outreach activities particularly targeting their affected populations (i.e., involving patients in engineering outreach involving therapeutic robotics). Other categories merged in the final iterations of coding: Economic benefits were coded to any impact that was related to markets, profitability, industry, benefiting the economy at large, or any other mention of fiscal or economic effects of research.

6.4.2 Distribution of Criteria Usage across Engineering Disciplines

In an effort to understand some of the ideological commitments of the writers across engineering disciplines, the data were disaggregated by participant discipline, as self-identified during data collection. Since no efforts were made to quota sample by discipline, there is a wide range of participant distribution. Aeronautical and Astronautical Engineering only had one participant, and so those data were grouped with Mechanical Engineering. Similarly, there was one “Ocean Engineering” participant, whose data were grouped with the Civil and Environmental Engineers. The total number of participants is shown in Table 6.3, in addition to the frequency counts and percentage of the discipline’s total codes are reported according to each of the intellectual merit and broader impacts themes characterized.

Table 6.3 Disciplinary Distribution of Themes

Distribution of Themes by Discipline									
Intellectual Merit Themes									
	ABE (N=2)	**BME (N=3)**	**CHE (N=6)**	**CE/ Env and Ocean (N=13)**	**ECE (N=4)**	**Eng. Phys (N=2)**	**MSE (N=3)**	**ME and AAE (N=14)**	**Systems (N=3)**
Conferences	4 (25%)	1 (4%)	1 (3%)	4 (4%)	1 (5%)	3 (18%)	-	5 (4%)	1 (4%)

Table 6.3 Continued

Journal Publications	1 (6%)	1 (4%)	1 (3%)	5 (5%)	-	1 (6%)	-	11 (10%)	1 (4%)
Extends body of knowledge	2 (13%)	10 (43%)	8 (24%)	17 (15%)	4 (20%)	4 (24%)	3 (20%)	13 (12%)	3 (13%)
Extend findings to other fields/ applications	1 (6%)	4 (17%)	5 (15%)	8 (7%)	5 (25%)	2 (12%)	-	11 (10%)	2 (9%)
Novelty	1 (6%)	2 (9%)	-	2 (2%)	2 (10%)	1 (6%)	-	4 (4%)	-
Broader Impact Themes									
	ABE (N=2)	**BME (N=3)**	**CHE (N=6)**	**CE/ Env and Ocean (N=13)**	**ECE (N=4)**	**Eng. Phys (N=2)**	**MSE (N=3)**	**ME and AAE (N=14)**	**Syste ms (N=3)**
Education (K-12)	-	-	1 (3%)	4 (4%)	2 (10%)	1 (6%)	-	11 (10%)	1 (4%)
Higher Education	-	-	-	4 (4%)	-	1 (6%)	-	4 (4%)	1 (4%)
General/Public Education	1 (6%)	1 (4%)		8 (7%)	1 (5%)	-	1 (7%)	6 (6%)	-
Technological Benefits to Disadvantaged Groups	-	-	1 (3%)	3 (3%)	-	-	-	3 (3%)	-
Broaden Participation in STEM	1 (6%)	2 (9%)	1 (3%)	1 (1%)	1 (5%)	-	-	7 (6%)	1 (4%)
Outreach to Affected populations	-	-	-	3 (3%)	-	-	-	1 (1%)	-
Benefits to Affected populations	2 (13%)	1 (4%)	6 (18%)	6 (5%)	1 (5%)	-	1 (7%)	11 (10%)	4 (17%)
Environment and Climate	-	-	1 (3%)	4 (4%)	1 (5%)	-	-	4 (4%)	1 (4%)
Societal Benefit	-	1 (4%)	1 (3%)	2 (2%)	-	1 (6%)	-	3 (3%)	-
Economic Benefits	-	-	3 (9%)	4 (4%)	-	-	2 (13%)	7 (6%)	2 (9%)
General Safety/Health	1(6%)	-	1 (3%)	4 (4%)	-	1 (6%)	2 (13%)	-	-
United States Interests	-	-	-	-	-	-	1 (7%)	2 (2%)	1 (4%)
Energy and Power	-	-	2 (6%)	1 (1%)	2 (10%)	1 (6%)	3 (20%)	7 (6%)	2 (9%)
Collaborations	2 (13%)	-	1 (3%)	23 (21%)	-	1 (6%)	1 (7%)	2 (2%)	2 (9%)
Policy	-	-	-	10 (9%)	-	-	1 (7%)	-	1 (4%)

Table 6.2 Continued

Total Counts	**16**	**23**	**33**	**110**	**20**	**17**	**15**	**109**	**23**
Average Count per Document	**8**	**7.7**	**5.5**	**8.7**	**5.0**	**8.5**	**5.0**	**8.0**	**7.7**
Total Count Intellectual Merit	**9 (56%)**	**18 (78%)**	**15 (45%)**	**35 (32%)**	**12 (60%)**	**11 (65%)**	**3 (20%)**	**42 (39%)**	**7 (30%)**
Average Count Intellectual Merit	**4.5**	**6.1**	**2.5**	**2.8**	**3.0**	**5.5**	**1.0**	**3.2**	**2.3**
Total Count Broader Impacts	**7 (44%)**	**5 (22%)**	**18 (55%)**	**75 (68%)**	**8 (40%)**	**6 (35%)**	**12 (80%)**	**67 (61%)**	**16 (70%)**
Average Count Broader Impact	**3.5**	**1.7**	**3.0**	**5.9**	**2.0**	**3.0**	**4.0**	**4.8**	**5.4**
Key: Agricultural and Biological Engineering (ABE); Biomedical Engineering (BME); Chemical Engineering (CHE); Civil Engineering (CE); Environmental Engineering (Env.); Electrical and Computer Engineering (ECE); Engineering Physics (Eng. Phys.); Materials Science Engineering (MSE); Mechanical Engineering (ME); Aeronautical and Astronautical Engineering (AAE); Ocean Engineering (Ocean); Systems Engineering (Systems)									

The emphasis of certain disciplines in various areas of the chart is widespread. Particularly, the aggregate emphasis (percentiles) between Intellectual Merit criteria and Broader Impact criteria across disciplines in the bottom-most section of Table 4 indicate that some disciplines are primarily "merit" oriented while others are "impacts" oriented, summarized in Figure 6.1:

Merits-oriented Disciplines *(>50% themes classified as Intellectual Merit)*	**Impacts-oriented Disciplines** *(>50% themes classified as Broader Impact)*
• Agricultural and Biological Engineering • Biomedical Engineering • Electrical and Computer Engineering • Engineering Physics	• Chemical Engineering • Civil/Environmental Engineering and Ocean Engineering • Materials Science Engineering • Mechanical Engineering and Aeronautical and Astronautical Engineering • Systems (incl. Industrial) Engineering

Figure 6.1 Merits- and Impacts-Oriented Engineering Disciplines

That Biomedical Engineering participants were so extensively merit-oriented should be of note with respect to prior literature, most of which is conducted at the undergraduate level, which surmises that biomedical engineering has a high number of women because of its human-oriented applications. Similarly, Gilbert (2009) proposes that the gendered nature of departments may have to do with disciplinary values of collaboration and teamwork: That those fields that value both independent and collaborative advances (in the paper, Materials Science Engineering) had higher proportions of women than did Mechanical Engineering, which reproduced hierarchical male-dominated norms. Although this study reports results from a very small number of samples, these data may offer the beginnings of a deeper understanding of disciplinary identity for graduate students. In the present study's data, over three-quarters of the total themes for biomedical engineering are focused on intellectual merits despite the anecdotal linkage between biomedical research with impact on the lives or well-being of groups of people. One reason for this discrepancy may be that they felt like the broader impact to affect humans was so obvious they need not discuss it explicitly within the paragraphs that discuss explicit impacts of the projects. Another alternative or simultaneous explanation is a potential need to maintain engineering "rigor," understanding that human-centered research may be considered outside the typical engineering role.

The other surprising categorization for these data is the impacts-oriented nature of some of the most established engineering disciplines, like civil and mechanical engineering. As one of the oldest disciplines, Mechanical Engineering is one of the most diverse in terms of applications spanning both fundamental and applied research, and although some areas of expertise directly impact human welfare, many may be several product-generations away from applying to the betterment of society. These findings may be explained by the wide distribution of Broader Impacts themes: Mechanical Engineers covered all the categories, including all the education and outreach categories. This may be a reaction of the writers to their discipline's traditional background, thinking of ways to expand the impacts of their work through K-12, higher education, or public venues.

6.5 Discussion

The 50 engineering graduate students described the intellectual merit and broader impacts of their research through a variety of themes, characterized into five broad constructs of intellectual merit and 15 constructs of broader impacts themes. The merits and impact are posed at various levels of specificity, from general claims of importance to the discipline or plans to publish, to the very specific: identifying specific journals to which findings will be submitted. In terms of broader impact of research, some participants extended the technical impacts, outcomes and benefits of their research projects, such as financial gains, effects on the climate or environment, or betterment of human health, to broader impacts that are related to outreach, education, and broadening participation in science, technology, engineering, and mathematics (STEM).

Although the NSF outlines activities that might be considered as Broader Impacts, many students noted specific outreach avenues and activities that directly connected with their research that go beyond the general categories outlined in the NSF Guidelines. As one example, the educational components in the NSF's language, when analyzed according to the themes emerging from the research statements, showed a multifaceted commitment to education at various levels, which were more specific categories than the NSF guidelines showed. This extrapolation of the broader impacts and intellectual merits criteria outside of the explicitly stated activities provided by the National Science Foundation also indicates the development of an identity within research and a commitment to extending one's research into the venues that she or he finds most rewarding. Since the coding of the data occurred through a blend of emergent and *a priori* codes, some participant activities explicitly noted were coded into categories that were different than the language provided by NSF. One example of this is the NSF example of "enhanced infrastructure for research and education" (NSF, 2016). Examples of activities meeting this, according to the emergent coding scheme (which is more specific), would have fallen either into the educational components or the collaboration theme, depending on the context. The participants chose not to use the exact language of this factor from the NSF guidelines, and this is another way in which the student-participants interpreted the criteria in their own ways or were guided toward these interpretations by trusted disciplinary advisors.

Some students aligned their broader impacts work with the education and outreach activities with which their advisor and/or research group are already involved. While this may potentially seem like an easy way to define intellectual merit, we can think of the commitment to service in the light of socialization. This means that in these research-intensive universities, whose researchers conduct world-class research, there exists a commitment to broadening participation, reaching underserved populations of K-12 students, and impacting the community through science and engineering outreach.

This focus and priority is being effectively passed from advisor to student, and then formally announced to the academic community by the early-career graduate students as they assimilate into a research environment and try a new narrative of self, regarding their academic identity. Viewed through academic literacies theory, the narratives employed by these graduate students are meant to closely align with disciplinary values and norms in order to argue most effectively for the merit of the research proposals. The graduate students are practicing their academic literacy through the use of both disciplinary language and jargon and the types of activities that they perceive best demonstrate the intellectual merits and broader impacts of their research proposals.

The main limitations of the study result from the overall small sample size for the population, compounded by the uneven distribution across disciplines, as well as the unknown influence that research advisors or writing mentors had on the students. However, a discussion of disciplinary identity at the graduate level is interesting when considering identity development as an engineer as it relates to persistence and retention rates. While individual variation may occur, disciplinary ideology and identity is a concept that may be discussed with respect to whether the discipline is impact-oriented or merit-oriented.

Noting the sample size limitation, some of the findings were counterintuitive to prior literature regarding engineering identity studies working within specific disciplines; for example, one would expect biomedical engineering to have been more impacts-oriented than merit-oriented. Similarly, the research proposals from mechanical engineers were overwhelmingly concerned with the broader impacts of the work, which may not be expected from one of the oldest and most established engineering disciplines.

Another way of thinking about this difference between the nature of the outcomes of the field has been proposed in a different way through Biglan's classification of higher education academic disciplines (across humanities, social sciences, science and engineering) into hard and soft disciplines, pure and applied outcomes, and life- or non-life-topics of interest (Biglan, 1973; Schommer-Aikins, Duell, & Barker, 2003). While Biglan sorts disciplines into one of eight categories along these themes (e.g. most engineering fields are in the "hard," "applied," and "non-life" category), as future work, we can potentially consider a similar model to map the various engineering disciplines along an axis of "merits" and "impacts" as vocabulary to discuss where disciplinary ideological commitments and values lie.

Although the total sample of participants was relatively large for qualitative analysis, much larger samples within each engineering discipline across the U.S. would be needed to confirm these disciplinary discourses of identity. In light of recent campaigns by the National Academy of Engineers concerning "Messaging for Engineering" (NAE, 2013) and "Changing the Conversation," (NAE, 2008) perhaps the focus of new generations of graduate students have been enculturated into a newer engineering ideal which may focus more explicitly on the impact that engineering can have on human lives, as is the focus of many recruitment campaigns and messages within undergraduate engineering programs as part of diversity campaigns. Indeed, the fact that the National Science Foundation requires the graduate students to meet the same Intellectual Merit and Broader Impacts criteria required by grant awardees may signify a commitment to requiring engineers, future academicians, and researchers to carefully consider the merits and impacts of their work. This is potentially a valuable form of reflective practice (essential for developing expertise (Schön, 1983), and contributes to the definition of the essence of engineering and what it means to be an engineer, although faculty definitions of engineering largely still differ from the proposed messaging (Pawley, 2009).

Although few studies specifically study or report the disciplinary identities or visions for particular engineering disciplines, this research suggests that a more thorough understanding of the ideologies and disciplinary identities may help students select an engineering research discipline that fits their personal epistemologies regarding the purposes and impacts of engineering research careers. Although cutting-edge research is becoming increasingly inter- and multidisciplinary, it is important to understand the relationships of the engineering disciplines to each other. By understanding what each discipline is and is not, students can select to pursue advanced degrees within fields that fit their professional-personal identities merged identities that are developed in graduate school.

Along with this discussion of disciplinary identity as it relates to student identity, another implication of this research is in the use of engineering writing activities to foster engineering identity and commitments within graduate students. Because the NSF GRFP is specifically judged via the criteria of Intellectual Merit and Broader Impacts, applicants frame their research projects around these definitions and begin to think about the ways in which their research activities impact different stakeholders, and/or how they can begin to reach out to extend science and engineering to diverse populations. Indeed, the NSF GRFP can be considered an authentic engineering writing task that helps students "ventriloquize" (Winberg, 2008) their engineering research identities as contributing members of the discipline, which in turn promotes the learning and fluency in technical engineering research rhetoric, which inspires identity development and commitments to their academic choice.

6.6 Future Work

Future work related to these concepts will require more work in terms of what it means to be a Mechanical Engineer (for example), at an undergraduate, graduate, junior career faculty, and senior career faculty member. Studies on engineering students' choice of engineering discipline suggest that the match between disciplinary values and students' self-concepts and values is important, and that better understanding of each discipline may lead to better matches (Ngambeki, 2012). In addition, this topic has not been addressed for graduate students, especially among those graduate students who switch disciplines for their graduate work or between master's and Ph.D. programs. Longitudinally, it may be interesting to map these disciplinary identities over long periods of time, especially in times of significant technological revolution and innovation. This research might seek to answer questions such as "What is the cohesion that brings together often disparate research topics and applications in engineering?" Furthermore, the effects of knowing the disciplinary identities is equally important, and therefore research answering questions like "Is the alignment of disciplinary ideals with personal epistemologies and ideals a good indicator of engineering identity and persistence?" may be an interesting future step for disciplinary discourse and engineering education research.

Outside the participant sample size for the study, the limitations of this study stem from the fact that no data was collected from the panels of disciplinary experts who judged the NSF GRFP winners recruited for this sample. The preferences of the judges—likely disciplinary experts—may have an impact on the types of merit and impact in the awarded research proposals. In addition, the participants were judged on these criteria overall, whereas in this work, I study only the research proposals from the participants. In addition, data was not taken regarding if students had explicit help from their research advisors or senior graduate students that may have influenced their decisions to focus on certain aspects of merit or impact and/or avoid others.

6.7 Conclusion

This research analyzed 50 research proposals from engineering graduate students who won the National Science Foundation's Graduate Research Fellowship Program in 2015, a prestigious national award presented to promising early-career researchers upon their proposal of a worthy research statement, personal statement, and application package. The characterization of the ways in which the Intellectual Merit and Broader Impact criteria were employed in the research proposals showed the ways in which engineering graduate students overall consider the impact and merit of their intended graduate research. Additionally, when disaggregated by discipline, there were differences in the emphases that different disciplines gave in terms of prioritizing the impacts and merits of the research. These distributions may represent facets of engineering disciplinary identity that have been understudied. However, as graduate students new to graduate school are in the process of developing a new “narrative of self” and commitment in an engineering research identity, it is important to understand how differing disciplinary values may affect persistence, in that graduate students may be more committed to staying in academic graduate disciplines which align with their personal ideologies of their engineering.

CHAPTER 7. GENDER DIFFERENCES IN USE OF INTELLECTUAL MERIT AND BORADER IMPACTS CRITERIA

7.1 Overview

In engineering, the underrepresentation of women at all levels has been the focus of large-scale national and university programs across the United States. According to the American Society for Engineering Education, only 21.6% of engineering Ph.D. recipients and 13.8% of tenure-track and tenured engineering faculty are women (Yoder, 2012). Multiple models have been posited to describe reasons for the increasingly widening gaps between numbers of men and women in engineering fields with academic level. The "leaky pipeline" model envisions the pathway into engineering careers as a series of pipes, the junctions of which "leak," with women leaving engineering at each academic junction (between undergraduate and graduate school, for example) (Mavriplis et al., 2010; Blickenstaff, 2005). However, critics of this model feel that this model does not describe women's reasons for leaving engineering, usually preferring a "chilly climate" model (Litzler, Lange, & Brainard, 2005).

At the faculty level, women are often "caught" between societal expectations of women (caring, family-oriented) and an ideal expectation of a researcher (focused, work-oriented) (Case & Richley, 2014; Wolf-Wendel & Ward, 2003). Studies have even shown that women need to achieve more in order to earn tenure compared to their male counterparts (see, for example, Bonawitz & Andel (2009) or Krefting (2003)). Faculty women of color have additional barriers, caught in the “double bind” of both racism and sexism (Ong, Wright, Espinosa, & Orfield, 2011; Kelly & McCann, 2014; Williams, Phillips, & Hall, 2014): Indeed, theories of Intersectionality posit that the more layers of non-normativity a person exhibits, the more difficult success is (Johnson, 2001; Johnson, 2011). The engineering “norm” is a highly masculine environment that tends to propagate masculine ideals of communication, behavior, and social norms, which can lead women to feel isolated (Lester, 2008). Microaggressions, or the small, subtle discriminations, can add up over time to create an environment that is highly uncomfortable and unproductive for women to work. Issues related to family expectations, exclusion from the “boys’ club,” and gendered expectations of roles (including academic service) have been studied as common experiences for women working in engineering environments, especially in higher education (Denker, 2009; Case & Richley, 2014; Swanson & Johnston, 2003). Unconscious and implicit bias studies also document these confounding factors for women in STEM (Hill, Corbett, & St Rose, 2010; Williams, Phillips, & Hall, 2014).

Although the faculty gaps and potential models for attrition have been documented (Turner & Bowen, 1999; Winslow, 2010; Kaminski & Geisler, 2012), not many studies understand where exactly the gender gap in faculty “starts.” Efforts in introducing girls and young women to engineering are becoming prominent, as are women in engineering (WiE) programs and societies such as The Society for Women Engineers (SWE) on campus for undergraduates and graduate students. Despite these efforts, numbers of women in engineering have risen only a few percentage points in the last several decades (Yoder, 2012). This fact indicates that researchers and the engineering community are not accurately diagnosing where the gap begins, or how to intervene for qualified and capable women engineers.

This dissertation so far has studied the role that language and engineering writing plays in the development of a disciplinary identity and the acquisition of the "language of engineering" as a producer of knowledge. The development of an engineering identity has been linked with persistence rates, and therefore, it is possible that enhanced enculturation through membership in a discourse community may affect issues of persistence, especially for people who identify within non-normative groups in engineering (underrepresented minority graduate students, women graduate students, etc.)

As part of this larger study, when the research proposals for the 50 NSF GRFP winners were analyzed for the Broader Impact and Intellectual Merit criteria, some differences were noted in the ways in which men and women discussed their research plans. Using the same methods and coding schema from Chapter 6, this chapter of the outlines findings related to gender and discusses them in light of the persistent faculty gender gap in engineering fields.

7.2 Distribution of Themes by Gender

As a reminder, of the total N = 50 participants in the study, nearly half (N = 23) were women. Figure 7.1 reports on the average total Intellectual Merit and Broader Impact criteria explicitly noted for men and women, as well as the average counts of intellectual merit, and average counts of broader impact for each group as well. After conducting a two-tailed Z-test, it was concluded that there are no statistically significant differences between the means of criteria usage in total or for either of the separate criteria data between men and women.

Table 7.1 Average Counts of Intellectual Merit and Broader Impacts by Gender

Participant Identity Characteristics		**Average Intellectual Merit and Broader Impact Themes per Document**	**Average Intellectual Merit Mentions per Document**	**Average Broader Impact Mentions per Document**
Gender	Women	6.91 (SD = 2.63)	2.95 (SD=1.94)	3.96 (SD =2.42)
	Men	7.78 (SD = 3.48)	3.48 (SD =2.59)	4.29 (SD=3.15)
	p value	0.31	0.41	0.66
	Cohen's d	0.28	0.23	0.12

Table 7.2 shows the numerical data according to theme between men and women. The numbers in the chart indicate the frequency counts of each theme within the document, followed in parenthesis with the percentage of that group's themes. For example, there were 8 counts mentioning conferences within the women's research statements: These counts comprised 5% of the total women's themes for both broader impact and intellectual merit. This way of showing the data normalizes the numbers such that the distribution of themes can be compared across gender groups.

Table 7.2 Distribution of Intellectual Merit and Broader Impacts Themes by Gender

Distribution of Themes by Gender		
Intellectual Merit Themes		
	Women's Theme Frequency (% of Women's Themes)	**Men's Theme Frequency (% of Men's Themes)**
Conferences	8 (5.0%)	12 (5.7%)
Journal Publications	6 (3.8%)	15 (7.1%)
Extends body of knowledge	33 (20.8%)	36 (17.1%)
Extend findings to other fields/applications	14 (8.8%)	26 (12.4%)
Novelty	7 (4.4%)	5 (2.4%)
Broader Impact Themes		
	Women's Theme Frequency (% of Women's Themes)	**Men's Theme Frequency (% of Men's Themes)**
Education (K-12)	5 (3.1%)	15 (7.1%)
Higher Education	2 (1.3%)	8 (3.8%)
General/Public Education/Engagement	8 (5.0%)	7 (3.3%)
Technological Benefits to disadvantaged groups	4 (2.5%)	3 (1.4%)
Broaden Participation in STEM	6 (3.8%)	8 (3.8%)
Outreach to Affected populations	2 (1.3%)	1 (0.5%)
Benefits to Affected populations	13 (8.2%)	18 (8.6%)
Environment and Climate	5 (3.1%)	6 (2.9%)
Societal Benefits	3 (1.9%)	5 (2.4%)
Economic Benefits	6 (3.8%)	4 (1.9%)
General Safety/Health	4 (2.5%)	5 (2.4%)
United States Interests	1 (0.6%)	3 (1.4%)
Energy/power	9 (5.7%)	9 (4.3%)
Collaborations	12 (7.5%)	15 (7.1%)
Policy	8 (5.0%)	4 (1.9%)
Total Counts	**159**	**210**
Total Intellectual Merit	**68 (43%)**	**94 (45%)**
Total Broader Impacts	**91 (57%)**	**116 (55%)**

Unlike in the aggregate data, the disaggregated data show trends in the different ways in which men and women may use elements of intellectual merit and broader impact within their research statements. For example, looking at the Intellectual Merit sections, although approximately 5% of both men's and women's codes discuss presenting research at conferences (either generally or mention of specific conferences), only 3.8% of women's counts mentioned journal publication, whereas 7.1% of men's codes focused on disseminating their findings in formal scholarly journals. Women were slightly more likely to discuss the specific intellectual contribution to their discipline, and claim the novelty of their research compared to men, but men were slightly more likely to explicitly extend their results to other scholarly research fields or diverse applications.

Table 7.3 Usage of Publication-Related and Education-Related Themes by Gender

Participant Identity Characteristics		**Average usage of Conference and Journal Themes per Document**	**Average usage of K-12 and Higher Education Themes Per Document**
Gender	Women	0.61 (SD = 2.63)	0.30 (SD=0.69)
	Men	1.00 (SD = 3.48)	0.85 (SD =1.14)
p value		0.34	0.04**
Cohen's d		0.28	0.59

**p<0.05

In broader impacts, the percentages of themes addressing various broader impacts criteria are relatively similar between men and women. The areas of difference are surprisingly in broader impacts dealing with education. 7.1% of men's codes were devoted to K-12 STEM education and outreach, compared with 3.1% of women's codes.

Together, the K-12 and higher education codes for men constituted a total of 10.9% of the total themes counted, whereas for women these educational components constituted a total of 4.4%. A z-test probing the differences between the means of men's and women's usage of these specific themes indicate that there are statistically significant ($p<0.05$) differences in the way that men discuss educational components in NSF GRFP research statements, as shown in Table 7.3.

7.3 Discussion

The broader impacts finding as they relate to educational contexts may seem counterintuitive to the gendered nature of education, which is usually dominated by female teachers and the "caretaker" identity of women (Williams, 1992). However, these findings are consistent with other higher education, sociological, and gender theory, either consciously or subconsciously adopting or rejecting non-academic or academic identity-based norms ("undoing gender" by "doing engineering," according to Powell, Bagilhole, and Dainty, 2009). For example, women engineers may (consciously or subconsciously) reject the "caretaker" role that may be exhibited through a lot of K-12 outreach activities, leading to their focus on different indicators of broader impact within their research proposals. They may also be aware that their service and outreach activities in academic contexts would be considered "normal" for a woman, for instance women faculty are expected to teach more and spend more time on service (Winslow, 2010), and therefore a traditionally feminine value would perhaps be undervalued by judging panels. Conversely, the double-standard that lauds and praises men as they perform "caretaker" roles may also be at play (Williams, 1992), and men (consciously or subconsciously) may be taking advantage of this in their discussion of the educational components within their broader impacts statements. Since this study was a document analysis study, it was not possible to interview participants about their inclusion and exclusion of their research proposal components and intentions.

The fact that higher education faculty careers, especially in engineering fields, are dominated by men is also mirrored in these early-career graduate students, who may not even fully understand the sociological forces at play in academia. The data trends are consistent with the trajectories and persisting gender gap in academic faculty: Men may be more willing to extend their research findings immediately into the higher education teaching and mentorship environment. Coupled with the possibility of a trend toward planning from the onset of the research projects to publish their findings in journals, one interpretation of these data are that we may be seeing men *planning* to become successful academicians earlier in their careers.

To further this interpretation of the very preliminary trends, understanding that this is a very small data set probing only winners of NSF GRFP (and not all graduate engineering students), ultimately, if all these participants were to fulfill their "intellectual merits" claims exactly as proposed in the research statement, the men would be twice as prepared for careers in academia as women. Although this is an extrapolation of a short research proposal, the fact that men *know* to think even at the beginning of their careers about which journals they think their research would be aimed toward is something worth noting. According to discourse and genre theory, using the most suitable words and ideas indicates a commitment within an identity, and therefore, we see further mental and sociological performance in men's research statements regarding the expectations for an academic career.

This is an especially important finding in light of the previous research findings, which show no correlations with gender to any of the writing patterns and concepts, low writing self-efficacy, or high writing apprehension. Similarly, there is no gender discrepancy in the distribution of the enacted genre patterns employed by men and women as they applied for the NSF GRFP. The only area where men and women differ is in this language usage and how the two groups are learning to discuss the merits and impacts of their research as it relates to the activities that are merited by the wider academic community. Equally promising in all other respects, and equivalent statistically in terms of writing patterns and dispositions, men and women do not discuss the value of their research in the same ways.

The sample size of this study presents a limitation in terms of proving statistically significant findings, but indicates potential trends that may be present in the linguistic patterns between men and women in academic engineering writing tasks. This study, with its small N=50, may provide preliminary justification for enacting a similar study on a very large scale in order to understand potential gender differences.

7.4 Recommendations for Future Research

Since the role of graduate education is to socialize students into disciplinary norms and expectations of a research community, it is interesting that academically successful women and men engineers across the United States, from some of the most prestigious engineering research programs in the world, may have ways in which they interpret the intellectual merits and broader impacts of their research. While the role of this research project was not intended to think explicitly about the role of gender in developing academic literacy and fluency in disciplinary discourse and argumentation, this finding cannot be ignored.

These findings raise more questions than they answer, first, about the disciplinary messaging that women receive regarding the purpose of their work or the expectations to publish as part of their graduate programs at very early stages in their graduate research careers. Certainly, this sample indicates that men are more likely to be thinking explicitly about multiple specific publication venues, whereas women paint the merit of their projects in broad strokes of extending the body of knowledge or novelty. While these claims are as valid, the merit is measured in terms of research productivity via journal publications. Research questions for future work might include an extension of this same study to look at a much larger sample of high-achieving engineering researchers to see if the trend is more generalizable. Since, according to sociocultural theory (Vygotsky, 1986), the ideas and culture of a community is embedded within individual identities and perceptions, researchers might also work to understand the pathways into academic engineering, and how students become aware of publishing and other professional obligations and opportunities. It has been suggested that male research advisors expect less from their female students and spend less time with them on professional development opportunities, including publishing (Wilson, 2004). Along these lines, other research questions might include: Are advisors more likely to suggest publication opportunities to men than women earlier in their graduate careers, and how do these conversations occur? What effects over time do these small advantages have on professional development and career attainment after graduation? Are women less aggressive in asking for opportunities to publish in journals and conferences? These kinds of research questions at the junction of academic literacy, communication and writing, and engineering education will be of importance in determining the role that discourse development has on women in engineering.

The most effective way to combat the disparity between men and women is for research advisors to consistently encourage their women graduate students to publish at the same level as the men in their research group, helping early career graduate women think about appropriate venues, planning their publication trajectory through conferences and journals. By learning the publication “language” and expectations of academic engineering, the women will also “learn the language” of their disciplinary discourse, which in turn can affect internal development of self-efficacy and identity, and external preparation for success in future career applications in academia or industry. While students can and should take responsibility for their own professional development in graduate school, this recommendation supports the undeniable linkage between mentorship and advocacy in academic careers, especially for women in science and engineering (Chandler, 1996).

7.5 Conclusion

In aggregate, early-career men and women engineering graduate students have similar frequencies of the impacts and merits within their NSF GRFP research proposals.

However, when the data are disaggregated, differences exist in the *ways* in which men and women discuss the criteria. Findings show that men are twice as likely in their proposals to address the dissemination of research results in conferences or journal publications, and are twice as likely to discuss the ways in which they will apply their research to educational settings. Ultimately, if, according to discourse and content analysis theory, language usage is an indicator of identity and priority, then men will be twice as prepared as women to apply for and attain faculty jobs. Through this analysis we may see the beginnings of the academic engineering gender gap, in a group of nationally-acclaimed young engineering researchers—equally competent in the eyes of the academic community—who have been awarded a career-launching and prestigious research fellowship and who are equally promising in all respects.

CHAPTER 8. FUTURE WORK AND CONCLUSIONS

8.1 Future Work

Future work for this study includes developing interventions based on these findings that can be employed and validated with engineering graduate student populations. In addition, this small study (N = 50) provides justification for researching engineering graduate students' concepts and processes of writing, not just those of NSF GRFP engineering award winners in order to be able to more fully understand the needs and discourse patterns of engineering graduate students more generally. This will require a very large national study. Future work on the genre analysis study will include reliability calculations through inter-rater reliability and further validation of the coding scheme on other proposal artifacts for engineering. The validation of the linguistic maps is a promising novel addition to the field of English for Specific Purposes. Further extensions of the disciplinary discourse and the gender differences studies will also be very interesting to follow up with a larger sample size of NSF GRFP award winners from across the country to note if the same discrepancies of language usage and patterns occur on a larger scale.

Beyond the immediate next steps based on the data presented here, no studies to date have correlated persistence in graduate engineering with writing preparation or the development of academic literacies skills as applied to disciplinary discourse in engineering. Since literature in this area points to engineering writing as a skill that should be developed, it would be very interesting to note what effect preparation or lack thereof contributes to the attrition rates of graduate students. Potentially mixed methods studies can provide both qualitative and quantitative insight into this particular phenomenon.

8.2 Final Conclusions

Learning the language of academic engineering is a complex process that incorporates both the cognitive and the social aspects of engineering. This mixed methods study employed survey methods and document analysis methods to work to understand the development of engineering graduate student attitudes about writing and corresponding enacted writing patterns, using the NSF GRFP as a vehicle by which to study an authentic engineering writing task.

Quantitative results yield interesting correlations between a number of writing constructs, some of which that have been anecdotally observed (e.g. the relationship between low writing self-efficacy and procrastination) and others that were uncovered through this research through the deployment of several different writing scales. Engineering NSF GRFP winners differ significantly from social science students in their processes and concepts surrounding writing, and therefore, there is a great need to develop specific courses to teach engineering writers within the disciplinary community, especially at the graduate level. Other potential implications for this work include the development of specific writing interventions based on students' particular dispositions and tendencies toward writing. Students, too, should be aware of their dispositions and aware of strategies that may help to overcome debilitating tendencies, such as writing apprehension or writer's block.

Qualitative research was conducted through genre analysis and content analysis methods, through which a moves-steps schema was employed to interpret the variety of linguistic moves employed by engineering graduate students within winning research proposals for the NSF GRFP writing tasks. Along with a traditional genre analysis, this study is the first to visualize linguistic moves on a plot as a function of the argument progression. Four characteristic shapes representing different typologies of enacted argumentation patterns were uncovered that correlate with different writing dispositions of the engineering participants. Since all the research proposals in the sample are from high-achieving engineers that wrote strong and compelling research proposals, the finding that the proposals' argumentation patterns varied widely confronts the "ideal" of the linear engineering argumentation pattern. Findings indicate that for NSF GRFP-winning graduate students, explicit writing courses may be encouraged that help students learn to construct an optimal argumentation strategy, rather than a blind adherence to technical writing rules that may have been acquired at early ages in undergraduate degree programs. Some students may need to "unlearn" some of their writing habits in order to develop disciplinary writing habits at the graduate level.

Content analysis methods were employed in order to characterize the ways in which engineering graduate students argued for the intellectual merit and broader impacts of their research proposals for NSF GRFP, the two criteria on which the written tasks are judged. The findings, separated by discipline, show that different disciplines may be promoting a stronger identity as more “merits-oriented” or “impacts-oriented.” This discussion of disciplinary discourse patterns of merit and value may add to the discussion on retention of graduate students, if students can align their personal values with the values of an engineering disciplinary community.

Lastly, the same analysis of the broader impacts and intellectual merit criteria of the research proposals yielded fascinating differences in the ways in which men and women discussed the merits and impacts of their research proposals. Men were twice as likely to discuss specific plans for publishing in conference proceedings and journal publications, and twice as likely to engage in an educational context. Ultimately, this may make them more prepared for future faculty jobs. In this way, the men have “learned the language of academic engineering,” that values publications, and are learning to enact these values through their discourse in this national setting. In this way, the beginnings of the faculty gender gap may be identified in this context.

Although the context for this study was in NSF GRFP engineering winners, and the data suggest trends may be representative of that population, it is important to not automatically extrapolate findings to the entire engineering graduate population in the United States. However, it is justification for future work in this area, and if the trends hold (and based on the literature noting significant lacks of writing resources for engineers), the final overall recommendation from this research is that formal writing instruction should be provided for graduate-level engineering students, taught in-house by disciplinary *engineering* experts, in order that students achieve the most applicable strategies for becoming a member of the discourse community. According to academic literacies theory, as graduate students are becoming experts of their discipline, the ways in which they communicate become increasingly specific to the discourse community of which they are a part. In this way, engineering discourse is similarly different from the other disciplinary discourses. The statistical findings indicate that (at least for NSF GRFP winners), writing conceptions and the relationship that engineering grad students have with writing may be different than other disciplines that engage in writing and communication tasks more formally throughout their graduate education.

To this end, technical writing experts who know how to teach writing should partner with engineering faculty in order to develop interventions that meet both needs at the same time. Graduate-level writers, even native English speakers, need to have resources through which to develop their academic literacy and disciplinary discourse. As graduate education is a time for intensive enculturation and socialization, where a student’s role changes from a consumer to a producer of knowledge; the language of engineering and a proficiency and confidence in academic writing may lead to lower attrition rates for doctoral students as a result of a stronger disciplinary identity and fluency in as a member of a discourse community.

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APPENDICES

Appendix A: Survey Items Deployed to Participants

Demographic Questions

1. Full Name (First and Last):
2. Email address:
3. I identify as a:
    a. Female
    b. Male
    c. Prefer to not answer
4. Current Degree Objective:
    a. Master's Non-Thesis Degree
    b. Master's Thesis Degree
    c. Ph.D.
5. Final Degree Objective:
    a. Master's Non-Thesis Degree
    b. Master's Thesis Degree
    c. Ph.D.
6. Undergraduate Institution:
7. Undergraduate Major:
8. Graduate Institution:
9. Graduate Discipline:
10. Area of Research:
11. First Language:
    a. English
    b. Spanish
    c. Other (please specify)
12. Academic Level:
    a. Undergraduate senior
    b. First-year graduate student
    c. Second-year graduate student
13. Level of research:
    a. I have started research
    b. I have not started research
    c. Not applicable
14. Race/Ethnicity (check all that apply):

a. African American or Black
    b. Hispanic or Latin American
    c. Asian/Pacific Islander
    d. Native American or Native Alaskan
    e. White
    f. Other (please specify)

15. Please upload a copy of your personal statement that you submitted to the NSF GRFP Competition in Fall 2014.
16. Please upload a copy of your research statement that you submitted to the NSF GRFP Competition in Fall 2015.
17. All documents will be kept in a secure database, and will only be used for the purposes of studying engineering writing. If your data includes extra sensitive information, please check this box in order to alert the researcher.

Directions: Below are a series of statements about writing. There are no right or wrong answers to these statements. Please indicate the degree to which each statement applies to you by circling whether you (1) Strongly Disagree, (2) Disagree, (3) Agree, or (4) Strongly Agree with the statement. While some of the statements may seem repetitious, take your time and try to be as honest as possible.

1. When writing an academic paper, I stick to the rules
2. I set aside specific times to do academic papers.
3. I reexamine and restate my thoughts in revision.
4. Writing academic papers makes me feel good.
5. I closely examine what the academic paper calls for.
6. I can hear my voice as I reread papers that I have written.
7. Revision is a onetime process at the end.
8. There is usually one best way to write an academic paper.
9. When faced with an academic paper, I develop a plan and stick to it.
10. I keep my topic clearly in mind as I write.
11. When writing an academic paper, I tend to write what I would say if I were talking
12. The thesis or main idea dictates the type of paper to be written.
13. I can write a term paper without any help or instruction.
14. Originality in writing is highly important in academic writing.
15. I worry about how much time my paper will take.
16. I tend to write a rough draft and then go back repeatedly to revise it.
17. Revision is the process of finding the shape of my writing.
18. Writing a paper is always a slow process.
19. Academic writing is symbolic.
20. Writing academic papers reminds me of other things that I do.
21. Academic papers usually have little to do with what I do in my career or my life.
22. It is important to me to like what I have written.
23. Studying grammar and punctuation would greatly improve my writing.
24. I visualize what I am writing about.
25. I can hear myself while writing.
26. My prewriting notes are always a mess.
27. I am familiar with the components of a research paper or thesis.
28. I put a lot of myself in my academic writing.
29. I never think about how I go about writing.
30. Writing assignments in graduate courses are always learning experiences.

31. In my writing I tend to use some ideas to support other, larger ideas.
32. Having my writing evaluated scares me.
33. I tend to spend a long time thinking about my writing assignment before beginning.
34. When writing a paper, I often get ideas for other papers.
35. I like to work in small groups to discuss ideas or do revision in writing.
36. I imagine the reaction that my readers might have to my paper.
37. I complete each sentence and revise it before going on to the next.
38. I cue my reader by giving a hint of what is to come.
39. My writing rarely expresses what I really think.
40. Writing an academic paper is making a new meaning.
41. My revision strategy is usually making minor changes, just touching things up.
42. I am my own audience.
43. The thesis or main idea is the heart of the academic paper.
44. Academic writing helps me organize information in my mind.
45. At times my academic writing has given me deep personal satisfaction.
46. The main reason for writing an academic paper is just to get a good grade on it.
47. When given an assignment calling for an argument or viewpoint, I immediately know which side I will take.
48. My essay or paper often goes beyond the specifications of the assignment.
49. I expect good grades on academic papers.
50. Writing an academic paper is like a journey.
51. I plan, write, and revise all at the same time.
52. I usually write several paragraphs before rereading.
53. I worry so much about my writing that it prevents me from getting started.
54. I like written assignments to be well specified with details included.
55. I start with a fairly detailed outline.
56. I do well on tests requiring essay answers.
57. I often think about my paper when I am not writing (i.e., late at night).
58. My intention in writing is just to answer the question.
59. I just write off the top of my head and then go back and re-work the whole thing.
60. Often my first draft is my finished product.
61. Writing an academic paper helps me develop my ideas.
62. Academic writing is cold and impersonal.
63. I need special encouragement to do my best academic writing.
64. I can’t revise my writing because I cannot see my own mistakes.
65. When writing an academic paper, my idea or topic often changes as I progress.
66. I do not normally expect to make significant changes to my text by revising it.
67. It is important to me to have my ideas or arguments clear before writing.

Directions: Below are a series of statements about writing. There are no right or wrong answers to these statements. Please indicate the degree to which each statement applies to you by circling whether you (1) Strongly Disagree, (2) Disagree, (3) Somewhat Disagree, (4) Neither Agree nor Disagree, (5) Somewhat Agree, (6)

Agree or (7) Strongly Agree with the statement. While some of the statements may seem repetitious, take your time and try to be as honest as possible.

1. When given a specific writing assignment, I can come up with a suitable topic in a short time.
2. I can start writing with no difficulty.
3. I can construct a good opening sentence quickly.
4. I can come up with an unusual opening paragraph to capture readers' interest.
5. I can write a brief but informative overview that will prepare readers well for the main thesis of my paper.
6. I can use my first attempts at writing to refine my ideas on a topic.
7. I can adjust my style of writing to suit the needs of any audience.
8. I can find a way to concentrate on my writing even when there are many distractions around me.
9. When I have a pressing deadline on a paper, I can manage my time efficiently.
10. I can meet the writing standards of an evaluator who is very demanding.
11. I can come up with memorable examples quickly to illustrate an important point.
12. I can rewrite my wordy or confusing sentences clearly.
13. When I need to make a subtle or an abstract idea more imaginable, I can use words to create a vivid picture.
14. I can locate and use appropriate reference sources when I need to document an important point.
15. I can write very effective transitional sentences from one idea to another.
16. I can refocus my concentration on writing when I find myself thinking about other things.
17. When I write on a lengthy topic, I can create a variety of good outlines for the main sections of my paper.
18. When I want to persuade a skeptical reader about a point, I can come up with a convincing quote from an authority.
19. When I get stuck writing a paper, I can find ways to overcome the problem.
20. I can find ways to motivate myself to write a paper even when the topic holds little interest for me.
21. When I have written a long or complex paper, I can find and correct all my grammatical errors.
22. I can revise a first draft of any paper so that it is shorter and better organized.
23. When I edit a complex paper, I can find and correct all my grammatical errors.
24. I can find other people who will give critical feedback on early drafts of my paper.
25. When my paper is written on a complicated topic, I can come up with a short informative title.

Directions: Below are a series of statements about writing. There are no right or wrong answers to these statements. Please indicate the degree to which each statement applies to you by circling whether you (1) Strongly Disagree, (2) Disagree, (3) Neither Agree nor Disagree, (4) Agree, or (5) Strongly Agree with the statement. While some of the statements may seem repetitious, take your time and try to be as honest as possible.

1. It is useful to get other people's comments on texts
2. When I write I am concerned about whether the reader understands my text
3. I often postpone writing tasks until the last moment
4. Writing is a creative activity
5. I find it difficult to write, because I am too critical
6. My previous writing experiences are mostly negative
7. I write regularly regardless of the mood I am in
8. I produce a large number of finished texts
9. Without deadlines I would not produce anything
10. I sometimes get completely stuck if I have to produce texts
11. I find it difficult to start writing
12. I find it easier to express myself in other ways than writing
13. I only write when the situation is peaceful enough
14. The skill of writing is something we are born with; it is not possible for all of us to learn it
15. I find it difficult to hand over my texts, because they never seem complete
16. I start writing only if it is absolutely necessary
17. I hate writing
18. I am a regular and productive writer
19. I could revise my texts endlessly
20. I write whenever I have the chance
21. Writing is a skill, which cannot be taught
22. Writing is difficult because the ideas I produce seem stupid
23. Rewriting texts several times is quite natural
24. Writing often means creating new ideas and ways of expressing oneself
25. Writing develops thinking

Directions: Below are a series of statements about writing. There are no right or wrong answers to these statements. Please indicate the degree to which each statement applies to you by circling whether you (1) Strongly Disagree, (2) Disagree, (3) Neither Agree nor Disagree, (4) Agree, or (5) Strongly Agree with the statement. While some of the statements may seem repetitious, take your time and try to be as honest as possible.

1. I avoid writing.
2. I have no fear of my writing being evaluated.
3. I look forward to writing down my ideas.
4. I am afraid of writing academic papers when I know they will be evaluated.*
5. Taking a composition course is a very frightening experience.
6. Submitting an academic paper makes me feel good.*
7. My mind seems to go blank when I start to work on a paper.*
8. Expressing ideas through writing seems to be a waste of time.
9. I enjoy submitting my writing to journals for evaluation and publication.*
10. I like to write my ideas down.
11. I feel confident in my ability to clearly express my ideas in writing.
12. I like to have my friends read what I have written.

13. I'm nervous about writing.
14. People seem to enjoy what I write.
15. I enjoy writing.
16. I never seem to be able to clearly write down my ideas.
17. Writing is a lot of fun.
18. I expect to do poorly in writing-intensive classes even before I enter them.*
19. I like seeing my thoughts on paper.
20. Discussing my writing with others is an enjoyable experience.
21. I have a terrible time organizing my ideas in writing intensive courses.*
22. When I hand in an academic paper, I know I'm going to do poorly.*
23. It's easy for me to write good academic papers.*
24. I don't think I write as well as most other people.
25. I don't like my papers to be evaluated.*
26. I'm no good at writing.

*Note for dissertation research readers:These survey items have wording changes from the original Daly and Miller (1975) survey items, most of which change the reference from "compositions," "magazines," or "composition classes" to "papers," "journals," and "writing-intensive courses." The following are the original wordings for reference:

4. I am afraid of writing essays when I know they will be evaluated.
6. Handing in a composition makes me feel good.
9. I would enjoy submitting my writing to magazines for evaluation and publication.
18. I expect to do poorly in composition classes before I even enter them.
21. I have a terrible time organizing my ideas in a composition course.
22. When I hand in a composition, I know I'm going to do poorly.
23. It's easy for me to write good compositions.
25. I don't like my compositions to be evaluated.

Directions: Below are a series of statements about research. There are no right or wrong answers to these statements. Please indicate the degree to which each statement applies to you and your research by selecting your level of confidence (0=no confidence in your ability; 100=fully confident in your ability).

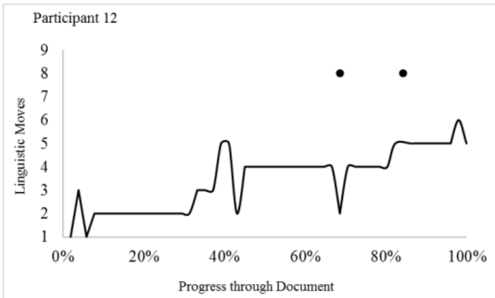
Rank your confidence in performing the following tasks related to your research:

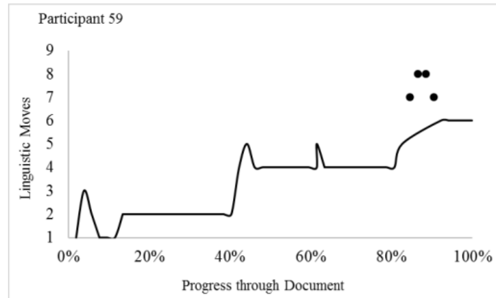
1. Follow ethical principles of research.
2. Brainstorm areas in literature to read about.
3. Conduct a computer search of the literature in a particular area.
4. Locate references by manual search.
5. Find needed articles which are not available in your library.
6. Evaluate journal articles in terms of the theoretical approach, experimental design and data analysis techniques.
7. Participate in generating collaborative research ideas.
8. Work independently in a research group.
9. Discuss research ideas with peers.
10. Consult senior researchers for ideas.
11. Decide when to quit searching for related research/writing

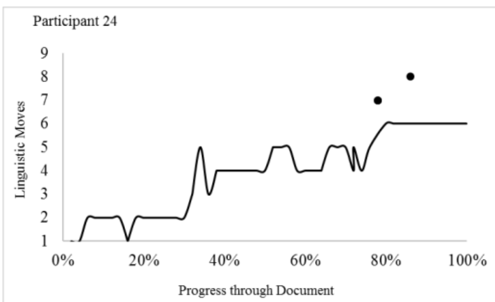
12. Decide when to quit generating ideas based on your literature review.
13. Synthesize current literature.
14. Identify areas of needed research, based on reading the literature.
15. Develop a logical rationale for your particular research idea.
16. Generate researchable questions.
17. Organize your proposed research ideas in writing.
18. Effectively edit your writing to make it logical and succinct.
19. Present your research idea orally or in written form to an adviser or group.
20. Utilize criticism from reviews of your data.
21. Choose an appropriate research design.
22. Choose methods of data collection.
23. Be flexible in developing alternative research strategies.
24. Choose measures of dependent and independent variables.
25. Choose appropriate data analysis techniques.
26. Obtain approval to pursue research (e.g. approval from human subjects' committee, animal subjects' committee, special approval for fieldwork, etc.)
27. Obtain appropriate subjects/general supplies equipment.
28. Train assistants to collect data.
29. Perform experimental procedures.
30. Ensure data collection is reliable across trial, rater, and equipment.
31. Supervise assistants.
32. Attend to all relevant details of data collection.
33. Organize collected data for analysis.
34. Use computer software to prepare texts (word processing).
35. Use computer software to generate graphics.
36. Use a computer for data analysis.
37. Develop computer programs to analyze data.
38. Use an existing computer package to analyze data.
39. Interpret and understand statistical printouts.
40. Organize manuscript according to appropriate professional format and standards.
41. Report results in both narrative and graphic form.
42. Synthesize results with regard to current literature.
43. Identify and report limitations of study.
44. Identify implications for future research.
45. Design visual presentations (posters, slides, graphs, pictures).
46. Orally present results to your research group or department.
47. Orally present results at a regional/national meeting.
48. Defend results to a critical audience.
49. Write manuscripts for publication.

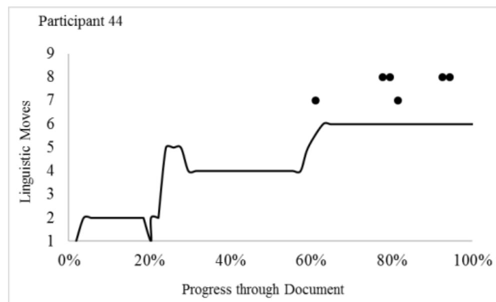
Appendix B: Genre Maps for 50 NSF GRFP Research Statements

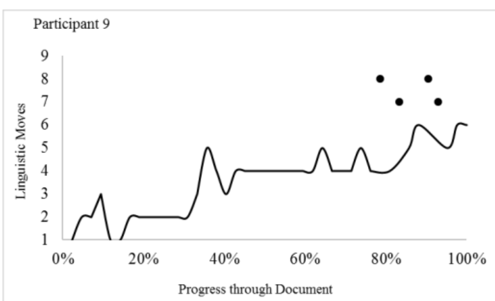
Outcomes-Oriented Characteristics

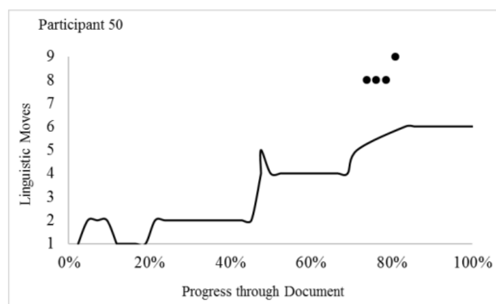


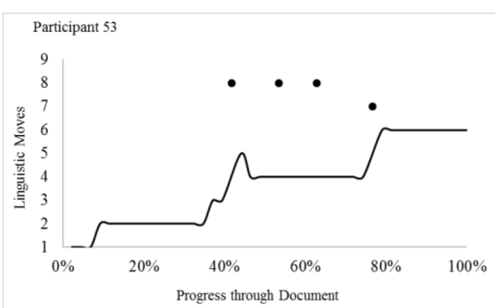


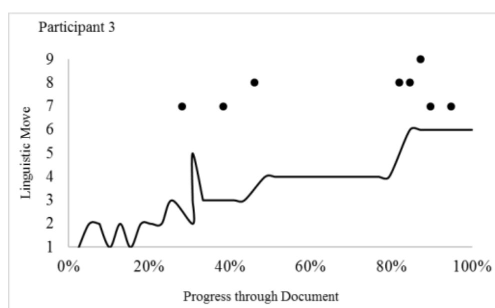


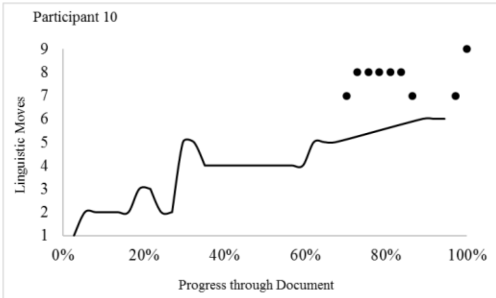


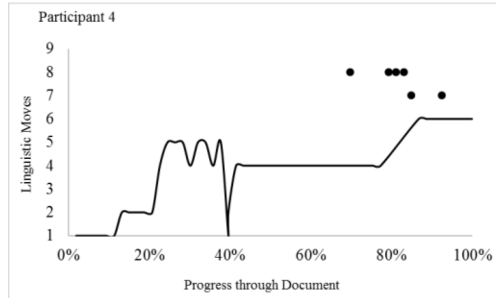


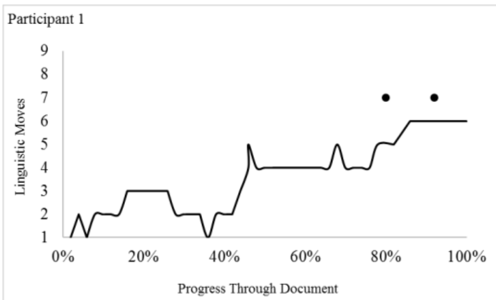




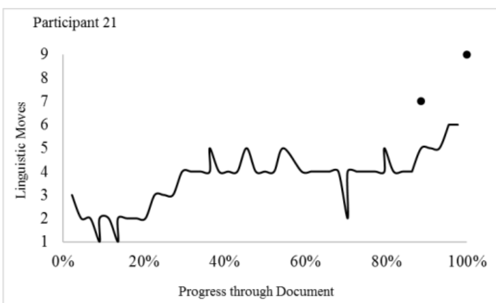


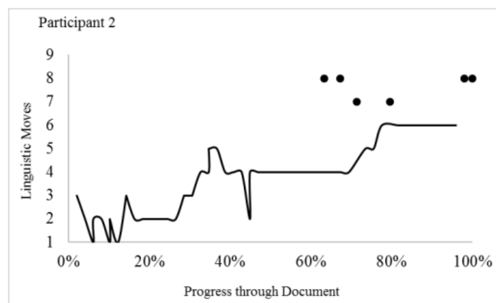


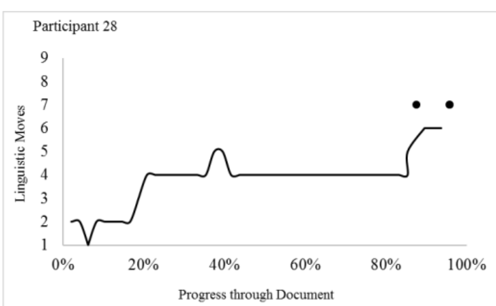


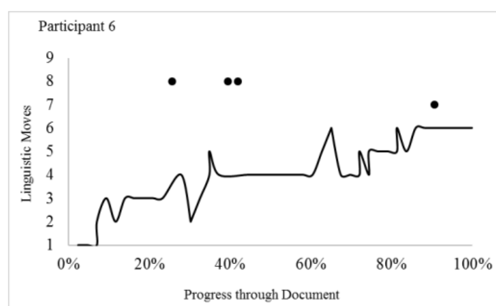


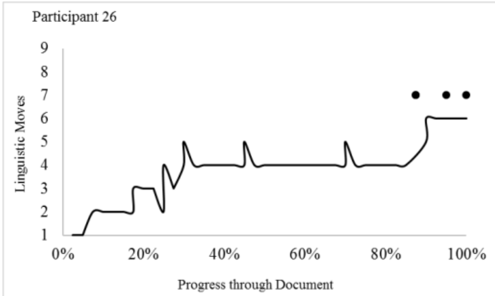
Process-Oriented Characteristics







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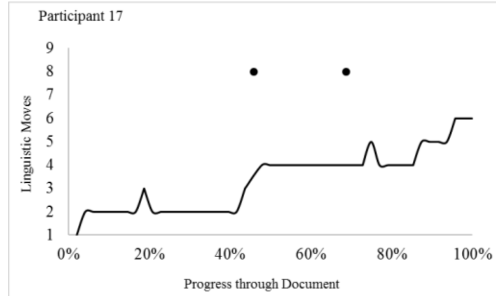
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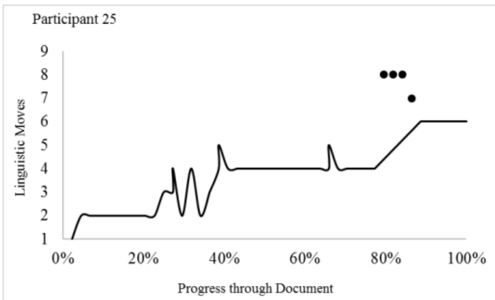
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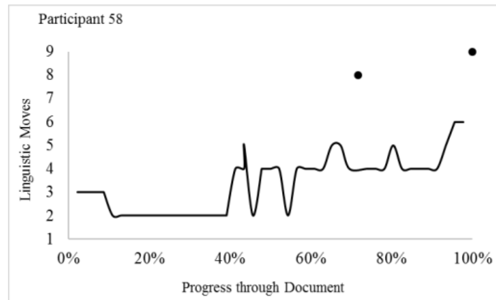
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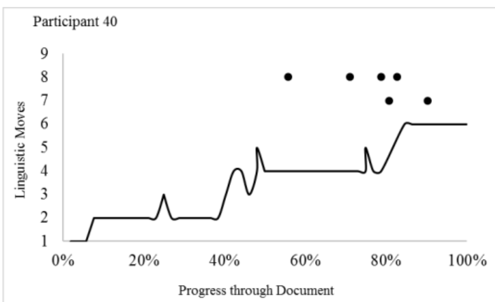
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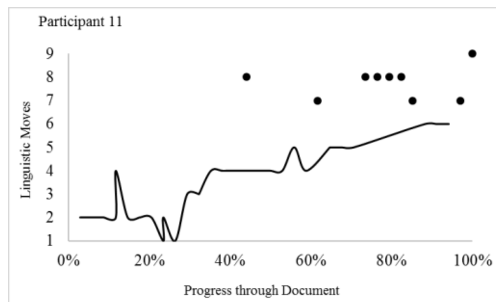
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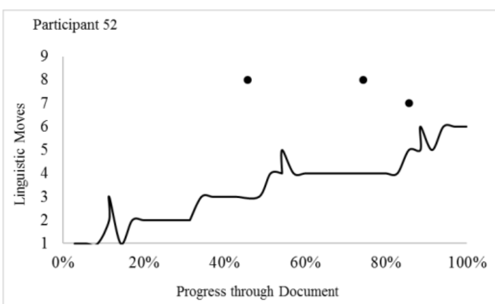
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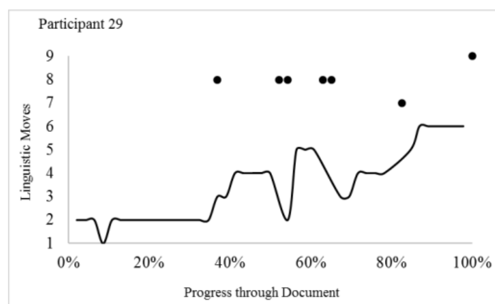
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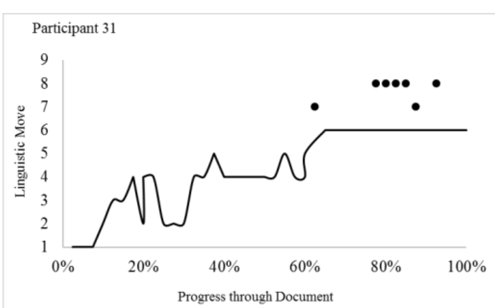
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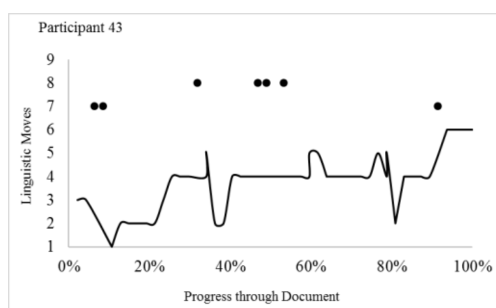
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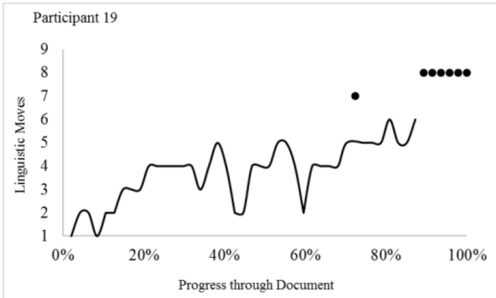
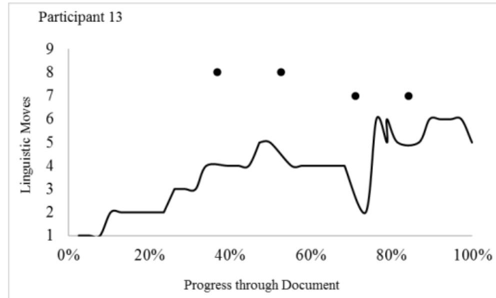
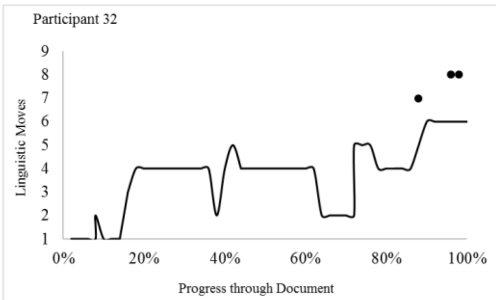
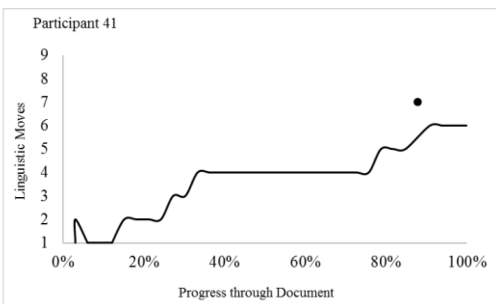
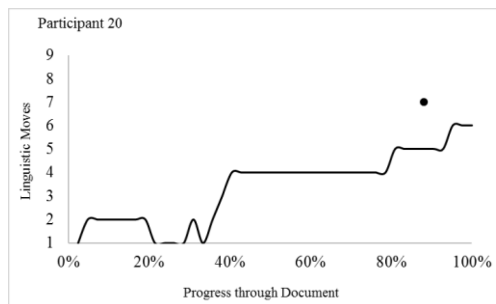


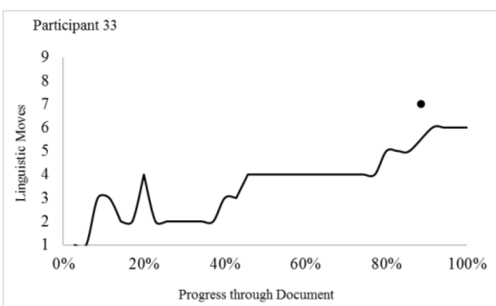


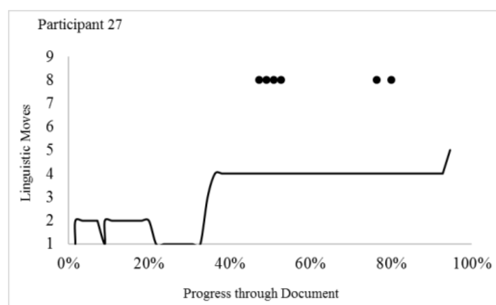


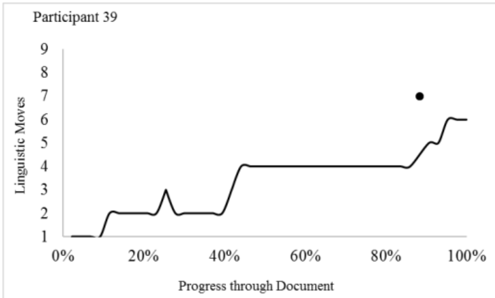
Methods-Oriented Characteristics







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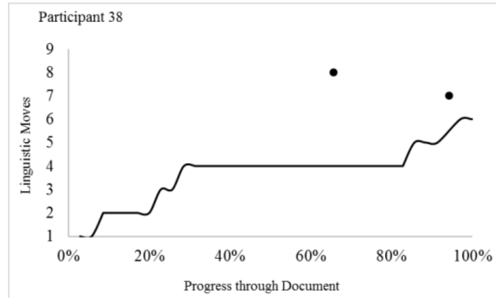
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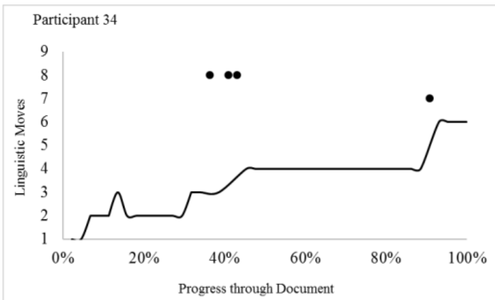
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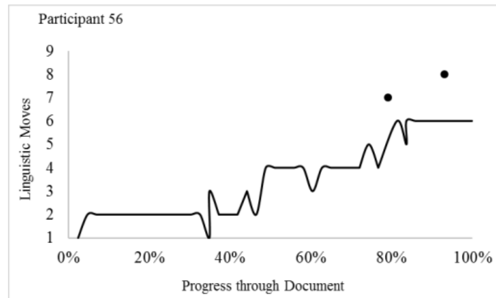
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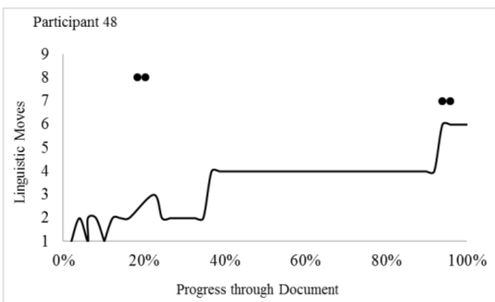
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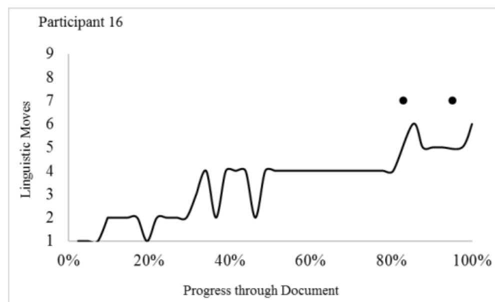
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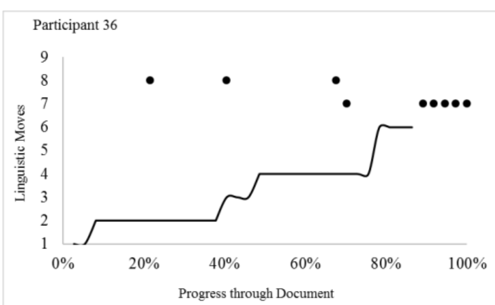
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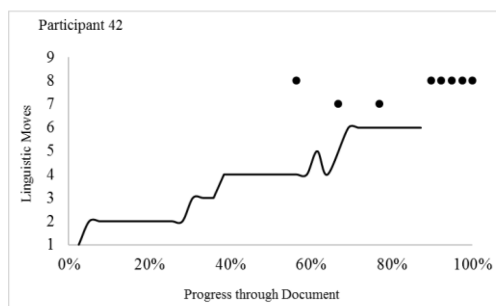
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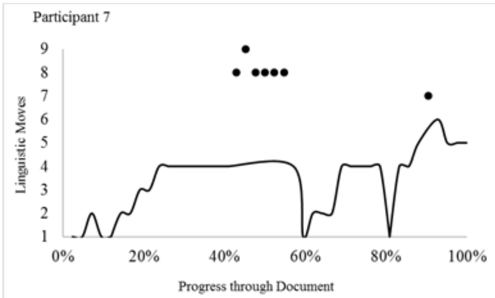
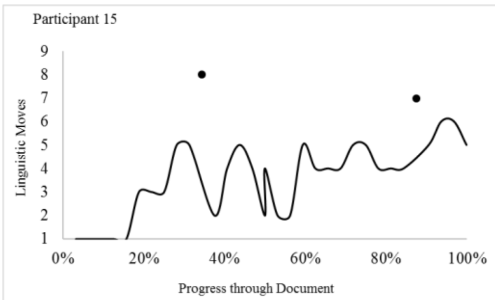
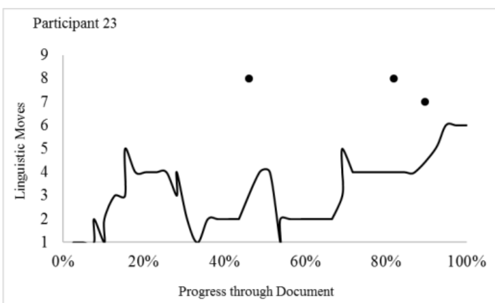
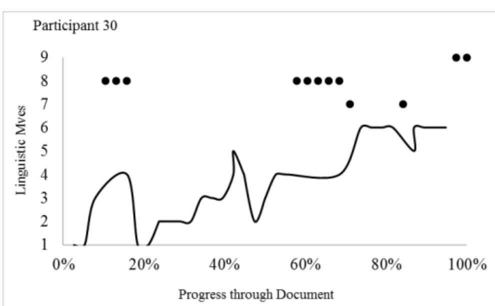
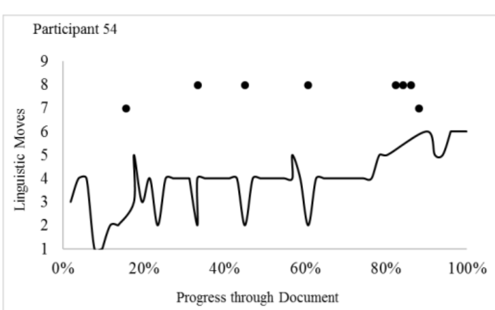
Motivation-Oriented Characteristics

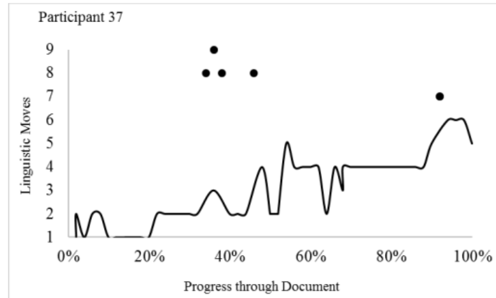


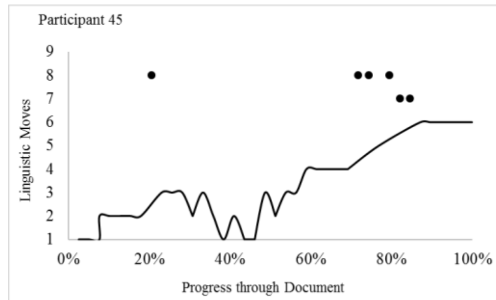


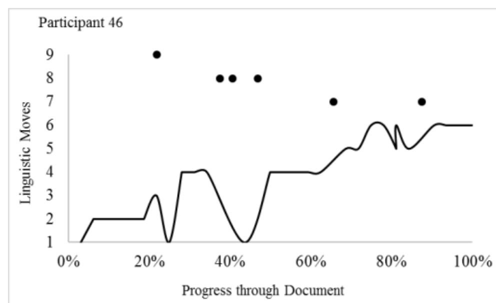


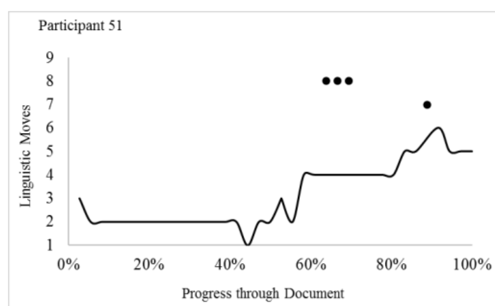












VITA

VITA

Catherine (Patrick) Berdanier
cgberdanier@gmail.com

Ph.D., Purdue University School of Engineering Education
August 2013-May 2016
Ph.D. Dissertation: *"Learning the Language of Academic Engineering: Sociocognitive Writing in Graduate Students"*

M.S., Purdue University School of Aeronautical and Astronautical Engineering
August 2010-August 2013—Major area: Propulsion; Minor areas: Mathematics, Optics
Master's Thesis: *"Flowfield Characterization of a Piloted Lean Premixed Injector by Particle Image Velocimetry. "* Accessible by ProQuest Dissertation and Theses: UMI 1549301.

B.S., University of South Dakota Department of Chemistry
August 2006-May 2010—B.S. Chemistry; B.S. Spanish; Minor: Physics
USD Senior Honors Thesis: *"Quantification of fuel emissions and boundary layer NOx formation from a two-stage-to-orbit scramjet scenario"*

Graduate Fellowships, Awards, and Honors

- **Purdue School of Engineering Education Outstanding Graduate Research Award** (2016)
- **NSF Integrative Graduate Education and Research Traineeship (IGERT) Fellow** (2013-2016)
- **Purdue School of Engineering Education Graduate Student Service Award** (2015)
- **NASA Graduate Aeronautics Scholarship Program Fellow** (2011-2013)
- **NSF Graduate Research Fellowship Program (GRFP) Awardee** (2011)

Research Experience

Purdue University **2013-present**
School of Engineering Education
Research Assistant under Dr. Monica Cox
NSF Integrative Graduate Research Education and Traineeship (IGERT) Fellow

Research work involves graduate- and professional-level engineering education. Work has included research on Knowledge, skills, and attributes needed for engineering Ph.D. students for careers in industry and academia; Women of color in the professoriate; Engineering leadership; Assessment and Pedagogy; and Global and interdisciplinary engineering experiences in India and France.

Purdue University **2010-2013**
School of Aeronautical and Astronautical Engineering
Graduate Research Assistant under Dr. Robert Lucht
NASA Aeronautics Scholarship Program Fellow

NASA Glenn Research Center **2012**
NASA Graduate Aeronautics Scholarship Program Intern,
Cleveland, OH
Propulsion Directorate

NASA Langley Research Center **2010**
LARSS Intern, Science Directorate
Hampton, VA

NASA Langley Research Center **2009**
LARSS undergraduate intern, Aeronautics Research Directorate
Hampton, VA

Oak Ridge National Laboratory **2008**
Research Experience for Undergraduates (REU) under Dr.
Oak Ridge, TN
James D. Hoefelmeyer, University of South Dakota.

Peru, International Research **2007**
Center for Social Well-Being
Lima and Carhuaz, Peru

Teaching Experience

Purdue University-School of Engineering Education **Spring 2015**
Faculty Apprentice for ENE 506: Theories of Engineering Thinking
with Dr. Tamara Moore

Teaching responsibilities included syllabus design, preparing and facilitating classroom activities and in-class discussions, and grading assignments. Content covered includes learning theories and theorists that inform engineering education practice. Theorists taught include Dewey, Piaget, Vygotsky, Bruner, and the behaviorists. This experience is intended to give senior Ph.D. students experience teaching at the graduate level.

IGERT Module Instructor—Technical Writing Module **Spring 2015; Fall 2015**

Teaching responsibilities include syllabus design, preparing and facilitating distance education classroom activities and in-class discussions, and providing feedback on assignments. This experience practically applied knowledge gained in dissertation research, promoting strong writing habits and skills in 32 materials science and engineering graduate students at Cornell University and Norfolk State University (over two years) as part of the IGERT collaboration.

IGERT Module Instructor—Pedagogy Module Spring 2016; Spring 2015; Spring 2014

Teaching responsibilities included syllabus design, preparing and facilitating distance education classroom activities and in-class discussions, and providing feedback on assignments. This experience introduced 40 materials science and engineering graduate students at Cornell University and Norfolk State University (over three years) to fundamentals of teaching theory and practical engineering education applications as part of the IGERT Fellowship program through an 8-week module.

Academic Service

- Reviewer for American Society for Engineering Education Annual Conference (2013-present)
- Reviewer for the American Society of Mechanical Engineers International Gas Turbine Institute Turbomachinery Technical Conference & Exposition (Education Committee) (2015)
- Graduate Student Representative to ENE Faculty Development and Recognition Committee (Spring 2015)
- Undergraduate Research Mentor (Summer 2014, Summer 2015)
- Judge for Summer Undergraduate Research Fellowship (SURF) Projects (2014)

Outreach and Leadership

- Purdue University Women in Engineering Program Graduate Mentoring Program (GMP) Leadership Team (2013-present); Member of GMP (2010-present)
- Leader of GMP Writing Small Group (2014-present)
- Coordinator (volunteer) for Purdue's Annual "Introduce a Girl to Engineering Day" (2015); Mentor (2011-2014)
- Chemistry Lab Coordinator for Lafayette, IN Science Olympiad (High School students) (Feb. 2015)
- "Access Engineering" Volunteer for Community-wide K-12 Engineering Outreach (Summer 2013, Summer 2015)
- Invited speaker for Undergraduate Women in Engineering Program Monthly Meeting (April 2014)

Peer-Reviewed Publications

Berdanier, C.G.P., Branch, S.E., Tally, A., Ahn, B., & Cox, M.F. (2016). A Strategic Blueprint for the Alignment of Doctoral Competencies with Disciplinary Expectations. Accepted to International Journal for Engineering Education.

Berdanier, C. G., Zephirin, T., Cox, M. F., & Black, S. M. (2016). Teaching MSE Students to Teach: A Design-Based Research Model for Introducing Professional Skills into the Technical Curriculum. In *Professional Development and Workplace Learning: Concepts, Methodologies, Tools, and Applications* (pp. 444-470). Hershey, PA: IGI Global, Business Science Reference. doi:10.4018/978-1-4666-8632-8.ch028

Berdanier, C.G.P., Zephirin, T.K., Cox, M.F., & Black, S.M., (2015). Teaching MSE students to teach: A model for introducing professional skills into the engineering curriculum. In H. Lim

(Ed.) *Recent developments in materials science and corrosion engineering education* (pp. 369-396). IGI Global: Hershey PA.

Berdanier, C.G.P. & Cox, M.F. (2015). Research and Assessment of Learning Environments through Photoelicitation: Graduate Student Perceptions of Electronics Manufacturing in India Advances in Engineering Education. *Advances in Engineering Education, 4*(4), 1-24.

Saravanakumar T. Pillai, Tom Fischer, Tyler T. Clikeman, Jennifer Esbenshade, **Catherine Berdanier**, …, James D. Hoefelmeyer. (2015). Single Site Metal Ions on the Surface of TiO_2 Nanorods—A Platform for Theoretical and Experimental Investigation. In Dimitri Kilin (Ed.) *Photoinduced Processes at Surfaces and Materials* (pp. 103-116). ACS Symposium Series, Vol. 1196. American Chemical Society. ISBN: 9780841230941. DOI: 10.1021/bk-2015-1196

<u>Peer-Reviewed Conference Papers</u>

*Presenting Author

***Berdanier, C.G.P.** & Cox, M.F. (2016). Characterization of intellectual merit and broader impacts criteria in NSF Graduate Research Fellowship Program applications. 123rd ASEE Annual Conference & Exposition, June 26-29, New Orleans, LA.

Berdanier, C.G.P., Tanyi, E.K., Cashwell, I., Zephirin, T.K., & Cox, M.F. (2016). Learning to conduct "team science" through interdisciplinary engineering research. 123rd ASEE Annual Conference & Exposition, June 26-29, New Orleans, LA.

***Berdanier, C.G.P.** & Cox, M.F. (2015). Understanding missions for engineering outreach and service: How new engineering faculty can learn from past generations of Ph.D.-holding engineers and engineering educators. 122nd ASEE Annual Conference & Exposition, June 14-17, Seattle, WA.

***Berdanier, C.G.P.,** Wallin, T.J., Murphy, M. … Cox, M.F., (2015). Learning non-technical skills from pedagogical training: Investigating IGERT student perceptions. 121st ASEE Annual Conference & Exposition, June 14-17, Seattle, WA.

Sambamurthy, N., **Berdanier, C.G.P.,** Cox, M.F., Lv, J., Maeda, Y., & Johari, S.M. (2015). Making meaning of data: Exploring representations of classroom activities from a first year engineering course. 121st ASEE Annual Conference & Exposition, June 14-17, Seattle, WA.

Louis, J., Osagiede, A., **Berdanier, C.G.P.,** Cox, M.F., & Ahn, B. (2015). Engineering leadership assessment to action: Development of leadership profiles for academic success. 121st ASEE Annual Conference & Exposition, June 14-17, Seattle, WA.

***Berdanier, C.G.P.**, Branch, S.E., London, J., Ahn, B. & Cox, M.F. (2014). Survey analysis of engineering graduate students' perceptions of the skills necessary for career success in industry and academia. 121st ASEE Annual Conference & Exposition, June 15-18, Indianapolis, IN.

Adams, R., **Berdanier, C.G.P.**, Branham, P., Choudhary, N., Fletcher, T., Goldstein, M., Joslyn, C., Mathis, C., Siverling, E., Trellinger, N.M., & Wilson, M.D. (2014). A community of practice approach to becoming an engineering education research profession. 121st ASEE Annual Conference & Exposition, June 15-18, Indianapolis, IN.

Zephirin, T.K., **Berdanier, C.G.P.**, Black, S.M., & Cox, M.F. (2014). Snapshot of an interdisciplinary graduate engineering education experience. 121st ASEE Annual Conference & Exposition, June 15-18, Indianapolis, IN.

McClurkin, J.D., Fitzpatrick, V.R., **Berdanier, C.G.P.**, & Cox, M.F. (2014). Development of industry modules for engineers pursuing advanced degrees. 121st ASEE Annual Conference & Exposition, June 15-18, Indianapolis, IN.

Cox, M.F. , Brunson, P.C., Sambamurthy, N., Branch, S., & **Berdanier, C.G.P.** (2014). Transformation of faculty dissemination practices via social media. 121st ASEE Annual Conference & Exposition, June 15-18, Indianapolis, IN.

Reports, Presentations, and Posters

Berdanier, C.G.P. (2013). *Flowfield Characterization of a Piloted Lean Premixed Injector by Particle Image Velocimetry.* (Master's Thesis). Accessible by ProQuest Dissertation and Theses: UMI 1549301.

"States of Matter: Beyond Solids, Liquids, and Gases." National Educator's Workshop (NEW), Nov 2-4, 2014, Seattle, WA.

"Flowfield Characterization of a Piloted Lean Premixed Injector by Particle Image Velocimetry." Purdue Women in Engineering Program Poster Session, March 2013

"A multidisciplinary analysis of a two-stage-to-orbit system utilizing scramjet propulsion," University of South Dakota IdeaFest Research Symposium Poster Session, April 2010

"Nucleation of Pt Nanocrystals in the presence of TiO_2 Nanorods: Towards the synthesis of polydomain nanostructured materials for photocatalysis applications," University of South Dakota IdeaFest Research Symposium Poster Session, April 2009.

"Llamas y Papas: Research in Peruvian Culture and Biodiversity." University of South Dakota IdeaFest Research Symposium Poster Session, April 2008.

Workshops and Invited Talks

Writing and Argumentation Workshop **October 22, 2014**

ASEE 2014 Workshop: "Convincing the Non-believers: Selling Engineering Education Experiences on the Job Market" **June 15, 2014**

The University of South Dakota, Department of Chemistry. **October 9, 2015**