

Quantitative investigation of engineering graduate student conceptions and processes of academic writing

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Abstract - Though many writing researchers link the role of writing with disciplinary socialization, there is little research outside of anecdotal evidence on how engineering graduate students in particular conceptualize and relate to the writing process. These affective components of writing are as necessary as the cognitive activities in terms of developing successful graduate engineering writers. To meet this gap, the present study shows survey data from N=210 graduate engineering students at research intensive universities across the United States. The survey comprised three validated writing scales investigating students' conceptions of writing, processes of writing, writing self-efficacy in a single survey deployment. Descriptive statistics show the common processes and conceptions with writing, but Pearson correlations calculated across scales reveal statistically significant relationships among the scale factors, for example that many graduate engineering writers often struggle with a "trifecta" of low writing self-efficacy, perfectionism, and procrastination. This study extends prior mixed methods and smaller scale quantitative work that has been done in the past with engineering graduate students, and also points to the importance of addressing the layered nature of student issues with writing. Findings are situated in terms of practical recommendations for technical writing researchers and faculty as they help graduate students navigate academic engineering writing.

Index Terms – Engineering writing; graduate students; writing concepts and approaches

INTRODUCTION

Graduate engineering students are typically not introduced to academic engineering writing until major academic deliverables, such as manuscript preparation, master's

theses, or dissertations. This is problematic for both the students themselves, as they often struggle to learn to write under high-pressure conditions, and is also an issue for faculty, who may not be prepared to teach graduate students to write and who depend on academic publications for promotion and tenure. Students with graduate degrees in engineering pursue both academic and industry careers, both of which require writing, albeit in different formats and contexts. However, the ability to tailor technical content to various audiences remains an essential competency [1], [2]. While the recommendations for stronger engineering communication skills, including writing, continue to be part of the calls for the technical writing and engineering communities [3], [4], at the graduate level, most engineering education writing literature is aimed at interventions or courses to prepare students to write[5]–[9], rather than employing methods from composition and rhetoric or doing foundational engineering writing research. There is a disconnect between the writing research that studies engineers and the engineering education literature research that pertains to writing; and indeed, in both communities, graduate students tend to be understudied with regards to communication competencies. With this disconnect in mind, the research questions this study answers include

1. What are the writing concepts, processes, and attitudes common among graduate engineering students at research-intensive universities?
2. What statistical correlations among the surveys exist, and what might these results lend to the teaching of graduate level academic writing (formally or informally).

BACKGROUND

Studies investigating writing in engineering contexts tend to focus on undergraduate engineering

students [6], [10]–[13] and tend to be “intervention” oriented, rather than seeking to uncover information about the ways in which students conceptualize the writing process. There is a small recent increase in the number of writing-focused articles that have emerged in engineering education journals such as the *Journal of Engineering Education* [14] and the *European Journal of Engineering Education* [13]; however, most of the writing work is published in technical communications venues and struggles to translate into the engineering curriculum. Writing in the Disciples and similar initiatives may help, as writing faculty are incorporated into engineering courses; however, as there are no ABET-type standards at the graduate level, these initiatives typically stop at the undergraduate level.

There are only a few examples of engineering education literature that seeks to investigate writing using writing research methods. For example, Fillenwarth and colleagues [15] investigated engineering resumes through an activity theory framework, quantifying disciplinary discourse at the undergraduate level. Conrad [14] employed corpus analysis and rhetorical move-step analysis to civil engineering documents, noting that engineering students use of language is needlessly complex and follows a less direct rhetorical scheme than engineering practitioners writing similar documents. Her findings echoed a few other prior studies using genre analysis methods for science and engineering literature [16], [17].

At the graduate level, there is a lack of engineering writing literature across invested communities. Most literature emphasizes the need for disciplinary writing in the graduate curriculum in general [18]–[21] with suggestions focusing on the role of writing centers, student writing groups, and other sociological impacts. In terms of attitudinal or cognitive research, a few studies have investigated how students are affected by the psychological and affective aspects of writing, in particular writing anxiety, particularly for English as a Foreign Language (EFL) students [22]–[24], and on procrastination [25], [26] and other attitudes that affect writing processes [27]. Though these scales have been developed in other disciplines, and often for graduate students in particular, the results have not to date focused on the writing attitudes and issues of engineering graduate students, who are rarely exposed to writing in their coursework.

In sum, there are several gaps in the research. First, there is a need to study communication in graduate students, as a population that is typically ignored in both the engineering education and the technical communication literature. Second, the writing habits, attitudes, and approaches of engineers in particular is a topic of interest, since their attitudes play a large part in the effectiveness of any proposed interventions. Last, we identify a need for cross-disciplinary work, using methods from writing studies, applying it to engineering graduate

students, and translating findings to engineering educators and technical communications faculty.

The present study extends past work [17] which employed many of the same scales to a small subset of engineering graduate student writers—namely, those who applied for and won the National Science Foundation Graduate Research Fellowship award. These students are notably an exceptional subset of writers, and it could be argued that they had higher levels of writing aptitude since they were winners of the fellowship (which required a research proposal and personal statement as part of the application package.) Findings from that study indicated that even the strong engineering writers often struggled with writer’s block, low writing self-efficacy, and procrastination and perfectionism tendencies. Therefore, the purpose of this study is to investigate these potential statistical trends in a larger population of participants in order to get a more accurate “snapshot” of engineering graduate students’ attitudes, processes, and conceptions of academic engineering writing that can guide intervention development for graduate engineering students.

THEORETICAL ORIENTATION

This study is guided by academic literacies theory [28]–[32] which proposes that literacy in an academic context is more than simply being able to read and write, and extends into communicating within the disciplinary expectations of a research community. Academic literacies theory is typically applied at the graduate level, where students are especially stretched to learn to publish in their academic disciplines. Typically, academic literacies theory establishes the transition to “becoming” a member of a discipline, however, the affective and cognitive elements of writing are important in developing academic literacies. For example, if a student suffers from writing apprehension or writer’s block, these aspects can inhibit the development of academic literacy. In the present study, we employ academic literacies theory to interpret the results of the study. While several established surveys have probed different dimensions of writing attitudes, few studies to date seek to statistically correlate the writing surveys for students in a particular discipline. Many writing surveys probing writing attitudes, processes, and concepts were developed using participants that write more commonly in their coursework than engineers do; therefore, it is of value to uncover the common affective relationships that engineers have with writing as a task and competency housed within the context of their transition to becoming a member of their academic engineering discipline.

METHODS

I. Participants and Recruitment

The participants for this survey were graduate engineering students. To recruit participants, we sent an

email to the graduate coordinators (or similar positions) from all engineering departments at five R1 universities geographically dispersed across the United States. The link could be shared, so some participants taking the survey were graduate engineering students at other universities outside of the five surveyed. Participants were incentivized to complete the survey through a \$5 gift card if the entire survey were completed. There were no decisions to limit the disciplines of the graduate students with the exception that engineering education graduate students were not recruited to participate. Participants were incentivized to participate with the receipt of a gift card after completion of the study. The survey was deployed through Qualtrics online survey software, and with the exception of potentially sensitive demographic information, all the survey items were required such that we obtained a complete data set and did not have to negotiate missing data. The demographic portion of the deployed survey collected information about desired career trajectory and confidence in the ability to complete their desired degree objective. Then, participants were instructed to complete a series of scales, as will be discussed further.

The demographic characteristics of the participants who completed the entire survey in the study are as follows. Of the N=210 graduate student participants, 76 (36.5%) self-identified as women; 85 (40.5%) were U.S. domestic students, and 110 (52.4%) speak English as a first language. Of the participants, 110 (52.4%) categorized themselves as early-career graduate students (pre-qualifying or pre-candidacy exams or in years 1 and 2 of their graduate programs, for schools who do not have candidacy exams); 65 (31%) indicated they were a mid-career graduate student between their qualifying exams and their dissertation proposals (or years 3-4); and the remainder indicated they were late career graduate students. The heavy skew toward early career graduate students makes sense because the early career category would include students pursuing master's degrees. Most of the graduate students surveyed (78.1%) indicated they had started graduate research. As part of a wider research study, we probed for career trajectory information, as well as their academic history with writing. Approximately 63% of respondents reported not taking any writing-intensive courses in the past two years, and only 16.2% of students report communicating often with their advisors about academic writing tasks or writing skills while 44.3% of respondents "never" or "rarely" talked about writing with their advisors).

II. Survey and Analysis Methods

As part of a larger IRB-approved survey, three established writing scales were deployed to the participants embedded within the overall survey. These surveys are briefly described here, and all survey items can be found in the original references and in [17].

1. Inventory of Graduate Writing Processes [27].

The survey is conducted on a four-point Likert type

scale and measures dominant patterns of writing that correlate with the writer's beliefs about writing. Results are analyzed by summing and averaging within-construct items, and the averages are compared across constructs to determine a writer's dominant construct. The seven processes (factors) measured are

- **Elaborative**—writing is a personal investment and part of knowledge creation
- **Low Self-Efficacy**—lack of confidence in ability to articulate thoughts
- **No Revision**—avoids or resists deep revision
- **Intuitive**—Innate sense of writing, expectations, the ability to "see" or "hear" an argument affectively
- **Scientist**—follows a strict order to the writing process
- **Task Oriented**—strong adherence to "rules" of writing and may not see writing as a personal process
- **Sculptor**—highly fluent style of drafting text, typically only revises after an entire draft is written

2. Graduate Concepts of Academic Writing [33].

Developed to measure six factors that influence graduate student writing processes, the scale was originally deployed to correlate with well-being of graduate students. The survey is conducted on a 5-point Likert-type scale, and within-construct items are summed and averaged to determine the writer's dominant concepts. The six concepts (factors) measured are

- **Procrastination**—puts off starting or working on writing tasks
- **Perfectionism**—strives toward perfection and may not make progress due to continuous revision/editing
- **Innate Ability**—believes writing ability is a fixed attribute that cannot be taught
- **Knowledge-Transforming**—believes writing is a way to build and test knowledge and arguments
- **Productivity**—Stays on task, able to consistently make progress when writing
- **Blocks**—writing "paralysis" that inhibits the production of text or how to begin writing

3. Self-Regulatory Efficacy for Writing [34].

The scale measures a writer's self-described efficacy to carry out writing tasks. Low and high self-efficacy scores are measured with respect to the mean and the standard deviation of the sample, so it accommodates a variety of different audiences.

After cleaning the data for incomplete survey responses, the survey data were sorted into their respective scales and cleaned according to the procedures from the original sources using Excel. Reverse-coded survey items were corrected in order to analyze the data. Each individual's results for each of the surveys were calculated according to the methods for that particular survey. After calculating the results of the survey, the averaged scores for each factor were correlated against each other in SPSS statistical software using Pearson correlations and depicted in a correlation matrix. Demographic data related to gender, citizenship, first language, academic level, research experience, and how often students communicate

with advisors about writing were also with the writing factors.

RESULTS

The descriptive statistics for each of the factors within the surveys are shown in Table 1. Results indicate that on average, the engineering graduate students demonstrate high average levels of procrastination (mean=3.41) and knowledge transforming (mean=3.97) concepts of writing, while also exhibiting high levels of elaborative (mean=2.97), scientist (mean=2.90), and low self-efficacy (mean=2.83) writing processes. Cronbach alpha values were calculated to indicate the internal reliability of the scales. Most of the items exhibited acceptable levels of internal reliability. The factors that fell low (calling out the task-oriented and sculptor factors within the Graduate Writing Processes survey) may be due to multifaceted constructs. The reliability values calculated here are consistent with the reported reliability values in the original study (Lavelle and Bushrow (2007)). The purpose of the Cronbach alpha is to measure internal reliability, and the while the benchmark thresholds for reliability can be used as milestones, lower alpha values can be contextualized in terms of the constructs being measured and the potential areas for variability in student responses. However, since the correlation calculations discussed later indicate statistically significant correlations with other factors across scales, these low values are not consequential.

Table 1: Descriptive statistics for each of the three surveys measuring graduate engineering writing attitudes, including the number of items included within each factor of each scale, internal consistency, the mean, standard deviation, and minimum/maximum average scores on each factor.

Scale	N (items)	Alpha	Mean	SD	Min	Max
Graduate Writing Processes						
Elaborative	12	0.51	2.97	0.32	1.92	3.83
Low Self-	11	0.71	2.83	0.42	1.73	3.82
No Revision	9	0.67	2.36	0.42	1.44	3.66
Intuitive	12	0.62	2.92	0.49	1.83	4.00
Scientist	9	0.6	2.90	0.32	2.22	4.00
Task-Oriented	8	0.49	2.37	0.34	1.25	4.00
Sculptor	6	0.46	2.62	0.40	1.50	4.00
Graduate Concepts of Writing						
Blocks	5	0.65	3.03	0.78	1.40	5.00
Procrastination	4	0.70	3.41	0.85	1.00	5.00
Perfectionism	5	0.58	2.84	0.77	1.25	5.00
Innate Ability	2	-	2.13	0.95	1.00	5.00
Knowledge-Transforming	6	0.69	3.97	0.56	1.83	5.00
Productivity	4	0.72	2.50	0.83	1.00	5.00
Regulatory Self-Efficacy for Writing						
	25	-	4.58	0.80	2.52	7.00

Analysis of Results by Scale

In this section, the Graduate Writing Processes and Graduate Concepts of Writing scale results individually will be addressed. For each scale, we show the primary and secondary dominant processes/concepts of writing reflected by the graduate student population. Sums of either the dominant or secondary attributes may not total N=210, because many participants had “tied” scores with dominant primary and secondary attributes.

Figure 1 shows the dominant and secondary processes and Figure 2 shows the dominant and secondary concepts of writing demonstrated by the graduate engineering student participants.

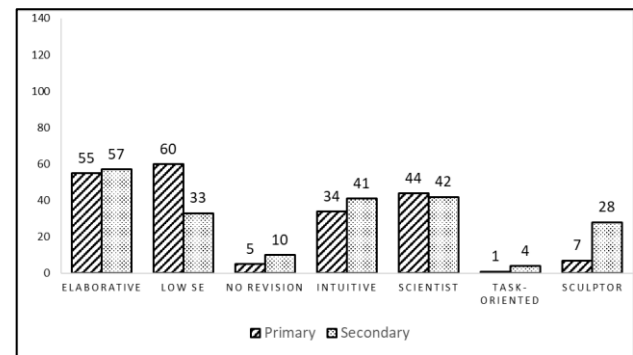


Figure 1. Histogram documenting the distribution of dominant and secondary graduate writing processes.

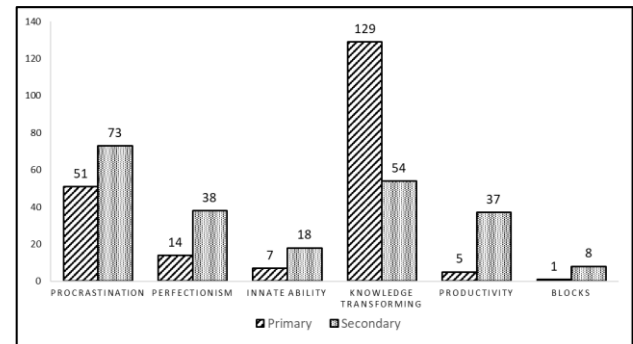


Figure 2. Histogram documenting the distribution of dominant and secondary graduate concepts of writing.

While it is evident that graduate engineering writers don't all necessarily write in the same way, demonstrated by the wide distribution in writing processes (Figure 1), there is a heavy indication that graduate engineering students understand writing to be part of the knowledge-transforming process, and procrastination is the second-most common concept of writing. (Figure 2). These descriptive data are useful in understanding, at a glance, what the main issues for many graduate-level engineering writers are—for example, procrastination is an issue less with writing, but with time management in general (though it may be augmented due to other issues such as tendency toward block or perfectionism.)

These histograms show data at a glance on two scales, but cannot show connections either between factors in the scale or across scales. Therefore, a correlation analysis is necessary to show trends and relationships among these variables.

Correlation Analysis

Pearson correlations were calculated between each of the factors within the scales and across the demographic

variables in order to understand the relationships between them. The correlation matrix in Figure 3 shows the results. Statistically significant correlations are shown in bold and the significance level is indicated by the asterisks. For ease of at-a-glance use, the significant negative correlations in the matrix are shown in red, and the positive in green. It is of utmost importance to remember that correlation does not imply causation.

	Demographic Information						Scale: Graduate Writing Processes							Scale: Graduate Concepts of Writing						
	Gender	Citizenship	First language	Academic Level	Level of graduate research	Frequency of comm. about writing	Elaborative	Low SE	No Revision	Intuitive	Scientist	Task-Oriented	Sculptor	Blocks	Procrastination	Perfectionism	Innate Ability	Knowledge Transforming	Productivity	
Gender	1																			
Citizenship	0.134	1																		
First language	0.016	0.699**	1																	
Academic Level	-0.080	-0.032	0.036	1																
Level of graduate research	-0.068	0.133	0.042	0.252**	1															
Frequency of Comm. about Writing	-0.077	-0.058	-0.056	0.229**	0.036	1														
Elaborative	-0.067	0.071	0.061	-0.004	0.069	0.117	1													
Low SE	0.053	0.325**	0.212**	-0.114	0.057	-0.104	-0.280**	1												
No Revision	0.091	0.163*	0.067	-0.171*	0.085	-0.090	-0.080	0.098	1											
Intuitive	0.044	0.038	-0.045	-0.036	0.116	0.059	0.464**	-0.079	-0.172*	1										
Scientist	-0.031	-0.036	-0.159**	-0.015	0.054	0.157**	0.295**	-0.055	-0.025	0.344**	1									
Task-Oriented	0.015	0.214**	0.151**	-0.063	0.131	0.020	0.266**	0.057	0.414**	0.323**	0.174*	1								
Sculptor	0.045	0.253**	0.203**	-0.010	0.151*	-0.029	0.172*	0.014	0.109	0.372**	0.095	0.306**	1							
Blocks	0.062	0.227**	0.088	-0.106	0.183**	0.025	0.346**	0.021	0.506**	0.580**	0.487**	0.742**	0.654**	1						
Procrastination	0.001	0.027	0.013	-0.007	-0.020	-0.160*	-0.317**	0.558**	0.078	-0.057	-0.026	0.014	0.068	0.036	1					
Perfectionism	0.004	0.097	0.123	0.030	0.087	-0.186**	-0.126	0.459**	0.107	0.132	0.030	0.353**	0.204**	0.277**	0.422**	1				
Innate Ability	0.089	0.280**	0.180**	-0.065	0.111	-0.108	-0.070	0.283**	0.493**	-0.063	-0.072	0.388**	0.292**	0.385**	0.249**	0.379**	1			
Knowledge Transforming	-0.058	-0.047	0.014	0.097	0.014	0.080	0.505**	-0.105	-0.450**	0.461**	0.253**	-0.000	0.028	0.049	-0.046	-0.026	-0.301**	1		
Productivity	0.050	0.164*	0.177*	0.072	0.177*	0.162*	0.334**	-0.153*	0.248**	0.215**	0.081	0.433**	0.247**	0.416**	-0.253**	0.190**	0.290**	0.107	1	
Self-Regulatory Efficacy	-0.023	-0.199**	-0.216**	0.083	0.086	0.163*	0.416**	-0.528**	0.039	0.391**	0.343**	0.223**	0.171*	0.372**	-0.304**	-0.134	-0.064	0.370**	0.365**	

*p < 0.05 **p < 0.01

Figure 3: Correlation matrix for three writing scales with demographic data. Green shaded values indicate positive (direct) correlations, whereas red shaded values indicate negative (inverse) correlation relationships between the variables. Levels of statistical significance are shown using asterisks; all significant relationships are shown in boldface

DISCUSSION

While inter-scale correlations are expected, the intra-scale factor correlations are quite interesting. Some correlations are intuitive, such as the strongly positive relationship between procrastination concepts and low writing self-efficacy processes. However, others relationships are more nuanced, such as the strongly significant relationships between Blocks (concepts) and six of the seven processes of writing, but not low self-efficacy. Discussing each individual statistically significant correlation is too involved for this paper, and many are intuitive correlations that most instructors would posit anecdotally after years of teaching writing. The numbers now confirm statistically that these

relationships indeed occur in the ways in which graduate students approach their academic writing tasks.

One of the most compelling reasons to do statistical work to validate anecdotal hypotheses about writers' approaches and conceptions of the process is that, rather than simply using one study, layering scales over each other show the nuanced ways in which students have particular issues with writing. Indeed, all writers—even faculty—have their individual issues with writing, whether it be overcoming writer's block, procrastination, or the difficulty in sorting out thoughts after a “brain dump.” Statistical results such as those presented in this paper help instructors to anticipate what they “layered” issues embedded within their graduate student writers might be conquering while they're learning to write.

Furthermore, the demographic data indicate general trajectories in the ways that graduate students write, and continued data collection to obtain a larger sample size is in progress. There are statistically significant positive trends between level of graduate study and the frequency with which students are speaking with their advisors about writing tasks, which is good news for writing instructors. In addition, there is a significant negative correlation between level of graduate study and “no revision” tendencies, which is similarly good news!

There are many statistically significant trends with respect to citizenship (US domestic student vs international student). The statistically significant positive correlations between citizenship and many of the writing processes and concepts is indicative of issues that English as a Foreign Language students might be facing. Indeed, there are high statistical trends toward regarding the ability to write as an “innate ability” which may be a difficult threshold to overcome in typical graduate writing contexts in a research group. Of note, the numbering system by which the nominal data is arranged in the data set (citizenship, level of graduate study, etc.) impacts the direction of the correlation (positive or negative) but not the magnitude.

For engineers in particular, it is interesting that most students do understand that writing is a knowledge-transforming process, while still struggling with the trifecta of perfectionism, procrastination, and writer’s block. Leveraging writing strategies to overcome some of these issues, such as accountability structures, timed writing sprints, and time management techniques can be housed within a broader discussion of learning-to-write and writing-to-learn as a graduate student in the process of *becoming* a member of a discipline, calling to mind academic literacies theory.

Instructors who teach graduate engineering writing classes might use the data from this paper, and the larger-N data that will be presented in forthcoming publications, as a demographic and writing “personality” snapshot of graduate students across the United States. While it may not be feasible to deploy the scale to every student in order to give them their own results, it may be useful to present these results to students with the definitions of the processes and concepts and ask them to reflect on their own writing issues before they even begin writing. Knowing that all writers struggle with various aspects of the writing process might ease some anxiety that comes with writing.

Future work for this project includes analyzing data from a much larger current engineering graduate students across the U.S. and investigating writing processes and concepts with respect to attrition and persistence from graduate studies.

CONCLUSION

In sum, this article used statistical data from N=210 U.S. engineering graduate students studying at research-intensive universities in the United States in order to begin to investigate statistically-significant relationships between factors presented in various writing studies. Results indicate statistically-significant correlations among many of the intra-scale factors, which lend depth and nuance to understanding common issues that graduate engineering students may encounter. The authors encourage other faculty and researchers to reach out to us for the survey instrument for use in their own research and classes, and practical suggestions for research-to-practice mechanisms are discussed. In light of the paucity of graduate engineering writing literature, and statistical literature investigating engineering writing in both the technical communication and engineering education literature, this work presents valuable findings to many disciplinary communities.

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