Correlations between graduate student writing concepts and processes and certainty of career trajectories

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Abstract— **At the graduate level, most milestones are based on the ability to write for an academic audience, whether that be for dissertation proposals, publications, or funding opportunities. Writing scholars often discuss the process by which graduate students learn to join their academic "discourse communities" through academic literacies theory. Graduate attrition researchers relate the feeling of belonging with persistence in doctoral programs; however, there has not to date been any research that directly studies engineering writing attitudes and perceptions with student career trajectories, persistence, or attrition. To meet this need, this paper presents research from a larger study analyzing graduate level engineering writing and attrition. The explicit objective of this paper is to present quantitative data relating current graduate engineering students' attitudes, processes, and concepts of academic writing with the certainty of their career trajectory. Five scales measuring aspects of writing were deployed to engineering programs at ten research intensive universities across the United States, with a final total of n = 621 graduate student respondents that represent early-career, mid-career, and late-career stages of the graduate timeline. Results indicate that graduate student processes and conceptions of engineering writing correlate with the likelihood of pursuing careers in various engineering sectors after completing their graduate degree programs.**

Keywords—graduate education; career trajectories; engineering writing

I. INTRODUCTION

Most graduate engineering students are ill-prepared for the amount of academic writing required during graduate school. Most undergraduate programs incorporate writing only in laboratory or design classes, where emphasis is rarely placed on writing for disciplinary or academic audiences. However, writing is a critical skill for graduate students as future engineering professionals; even though nearly 80% of engineering PhD students will pursue industry careers, [1], [2] the ability to translate technical information to a variety of audiences clearly and appropriately in writing has been documented as a critical competency for graduate students[3]–[5]. Students who are considering a career in academia may have a better understanding of the role that writing will play in their professional life (success lies on one's ability to publish journal and conference papers, and to win money through [written] grants); however, most engineering graduate students are not given opportunities to learn how to write for these venues until late in their graduate careers.

As part of a larger mixed methods study working to explore relationships between graduate engineering writing and tendencies toward persistence, attrition, and career trajectories, this paper seeks to unveil the correlational relationships between graduate students' writing processes and writing concepts, as measured through validated survey scales, with their confidence in the sector in which they intend to work after graduation.

II. LITERATURE REVIEW

A. Graduate Students and Career Trajectories

Very little work is done with respect to graduate students in the engineering education research community. That that has been done typically corresponds to the knowledge, skills, and attributes required by engineering graduate students [3], [6], [7]; to the development of research competencies [6], [8], [9]; or to factors related to attrition or persistence of graduate students [8], [9]. However, fewer researchers investigate how or why students pursue a variety of careers after a graduate degree. Recently, Borrego et al. [10] recently published one of the first studies exploring why engineering students pursue graduate school, indicating that prior exposure to research and positive faculty relationships are important to facilitate decisions toward graduate school. However, to date, no researchers have investigated how or why students pursue a variety of careers after a graduate degree. As literature estimates, nearly 80% of engineering students will work in engineering industry rather than pursuing an academic route [1], but the research community as a whole has not investigated how underlying skills and attributes may either explicitly or implicitly guide students toward certain career paths.

In the literature related to science higher education, there is a similar paucity of literature. Roach and Sauermann [11] found that PhD students in science disciplines who pursued industry careers over academic careers had a weaker "taste for science" (p. 422), noting that instead, doctoral science students

interested in pursuing industry research and development careers were more interested in the application of science, more concerned with salary, and less concerned with publishing and the ability to conduct independent research. Fuhrmann et al. [12] suggest the importance of developing a different model for graduate-level biomedical science education motivated by the modern diversity in career pipelines for doctorates holding these degrees. These papers are specific applications of common critiques of an antiquated higher education system in general [13]–[15], especially as humanities disciplines in particular are noting a surplus of doctorates for a shrinking number of available professor positions. However, the PhD across disciplines is still seen as a mechanism by which to prepare students to fit the mold [16] in a traditional career in the professoriate [17]–[19].

B. Research Engineering Writing at the Graduate Level

For the purposes of this research, we are particularly interested in engineering writing as the competency of interest for this study, and attitudes and conceptions of writing being the attribute of interest. While no published studies to date make a direct statistical link between writing and doctoral persistence, researchers across the higher education and writing research communities note that there is a link between writing competency and the development of disciplinary identity [20]–[23], which is independently related with persistence through the doctorate [24].

The lack of disciplinary engineering writing in the engineering curriculum either at the undergraduate or graduate level may have some effect on career paths that students pursue; however, no researchers to date have studied this. Conceivably, if a student has not been taught to write in for an academic engineering audience, and then has a difficult experience writing a master's thesis and is ill-supported in the endeavor, she or he could potentially decide against continuing for a PhD, or against pursuing a faculty career, regardless of how promising a researcher she or he could be. However, provided effective education, the student could be scaffolded with the tools and practice to learn to communicate effectively and efficiently in academic writing tasks, and not be overwhelmed by the prospect of a dissertation, grants, or publications. The emotional and affective parts of the writing part are incredibly influential on a writer's self-efficacy [25]–[27], and it is possible that one's relationship with writing could influence their decisions to pursue one career trajectory over another, if the student perceives she or he will have to write less in an industry career than in academia, for example.

Much of the graduate engineering writing literature is "intervention"-oriented to better prepare graduate students for academic writing venues. For example, Leydens and Olds [28] and Fang [5] reported outcomes from graduate writing courses intended to teach grant writing to graduate students, so they can practice this skill set in a low-stakes setting before attempting it in a faculty career. Other interventions include those such as the Dissertation Institute [29], which propose a bootcamp-type workshop to help doctoral students from underrepresented groups overcome challenges related to the dissertation writing process near the ends of their doctorates. This model follows much literature from the writing literature, which proposes that graduate students are more productive if supported through peer mentoring groups through the writing process [30]–[32].

C. Gaps in the Literature

There is a lack of literature surrounding engineering graduate student career trajectories in terms of the factors driving students to attempt academic careers or to pursue industry careers. This knowledge is important in developing more modern graduate curricula in the doctorate to reflect the changing career pathways that graduate engineering students can take after achieving their PhD. Further, the linkages between engineering graduate students career trajectories with various technical and non-technical competencies is similarly uncovered in the engineering education and higher education literature. With respect to writing in particular, there is strong anecdotal evidence that links one's ability to write for academic audiences with success in academic careers, which posit that a person should be able to write well and clearly in order to publish research and win grant money; however, very little research is done to understand the ways in which a student's writing concepts and processes affect (even unintentionally) desired career trajectories.

III. THEORETICAL FRAMEWORK

The theoretical orientation that guides this work is academic literacies theory [33], [34], which posits that literacy in the disciplines extends being able to read and write, but rather that one is adept at communicating with the correct language to follow the embedded expectations and norms of those in the discipline. The "discourse community" that follows the same rules for language patterns, both written and verbal, can feel overwhelming to graduate students, who are learning to become producers of knowledge rather than simply consumers of knowledge [35]. The development of disciplinary discourse signifies entry and belongingness to a disciplinary community, and is one sociocultural lens for understanding the multifaceted process of academic socialization [36]–[39].

Academic literacies theory is a convenient and appropriate one for this research, as we seek to understand the ways in which one particular attribute—a graduate students concepts and processes of academic writing—may influence their confidence in their career trajectory. While we understand that there are likely many factors that play a role in trajectory decisions, such as the "taste" for research (as [11] put it), or family or geographical constraints or preferences for jobs out of graduate school, or concerns over timing to start families [40], [41] (which has been one factor influencing women to opt out of academic careers across disciplines), we are interested to understand the role that one's relationship with writing has to play in a graduate students' future career choices. Through academic literacies theory, we would expect that graduate students who either have developed disciplinary discourse and disciplinary identity might be more likely to consider staying in academia as a professor than an individual who has not developed these competencies.

IV. METHODS

A. Participants and Recruitment

As part of a larger mixed methods studying writing, persistence, attrition, and career pathways, this quantitative research is one phase of a multiphase study. The survey was sent out to directors and chairs of engineering graduate departments of ten research intensive universities. They were asked to forward it on to engineering graduate students across many fields. The specific discipline within engineering was not important. Students were incentivized with a gift card for completing the survey.

Of the n = 621 participants who completed the survey, 235 (38%) were male, 337 students (54%) were domestic, and 378 (61%) spoke English as their first language. Participants were asked to identify their academic level. Fifty-six percent of participants classified themselves as early career graduate students, a category that includes students who have yet to take any qualifying exams, are in the first two years of their degree, or are a Master's students. Only 15% of the participants were late career graduate students (described as either having defended a dissertation proposal or having completed at least four years of their PhD program). We also collected data on the students' final degree objectives (e.g., PhD or MS).

In the demographic section of the survey, we also surveyed participants about the number of intensive writing classes they have taken in the last two years and how often they communicate with professors about the writing process. As shown in Figure 1(a) and 1(b), 61% of students have not taken a writing-intensive class in the two years prior, and 49% report either "rarely" or "never" talking with their research advisors about writing-related tasks. These characteristics confirm anecdotal evidence that most engineering graduate students do not engage in either formal or informal writing instruction.
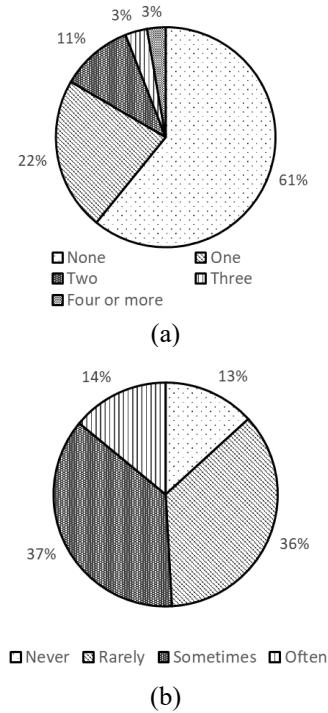

(a)

(b)

Figure 1: Participant characteristics. (a) Participant responses to number of writing intensive courses in past two years. (b) Participant responses to the frequency with which they communicate with professors about writing

Participants were also asked to select the likelihood that they believed they would pursue a certain career. Figure 1 shows the distribution of the student-reported likelihood for pursuing careers in a variety of generalized engineering sectors.
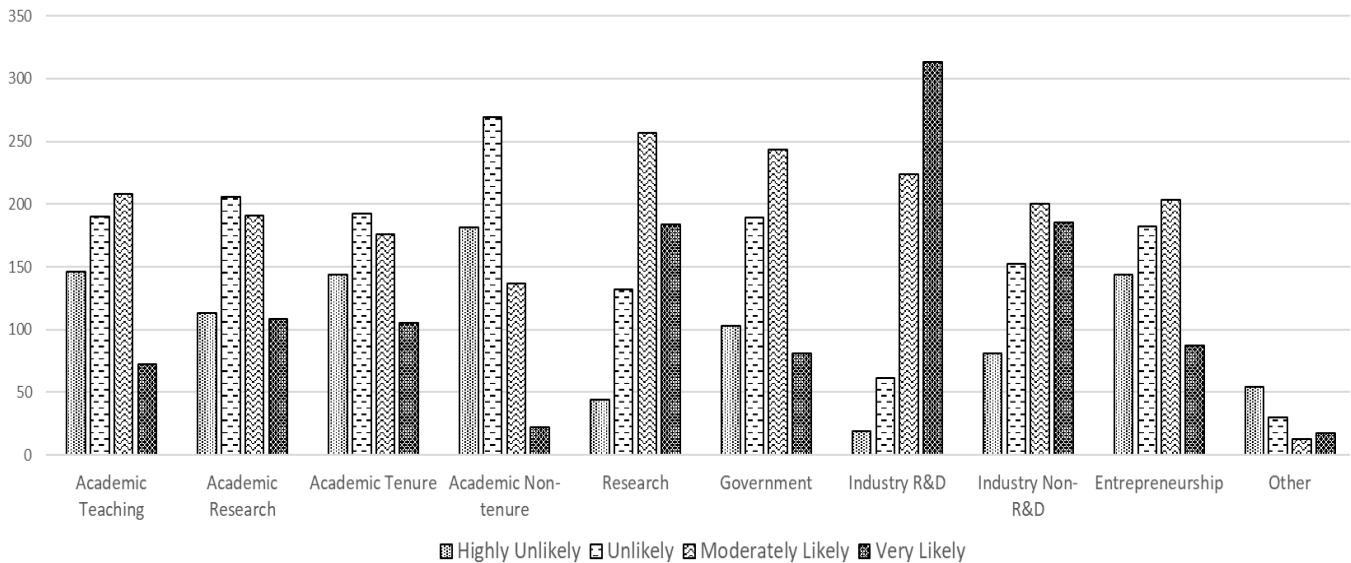

Figure 1: Graduate student participants' reported likelihood of pursuing a given engineering career sector.

As shown in Figure 1, most participants indicated interest in industry or research sectors. Careers in academia, except for non-tenure track positions, were also of interest to participants. It should be noted that this distribution may be due to the sampling population of current graduate students at research-focused institutions. The total number of participants represented by Figure 1 does not total the number of participants in the study because participants were requested to simply indicate the likelihood they would pursue a career in any given sector, and therefore a single participant could indicate a high likelihood of pursuing careers in all the sectors. The decision to open this question is representative of the open-ended career planning paths that many students embark upon, if they are open to certain career paths more than others, but may hesitate to reject opportunities in other sectors. The distribution of frequencies also reflects the current job climate for engineering graduate students, which offers fewer faculty opportunities and more industry and research positions.

Survey Description

The survey consisted of a total of four different validated surveys from prior work: Two that assess writing attitudes and processes [26], [42], one that assesses writing self-efficacy [43], and one that addresses research self-efficacy [44]. These surveys have been employed together in the authors' past work [25], [45] but have not to date been employed on a sample size this large or correlated with career trajectories of graduate students. For the purposes of this work, we simply seek to correlate student writing concepts and processes with a student's self-reported career trajectory likelihood. The two writing scales employed in the survey are described as follows.

It should be noted that the names of the constructs within the surveys were named by the original developers of the survey, not the current researcher. In addition, while some of the names of the constructs have colloquial meanings (e.g., procrastination), as employed in the survey the items associated with the constructs measure a writer's affective relationship with the writing process, such that "procrastination" concepts of writing indicate an innate avoidance of writing.

1. Inventory of Graduate Writing Processes [42]

This survey uses a four-point scale to quantify the writer's approaches and beliefs of the writing process. Multiple questions pertaining to each classification were shuffled together. Results were collected by averaging the responses for each classification, listed below, and finding the writer's dominant and secondary constructs.

- Elaborative—The writer is investing in knowledge creation through writing
- Low Self-Efficacy—Lack of confidence contributes to inability to generate thoughts
- No Revision—Written work is completed with little to no revision
- Intuitive—Natural "feeling" for how the argument should develop
- Scientist—Strictly adheres to an order of the writing process

- Task Oriented—Writing is not a personal process and is completed by following specific rules
- Sculptor—writer easily creates a draft with revisions taking place once draft is completed

2. Graduate Concepts of Academic Writing [26]

This survey uses a five-point scale to measure six concepts that influence the student's writing process. Similar to the previous survey, the multiple questions for each factor were averaged together and the dominant and secondary factors for each participant were collected. The writing factors are as follows:

- Blocks—Writer's block prevents the writer from starting
- Procrastination—Delay in starting or completing writing tasks
- Perfectionism—Continuous editing and revising inhibits progress
- Innate Ability—Believes writing is talent that cannot be taught
- Knowledge-Transforming—Uses writing as a mean to test knowledge and arguments
- Productivity—Writer stays on task and can consistently make progress

B. Analysis Methods

The survey data were first cleaned to remove any participants who did not complete the entirety of the survey, except for demographic data. After, the individual surveys were analyzed per their original intents and purposes in their original citations. We employed a MATLAB script to reverse-code appropriate items and to sort the survey responses into construct-specific item categories, such that the within-construct items could be averaged for each participant. The MATLAB script was also programmed to determine each participants' primary and secondary writing concepts and writing approaches. Correlation tables using Pearson correlations were created to find relations between a participants' score on various writing approaches and concepts and their self-assessed career trajectory. The correlation tables and statistical analysis was performed using SPSS statistical software.

V. RESULTS AND DISCUSSION

The correlation table calculated from the trajectory and writing data is shown in Table 1. In addition to career trajectory data, the chart also depicts participant responses to their stage in graduate school to provide context to the responses. As shown in the table, there are a several positive and negative correlations that are statistically significant. For the sake of space, we have not shown rows for the respective p-values for each of the correlations, but significance levels are demonstrated through the use of asterisks, and all statistically significant correlations are shown in boldface. Positive significant correlations are shaded in light grey, and negative significant correlations are not shaded, to further aid interpretability of the table.

Table 1: Correlation table indicating significant correlations between career trajectory likelihood and processes and concepts of writing.

		Demographic		Career Trajectory								
		Academic Level	Degree Objective	Academic (Teaching focused)	Academic (Research-focused)	Academic (Tenure Track)	Academic (Non Tenure Track)	Research	Government	Industry R&D	Industry Non-R&D	Entrepreneur
Demographic	Academic Level	1										
	Degree Objective	.371**	1									
Career Trajectory	Academic (Teaching focused)	0.062	.187**	1								
	Academic (Research-focused)	0.075	.226**	.590**	1							
	Academic (Tenure Track)	.126**	.290**	.645**	.767**	1						
	Academic (Non-Tenure Track)	0.066	.178**	.608**	.530**	.544**	1					
	Research	-0.012	.186**	.112**	.361**	.184**	.203**	1				
	Government	-.121**	-0.058	0.043	0.038	-0.011	.082*	.308**	1			
	Industry R&D	-0.035	0.076	-.165**	-0.052	-.151**	-0.058	.330**	0.006	1		
	Industry Non-R&D	-.121**	-.302**	-.257**	-.385**	-.405**	-.154**	-.181**	0.038	.331**	1	
	Entrepreneur	-.099*	-.194**	-.080*	-0.041	-.109**	0.019	-0.012	0.073	.226**	.377**	1
Graduate Processes of Writing	Elaborative	0.035	.103*	.121**	.241**	.217**	0.069	.161**	-0.055	.133**	-.169**	0.035
	Low SE	-0.079	-.083*	0.040	.101*	0.052	.105**	0.015	-0.012	0.062	0.041	.090*
	No Revision	-.148**	-.213**	-0.008	0.017	-0.076	0.023	-0.054	-0.007	-0.074	0.067	.091*
	Intuitive	0.004	0.064	0.075	.167**	.122**	0.023	.145**	0.024	.149**	-0.005	.102*
	Scientist	-0.014	0.014	0.025	0.063	0.019	0.021	0.070	-0.009	.080*	0.023	-0.023
	Task-Oriented	0.018	-.080*	0.047	.099*	0.039	0.038	0.049	0.004	0.011	0.058	.140**
	Sculptor	-0.030	-.099*	0.032	.118**	0.051	0.014	.118**	-0.005	.134**	-0.006	.102*
Graduate Concepts of Writing	Blocks	0.031	-0.046	-0.018	-0.030	-0.066	0.024	-0.039	-0.021	0.046	.104**	0.032
	Procrastination	0.004	-0.001	0.022	0.011	-0.009	.088*	-0.005	0.004	-0.033	-0.034	-0.048
	Perfectionism	0.077	-0.024	.097*	.093*	0.064	.096*	0.044	-0.006	-0.010	0.001	0.072
	Innate Ability	-0.057	-.211**	0.046	0.047	-0.027	0.053	-0.004	0.001	-0.003	.103*	.121**
	Knowledge-Transforming	0.053	.103**	0.033	.089*	.092*	0.013	.098*	-0.036	0.068	-.093*	0.023
	Productivity	0.039	-0.023	.136**	.168**	.128**	.124**	.080*	-0.038	0.056	0.014	.147**

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed)

We did not show the correlations between the factors within the writing scales, as those relationships have been investigated in prior work [25], [45] however, the correlational trends hold for our prior work investigated with smaller sample sizes. These confirmatory results indicate that the scales are performing the same way for the present participants. Of particular interest to the present study are the statistically significant correlations ($p < 0.01$) between writers who affiliate strongly with deep writing attributes such as Intuitive, Elaborative, and Knowledge transforming processes, and Productivity concepts of writing with all likelihood of pursuing most broad sectors of engineering careers. Conversely, statistically significantly negative correlations are shown between students who score highly in the weaker writing concepts and processes, such as Low Self-Efficacy, Procrastination, and Perfectionism with future academic careers. Students who strongly affiliated with the Elaborative writing approach significantly negatively correlated with intending to pursue non-R&D careers in industry. Students who strongly tended toward writer's block had no significant correlations except with industry non-R&D careers, and no writing concepts or processes correlated strongly with a student's intention to pursue engineering positions in government.

Though the correlation values are relatively low, it must be remembered that the statistical significance of the values is more important, and that the context of the data and the pragmatic meaning behind the correlations are important. Recalling that this study asked students to indicate how likely they were to pursue a variety of different career paths, student uncertainty in their career paths may be reflected in more "moderate" levels of confidence that they would pursue those career paths, particularly for early career PhD students who still have several years of study through which to decide on a path. The significant values indicate that the correlations are reliable, and indicate to researchers that student attitudes toward writing may be influencing student's consideration of various career trajectories.

While it might be anecdotally expected that students with higher degree objectives (e.g., PhD) would be more inclined to pursue faculty and research careers than those with a degree objective of a Masters, it cannot be necessarily assumed that all PhD students will or want to pursue careers in industry. Literature shows that over 80% of engineering PhDs pursue careers in industry [1]. We also cannot assume that students pursuing a master's are not considering faculty careers, as they may be deciding whether to continue on to the PhD after they earn the Master's degree.

These correlations indicate trends only, not the direction of causation. However, the data indicate that students may have a sense of the level of writing that academic careers often entail, and may be dissuaded from pursuing these routes either due to unfamiliarity with academic writing processes, their goals as a terminal Master's degree student, or their aversion to writing combined with an understanding of the amount of writing required for success in academia.

The case for the strong engineering writers; however, is more interesting, as the trends demonstrate that students with concepts and approaches of writing that indicate a familiarity and confidence in writing indicate a strong likelihood to pursue a wider breadth of careers. This may be a representation of the idea that communication competencies can facilitate success across a variety of sectors, and these students may be equally able and confident in their abilities to pursue a faculty career (in any type of university) in addition to pursuing careers in research, in industry, in government, or in an academic position.

While these trends will need to be tested to draw more conclusive claims, and will be bolstered by the qualitative elements of this mixed methods research project, findings would indicate that if graduate students would have more exposure to formal engineering writing such that they would develop more competencies in engineering writing, they may be more likely to pursue a wider breadth of careers after their graduate degrees, rather than being focused on a career in industry. This interpretation offers a unique perspective for instructors, research advisors, and engineering graduate programs: In order to increase competitive advantage and students' perceptions and potentially confidence in the ability to succeed in multiple engineering sectors, they should be taught to write in an environment that increases their competency to communicate in a disciplinary context. One such suggestion is the incorporation of graduate writing courses taught by engineering professors, perhaps in partnership with technical writing faculty, where students learn to write through authentic disciplinary tasks, such as journal manuscripts or grants [28], [46], or through peer writing and support groups, as recommended by writing researchers to add accountability and peer mentorship to make writing a more social experience [30], [47].

Further, from a broadening participation perspective, the correlations indicated in this research would push toward "leveling the playing field" for all students, regardless of their past experiences with research or academic writing. Future work includes deeper statistical analyses of the variables to uncover differences between groups of students with regards to their writing concepts and processes, and tendency toward career choices. If academic writing is a barrier for students who are lacking social or academic capital, then these students may be deterred from pursuing careers in academia or those that may require publishing. In order to demystify the academic engineering writing process for all graduate students, with the intention of not making graduate school more difficult than it already is, graduate students should be explicitly practice writing for academic engineering audiences in formal or guided informal settings.

VI. Limitations, Conclusions, and Future Work

This quantitative study presented correlation results from a moderately large (n = 631) sample size of graduate engineering students at research intensive universities across the United States. Statistically significant correlations were found between strong writing concepts and processes and students' reported

likelihood to go into all engineering career sectors, whereas students who reported lower-performing writing concepts and processes were less likely to indicate interest in pursuing academic or research careers that may involve publishing. While these results may indicate that students are reflecting on their understandings of the publishing requirements in academia, for example, the correlations cannot tell the direction in which causation occurs, nor any other reasons why students are pursuing a given trajectory (e.g., geographical location, family constraints, etc.) Similarly, the survey asked students to rate how likely they were to pursue certain sectors of engineering careers after graduation, which is not the same as one's confidence in succeeding in a given sector (though those may be related.). However, the difference in strong and weak writing concepts and processes with the breadth of career trajectory likelihoods indicates that students with stronger attitudes in favor of writing may have a competitive advantage in pursuing careers across sectors, a finding that has implications for the importance of teaching academic engineering writing at the graduate level, and also has implications for broadening participation in engineering at the faculty level.

Acknowledgments

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