How STEM Majors' Evaluations of Quantitative Literacy Relate to Their Imagined STEM-Career Futures

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Abstract: Framed by future-selves motivational theory, the present study explored intersections of STEM (science, technology, engineering, mathematics) students' evaluations of everyday and disciplinary quantitative literacy (QL) and how students imagined their STEM-related, future career selves. A quantitative design using data set-appropriate Spearman's rho tests of association was used. Results of Spearman's rho tests of survey responses of one hundred and thirty-four (N = 134) STEM majors showed that students' evaluations of everyday QL correlated positively with evaluations of disciplinary QL (p < .001) and that evaluations of both everyday and disciplinary QL correlated positively with how strongly they imagined using and writing about numbers in future STEM-related careers ($p \leq .001$). This study establishes patterns to understand and direct future research and guide first-year composition and WAC/WID practice with QL components.

Required for engagement in various scholarly disciplines and everyday matters, quantitative literacy (QL) has for years represented a critical objective in U.S. higher education (Erickson, 2016; N. D. Grawe & Rutz, 2009; Rutz & Grawe, 2009) and an increasingly explored alternative to Algebra-to-Calculus mathematics tracks at two- and four-year colleges (Gaze, 2018). Referred to elsewhere in relation to *numeracy* and *quantitative reasoning*, QL as referred to here comprises three dimensions:

1. *An ability to read, write, and understand material* that includes quantitative information, such as graphs, tables, mathematical relations, and descriptive statistics;
2. *An ability to think coherently and logically in situations* involving quantitative information, such as mathematical relations and descriptive statistics; and,
3. *The disposition to engage rather than to avoid* quantitative information, using one's mathematical skills and statistical knowledge in a reflective and logical way to make considered decisions. (Vacher, 2014, p. 11; Wilkins, 2000)

Since QL is a fundamental and developing movement in U.S. higher education, questions of how to incorporate and deliver QL instruction remain under robust consideration. In the present study, questions of QL are investigated in relation to U.S. college STEM (science, technology, engineering, mathematics) majors, who study in majors where QL is increasingly necessary for participation (Hoffman, Leupen, Dowell, Kephart, & Leips, 2016; Kosko, 2016; Meisels, 2010; Stroumbakis, Moh, & Kokkinos, 2016).

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In particular, while research has explored how the inclusion of QL objectives in writing assignments makes for engaging writing-to-learn and writing-in-the-disciplines experiences (Kinkead, 2018; Méndez-Carbajo, 2016), and while other research has considered links between quantitative writing and students' emerging STEM identities and dispositions (Paxton & Frith, 2015; Wilkins, 2010, 2016), this study seeks to begin to measure such relationships systematically. Specifically, the following research questions guided the present inquiry:

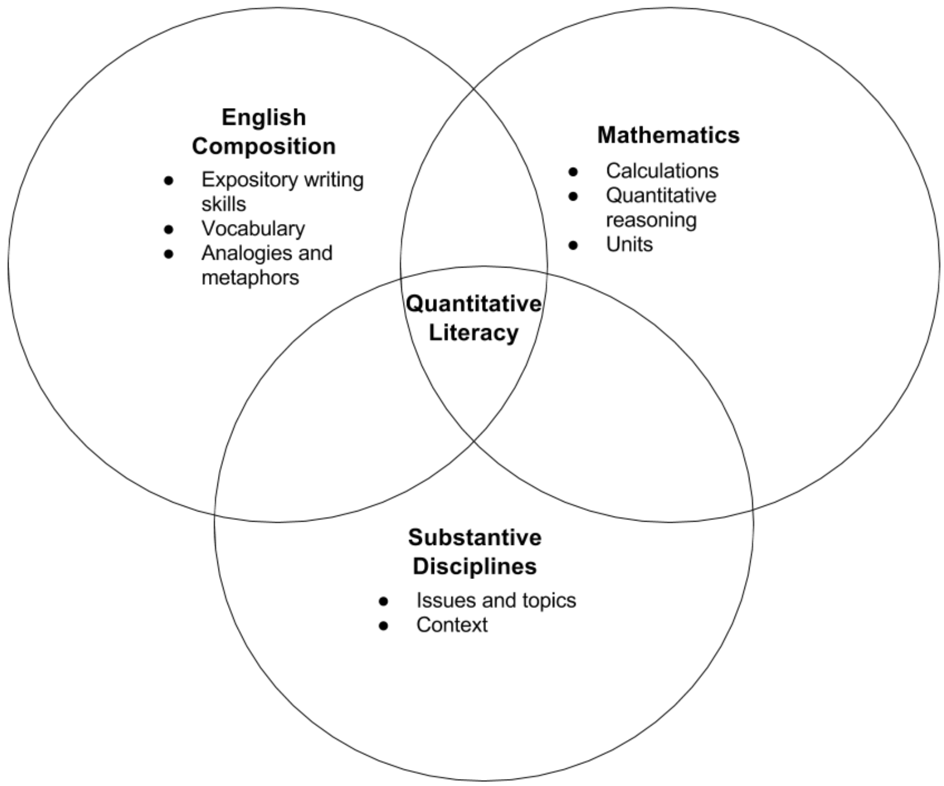
1. What is the association between STEM majors' attitudes toward QL in everyday contexts and in disciplinary contexts?
2. What is the association between STEM majors' attitudes toward QL and how they imagine numerical-data use and quantitative writing in their STEM-career futures?

According to Carter Robinson (2012), writing skill and QL represent two pressing needs for nearly all college students in a data-rich workforce and society. QL performance has been described as requiring writing moves and skills traditionally emphasized in composition, with Miller (2010) defining QL as comprising domain aspects of composition, mathematics, and "substantive" disciplines such as history and science (See Figure 1 below).

Further linking QL and writing, while also nuancing earlier definitions, N. D. Grawe and Rutz (2009) described QL as involving "the habit of mind to consider the power and limitations of quantitative evidence *in the evaluation and construction of arguments* in personal, professional, and public life" (p. 3, emphasis added). For N. D. Grawe and Rutz, QL informs persuasive communication as communicators contextualize numbers in writing describing real-world issues, and as communicators convey that information through "the rhetorical power of numbers" (p. 3). Writing assignments have also been described as ideal activities for nurturing students' quantitative literacy in general-education coursework (Lutsky, 2008). In describing statistics and quantitative data contextualized in prose as within the terrain of rhetoric, Wolfe (2010) has argued that "quantitative argument should be explicitly addressed in composition classes and should be part of the core training of new members of our field" (p. 455). Theoretically and practically, QL has long had an ally in composition and in college writing experiences generally.

In discussing the impact that WAC programs at various levels of integration leverage at institutions, Condon and Rutz (2012) noted that WAC, when integrated, may impact, inspire, and assist in the delivery of other movements, such as "quantitative literacy across the curriculum" (p. 371). Meanwhile, while the writing across the curriculum (WAC) and in the disciplines (WID) initiatives intersect with QL by having developed in response to higher-education needs (N. D. Grawe & Rutz, 2009; P. H. Grawe & Grawe, 2014; Hillyard, 2012; Rutz & Grawe, 2009) to prepare students for required disciplinary and personal-life engagement (Carter Robinson, 2012), Stroumbakis et al. (2016) have urged WAC/WID to focus efforts on quantitative writing teaching that is not necessarily presented as disciplinary field-specific. The concern for Stroumbakis et al., in their words, is that, among STEM faculty, "reluctance to use writing remains, as does skepticism about its effectiveness" especially when students are non-STEM-majors (p. 153). For these educators, WID or learning-to-write (LTW) approaches on a WAC-approach continuum (McLeod, 1992/2000) do not prompt STEM-educator investment when field-specific quantitative writing does not seem to figure into students' future coursework or careers. While Stroumbakis et al. were primarily concerned with STEM educators' motivation to use writing as a way to support content learning and quantitative writing, at issue as well is student investment in their curricular activities as seemingly preparing them for post-college lives.

Figure 1. Contributions of Major Scholastic Disciplines to Quantitative Literacy. (Adapted from Miller, 2010, p. 337.)



Relevant to the present study, one way of understanding college-student engagement and persistence is by exploring how students evaluate aspects of their current educational experiences, and how these evaluations of current learning conditions and experiences signal how students imagine their futures. In their future-oriented theory of motivation, Markus and Nurius (1986) argued for a view of motivation "not as a generalized disposition or a set of task-specific goals, but as an individualized set of possible selves" (p. 966). For Markus and Nurius, past and current social circumstances enabled and limited what a person visualized or could *imagine* as possible; in their words,

> An individual is free to create any variety of possible selves, yet the pool of possible selves derives from the categories made salient by the individual's particular sociocultural and historical context and from the models, images, and symbols provided by the media and by the individual's immediate social experiences. (p. 954)

In talking about future-dimensional (disciplinary) identity as a way of thinking about belonging and persistence in college, it is useful to draw on conceptions of identity that have been developed in relation to conditions and settings of learning. Referring to Anderson's (1983/1991) concept of imagined communities and coming from the point of view of a language teacher, and complementing Markus and Nurius's (1986) and Dörnyei's (2018) psychological constructs with sociological conceptions, Norton (2001) wrote that "different learners have different imagined communities, and that these imagined communities are best understood in the context of a learner's unique investment" in a topic area and the conditions under which that topic is taught and learned (p. 165). For Norton (2001), "a learner's imagined community invited an imagined identity" (p. 166). How students evaluate current educational experiences and how they talk about their futures offer valuable indicators for how invested students are in their immediate disciplinary contexts (i.e., department where they study) and the imagined communities to which they see themselves belonging.

Part of the value of drawing on future-oriented conceptions of investment and motivation, then, is that doing so addresses issues of student engagement, persistence, and retention, which for many four-year public U.S. colleges are institutional priorities. Tinto (2015), involved in retention-theory development since the 70s, more recently declared the variable of motivation as directly impacting students' persistence choices and actions. Meanwhile, researchers in applied linguistics have drawn on Markus and Nurius's (1986) future-selves theory of motivation to pose theoretically, and to test empirically, that, as Dörnyei (2018) and numerous colleagues have found, "the way in which people imagine themselves in the future plays an important role in energizing their learning behavior in the present" (pp. 2-3). Finding out, then, how students' future selves relate to those writing activities students are currently doing in college, and which they find meaningful and in which they are invested, is a potentially powerful way of isolating motivating activities that may focus and guide retention initiatives. This work may also lend an additional argument to writing studies generally, and WAC/WID specifically, that discipline- or major-specific writing (e.g., quantitative writing) perceived as relevant to students' present and future selves is especially engaging and motivating.

Method

To recap, the purpose of the present study was to understand intersections of STEM students' evaluations of everyday and disciplinary quantitative literacy (QL) and how they imagine numerical-data use and quantitative writing in their future STEM-related careers.

A quantitative design using data set-appropriate associational inferential statistics (Spearman's rho) was used. Given that past and current social circumstances enable and limit what people visualize as possible in their future (Markus & Nurius, 1986), including what immediate and future imagined communities a person belongs to (Norton, 2001; Wenger, 1998), it was assumed that the more positively students evaluated QL as relevant to their everyday and disciplinary lives, the more strongly they would report visualizing their future selves as using and having careers requiring QL performance. Accordingly, hypotheses for this study can be summarized as follows:

- *Alternative Hypothesis*: A statistically significant, positive relationship exists among evaluations of everyday and disciplinary QL and imagined STEM-career futures.
- *Null Hypothesis*: No statistically significant relationship exists among these variables.

Participation in this study was voluntary, anonymous, and IRB-supervised. IRB-approved email invitations were sent to STEM professors at one Eastern U.S. public four-year college, and also posted on writing studies-related listservs (WPA-L and WAC-L). A web-based survey (via Qualtrics) was then emailed to participating professors' STEM majors. Additionally, hard-copy versions of the informed-consent form and survey were administered and collected in the opening minutes of STEM-major mathematics classes. Participants were invited to pass the survey on to a STEM-major peer. Participants were (N = 134) STEM majors.

Table 1 - Participants' Characteristics

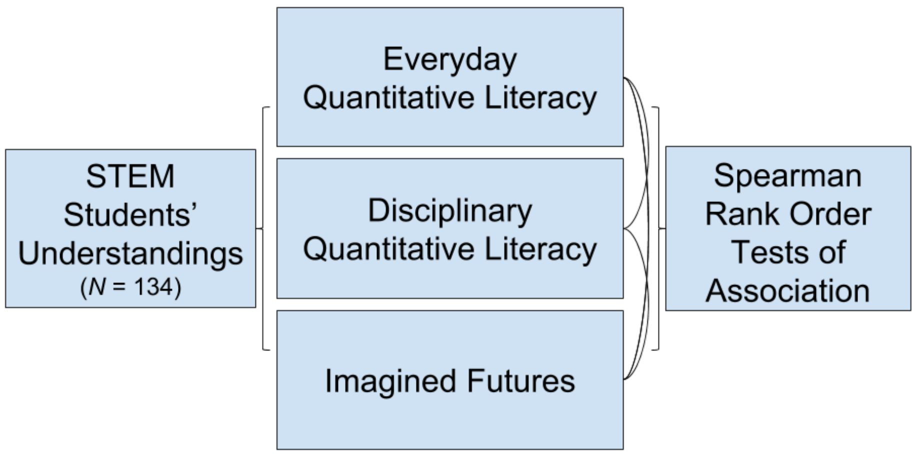
Category	Characteristic	Number

STEM Major	Anthropology	1
	Biochemistry	8
	Biology (Molecular)	27
	Chemistry	7
	Chemical Engineering	1
	Computer Science	28
	Engineering	1
	Geography	2
	Geoscience	11
	Health Science	1
	Mathematics	29
	Natural Science	9
	Physics	6
	Psychology	1
	Wildlife Science	1
Location	Midwestern/Great Plains	6
	Southern	12
	Western	9
	Eastern	107
Level of Education	Graduate	24
	Undergraduate	110
Self-Identified Gender	Female	59
	Male	72
	Preferred Not to Answer	3
Age	18-25	115
	26-35	18
	36-45	1

The survey used in this study (Appendix A) included items from the quantitative literacy/reasoning assessment (QLRA) instrument designed and validated to measure attitudes toward QL (Gaze, Montgomery, Kilic-Bahi, Leoni, & Misener, 2014). During validation of the instrument for comprehensibility in the present study, reverse-wording in one item from the QLRA was changed to positive-wording. Items were then adapted from the QLRA to measure participants' *attitudes toward everyday* QL (items 1-4) and *attitudes toward disciplinary* QL (items 5-7). Items were also adapted from Dörnyei and Chan's (2013) future-oriented motivation instrument to measure *imagined futures* or the degree to which students reported imagining themselves performing QL in future STEM-related careers (items 8-10). Constructed with Qualtrics, the survey also used piped text so that each respondent interacted with a tailored survey.

Shapiro-Wilk tests of normality for all items showed a significance value ($p < .05$) indicating that Spearman rho tests of association, a nonparametric approximation of the Pearson product-moment correlation, were most appropriate. Cronbach's Alpha to test the internal reliability of the *attitudes toward everyday quantitative literacy* items borrowed from the QLRA ($\alpha = .78$) was within an acceptable range (Nunnally, 1967) to create a composite variable, as was the Cronbach's Alpha for the *attitudes toward disciplinary quantitative literacy* items ($\alpha = .72$). Figure 2 summarizes the analytical design used.

Figure 2: Schematic Outline of the Design for Correlational Data Analysis.



Results

The results section is organized to present descriptive and inferential findings overall and then as pertains to each research question. In Table 2, descriptive statistics are presented for all survey items with the inclusion of composite variables for attitudes toward everyday quantitative literacy (QL) and toward disciplinary QL. Participants' responses can be understood with reference to a 5-point Likert scale in which 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree. Mean and median scores indicate that, overall, participants expressed positive attitudes toward everyday and disciplinary QL. Concerning participants' imagined futures, participants expressed agreement that they imagined themselves writing about numbers in a future career, and they expressed strong agreement that they imagined themselves at least using numbers in their future careers and, with a mean of 4.73 (SD = .60), imagined themselves having a job related to their current STEM major.

Table 2: Descriptive Statistics for Quantitative Literacy Attitudes and Imagined Futures

Scale	Item	*M*	*Mdn*	*SD*	95% Confidence Interval	
					Lower	Upper
Attitudes Toward Everyday Quantitative Literacy	Numerical information is very useful in everyday life.	4.41	5.00	.88	4.26	4.56
	Numbers are necessary for most situations.	4.15	4.00	.91	3.99	4.31
	Quantitative information is vital for accurate decisions.	4.30	4.00	.75	4.17	4.43
	It is a good use of time to learn information containing a lot of numbers.	3.84	4.00	.91	3.68	3.99
	Composite (α = .78)	4.17	4.25	.67	4.06	4.29
Attitudes Toward Disciplinary Quantitative Literacy	Knowing how to understand numbers is necessary to succeed in my major.	4.49	5.00	.83	4.35	4.63
	Knowing how to write about numbers is necessary to succeed in my major.	4.24	4.00	.90	4.08	4.39
	Writing can help me think about numeric concepts in relation to my major.	3.69	4.00	.98	3.53	3.86
	Composite (α = .72)	4.17	4.33	.75	4.04	4.30
Imagined Futures in Relation to Numbers, Writing, and STEM Major	I can imagine myself using numbers in my future career.	4.53	5.00	.80	4.39	4.67
	I can imagine myself writing about numbers as part of my future career.	4.06	4.00	1.13	3.87	4.25
	I can imagine my major being part of my future career.	4.73	5.00	.60	4.63	4.83

Table 3 below summarizes the results of Spearman rho tests of association for all variables used, with composite scores for attitudes for everyday and for disciplinary QL being used.

Table 3: Inferential Statistics (Spearman's rho) for Quantitative Literacy Attitudes and Imagined Futures

	1	2	3	4	5
1. Everyday Quantitative Literacy	—	.447**	.376**	.279**	.171*
2. Disciplinary Quantitative Literacy		—	.415**	.421**	.312**
3. Future Using Numbers in Career			—	.514**	.370**
4. Future Writing About Numbers in Career				—	.287**
5. Future STEM Career					—

**p < .01; *p < .05

Although level of education, self-identified gender, and specific STEM major were not grouping variables of interest in this study, it may be noteworthy to report that a Kruskal-Wallis test of difference did not show any statistically significant difference in any variable based on level of education (associate, bachelor, master, doctoral) or based on STEM major (e.g., biochemistry, computer science, mathematics). A Mann-Whitney test of difference likewise did not show any statistically significant difference in any variable based on self-identified gender status (male versus female). Turning now to the focus of the study, the significance of Spearman rho results of association will be presented in relation to the study's research questions.

What Is the Association Between STEM Majors' Attitudes Toward QL in Everyday Contexts and in Disciplinary Contexts?

A Spearman's rho revealed a statistically significant, positive relationship between *everyday QL* and *disciplinary QL*, $r_s = .447$, $p < .001$. The effect size for this relationship was medium (Cohen, 1988). Also noteworthy is that a Spearman's rho revealed a statistically significant, positive relationship between the expressed importance of knowing how to understand numbers and the expressed importance of knowing how to write about numbers in participants' STEM majors, $r_s = .610$, $p < .001$, with a medium-large effect size (Cohen, 1988).

What Is the Association Between STEM Majors' Attitudes Toward Everyday and Disciplinary QL and How They Imagine Numerical-Data Use and Quantitative Writing in Their STEM-Career Futures?

A Spearman's rho revealed a statistically significant, positive relationship between (a) attitudes toward *everyday QL* and the extent to which participants imagined themselves using numbers in future careers, $r_s = .376$, $p < .001$, with a medium effect size (Cohen, 1988); (b) attitudes toward *everyday QL* and the extent to which participants imagined themselves writing about numbers in future careers, r_s = .279, p = .001, with a small effect size (Cohen, 1988); (c) attitudes toward *disciplinary QL* and the extent to which participants imagined themselves using numbers in future careers, r_s = .415, p < .001, with a medium effect size (Cohen, 1988); and, (d) attitudes toward *disciplinary QL* and the extent to which participants imagined themselves writing about numbers in future careers, r_s = .421, p < .001, with a medium effect size (Cohen, 1988). Also noteworthy, a Spearman's rho revealed a statistically significant, positive relationship between the extent to which participants reported imagining themselves using numbers in their future careers and the extent to which they reported imagining themselves writing about numbers in their future careers, r_s = .514, p < .001, with a medium effect size (Cohen, 1988).

Summary of Findings

To summarize, in the current sample of U.S. STEM majors (N = 134),

1. The more students valued QL at the everyday level, the more they valued QL at the disciplinary level.
2. The more students saw understanding numbers as a key to success in their STEM major, the more they saw writing about numbers as a key to success in their STEM major.
3. The more students valued QL at the everyday level, the more they imagined themselves using numbers in a future STEM career.
4. The more students valued QL at the disciplinary level, the more they imagined themselves writing about numbers in a future STEM career.
5. The more students imagined themselves using numbers in a future STEM career, the more they saw themselves writing about numbers in a future STEM career.

Discussion

The results of the study presented here establish that participants imagined themselves having future careers related to their current STEM majors. This study's results also establish that participants' more positive evaluations of everyday and disciplinary quantitative literacy (QL) relate to how strongly they imagine themselves performing QL in future STEM careers in terms of numerical-data use and quantitative writing.

On a theoretical level, this study indicates that STEM majors as represented in this sample are *invested* (Norton, 2001) in QL (at least as far as they understand QL), in their majors, and in their imagined identities as STEM-field professionals that perform QL. Retention-theory models, such as Tinto's (2015), have indeed described the importance of students' perceiving that aspects of their curricula are relevant, meaningful, and beneficial. The systematic link between high evaluations of everyday QL and disciplinary QL may indicate that STEM students are able to view their majors as practical and relevant in disciplinary and in important everyday situations that require engagement with and communication featuring quantitative information. It may also indicate that their imagined future selves related to their science identities are sufficiently linked to activities they are currently encountering in their programs, which is a positive indicator for student motivation, persistence, and retention (Dörnyei, 2018). This data supports findings of Wilkins (2010), who theorized that "a quantitatively literate person would have an increased mathematical self-concept" (p. 270). Additionally, findings here lend support to Paxton and Frith (2015), who suggested that quantitative writing and genre knowledge among students in quantitative disciplines "assist students in taking on new scientific identities" (p. 161). Students' recognition of real-world application of their majors may prove to be a significant factor supporting STEM-identity construction and, therefore as per future-oriented identity theory, STEM-major engagement and persistence.

On a practical level, results presented here also lend evidence to arguments about how composition and WAC/WID can support STEM and other traditionally quantitative disciplines pedagogically. Engagement with everyday QL, at least for STEM majors here, related to positive evaluations of QL also in STEM-discipline settings. Not only are QL and writing pressing needs for a data-rich society (Carter Robinson, 2012), but also QL requires skills explicitly encouraged in first-year composition coursework and in the kinds of practices advocated by WAC/WID practitioners (Miller, 2010). WAC/WID practitioners can complement the argument that writing assists in coverage of course material across the curriculum (Scheurer, 2015), and that integrated WAC programs can assist with inspiring and delivering QL across the curriculum (Condon & Rutz, 2012), with the argument that disciplinary writing nurtures students' future imaginings and therefore promises theoretically to work in service of student-retention efforts. Explicit instruction of writing's ability to foster learning (via writing-to-learn [WTL] approaches: McLeod, 1992/2000) may be called for as well. Participants' responses were lowest, after all, on the item "Writing can help me think about numeric concepts in relation to my major." Investigation into what this kind of item meant to participants qualitatively could help isolate how participants may define "writing" in relation to learning. Is it the case, for instance, that participants see "writing" as belletristic or literary and, in that way, distinct from disciplinary writing as other writing-studies research has shown (Bergmann & Zepernick, 2007; Driscoll, 2011)?

What remains to be explored is how everyday and disciplinary QL evaluations relate for students who are undecided or are in majors in which they do not perceive quantitative data as salient or necessary for success. It has been documented that scientists tend to not realize how central writing is to their professional lives (Emerson, 2016); it may also be the case that non-STEM majors underestimate how central quantitative information use and quantitative writing will be in their futures (Feigenbaum, 2015). General-education coursework, including first-year composition and other general-education courses—such as Kinkead's (2018) that engaged English-Studies majors with quantitative data, or Feigenbaum's (2015) proposal that English-Studies educators team up with mathematics educators—may achieve the kind of QL integration into general-education writing for which both Wolfe (2010) and Lutsky (2008) have advocated. To be sure, QL has long figured into technical-writing service courses, reflecting an understanding that quantitative literacy and reasoning skills enhance a student's ability to compose effective quantitative writing (Columbini & Hum, 2017; Lutsky, 2008). It may be the case that such coursework prepares students for careers in a data-rich society requiring both writing skill and QL (Carter Robinson, 2012) in part via identity construction. Identity research linking writing experiences and students' self-concepts and performed disciplinary identities is called for.

Results and conclusions presented here, of course, must be understood in the context of this study's limitations and delimitations. The sample size limits generalizability, and, while a Kruskal-Wallis test of difference did not indicate any significant difference in any of the study's variables based on STEM major (e.g., biochemistry, computer science, mathematics), it may be expected that different majors expect different rhetorical outcomes when writing with quantitative data. Sampling from one major or a smaller number may assist in making discipline-specific conclusions, which can offer tailored conclusions about how composition and WAC/WID practitioners and researchers can leverage QL in writing-related instruction. It was also the case that no information was gathered about whether students had taken a technical writing service course, which may foster students' connections between quantitative data and writing. An important delimitation, too, is that this study cannot and does not attempt to establish cause-effect relationships among variables. This study, though, establishes patterns to direct future hypotheses to be explored possibly through larger-scale quantitative and smaller-scale, focused case-study or phenomenological studies into students' understandings of how QL relates to STEM-discipline community belonging—in present departmental and in imagined professional future contexts.

Appendix A

Quantitative Literacy and Imagined Futures Survey

1. In what department or program are you studying?
   - Biochemistry
   - Biology
   - Chemistry
   - Computer Science
   - Geoscience
   - Mathematics
   - Physics
   - Another _________________

2. At what level are you studying?
   - PhD
   - Master's
   - Bachelor's
   - Associate's
   - Another _________________

3. With what gender do you most identify?
   - Male
   - Female
   - Another _________________
   - Prefer not to answer

4. How old are you?
   - 18-25
   - 26-35
   - 36-45
   - 46-55
   - 56-above
   - Prefer not to answer

5. Please rate the degree to which you agree with the following statements.

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
Numerical information is very useful in everyday life.					
Numbers are necessary for most situations.					
Quantitative information is vital for accurate decisions.					
It is a good use of time to learn information containing a lot of numbers.					
Knowing how to understand numbers is necessary to succeed in my major.					
Knowing how to write about numbers is necessary to succeed in my major.					
Writing can help me think about numeric concepts in relation to my major.					
I can imagine myself using numbers in my future career.					
I can imagine myself writing about numbers as part of my future career.					
I can imagine my major being part of my future career.					

References

Anderson, Benedict. (1983/1991). I*magined communities: Reflections on the origin and spread of nationalism* (Rev. ed.). London, United Kingdom: Verso.

Bergmann, Linda S., & Zepernick, Janet. (2007). Disciplinarity and transfer: Students' perceptions of learning to write. *WPA Journal, 31*(1/2), 124-149.

Carter Robinson, Gaylynne. (2012). Developing quantitative literacy through writing. San Diego, CA: Cognella.

Cohen, Jacob. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Columbini, Crystal Broch, & Hum, Sue. (2017). Integrating quantitative literacy into technical writing instruction. *Technical Communication Quarterly, 26*(4), 379-394. doi:10.1080/10572252.2017.1382259

Condon, William, & Rutz, Carol. (2012). A taxonomy of writing across the curriculum programs: Evolving to serve broader agendas. *College Composition and Communication, 64*(2), 357-382.

Dörnyei, Zoltán. (2018). Motivating students and teachers. In Liontas, J. I. (Ed.), The TESOL encyclopedia of English language teaching (Vol. 7; pp. 4293-4299). Alexandria, VA: TESOL.

Dörnyei, Zoltán, & Chan, Letty. (2013). Motivation and vision: An analysis of future L2 self images, sensory styles, and imagery capacity across two target languages. *Language Learning, 63*(3), 437-462. doi:10.1111/lang.12005

Driscoll, Dana Lynn. (2011). Connected, disconnected, or uncertain: Student attitudes about future writing contexts and perceptions of transfer from first year writing to the disciplines. A*cross the Disciplines: A Journal of Language, Learning, and Academic Writing, 8*(2). Retrieved from http://wac.colostate.edu/atd/articles/driscoll2011/index.cfm

Emerson, Lisa. (2016). T*he forgotten tribe: Scientists as writers*. Fort Collins, CO: The WAC Clearinghouse.

Erickson, Ander W. (2016). Rethinking the numerate citizen: Quantitative literacy and public issues. *Numeracy: Advancing Education in Quantitative Literacy, 9*(2), 1-20. doi:10.5038/1936-4660.9.2.4

Feigenbaum, Paul. (2015). Rhetoric, mathematics, and the pedagogies we want: Empowering youth access to twenty-first century literacies. *College English, 77*(5), 429-449.

Gaze, Eric. (2018). Quantitative reasoning: A guided pathway from two- to four-year colleges. *Numeracy: Advancing Education in Quantitative Literacy, 11*(1), 1-4.

Gaze, Eric, Montgomery, Aaron, Kilic-Bahi, Semra, Leoni, Deann, & Misener, Linda. (2014). Towards developing a quantitative literacy/reasoning assessment instrument. *Numeracy: Advancing Education in Quantitative Literacy, 7*(2), 1-20. doi:10.5038/1936-4660.7.2.4

Grawe, Nathan D., & Rutz, Carol A. (2009). Integration with writing programs: A strategy for quantitative reasoning program development. *Numeracy: Advancing Education in Quantitative Literacy, 2*(2), 1-18. doi:10.5038/1936-4660.2.2.2

Grawe, Paul H., & Grawe, Robin J. (2014). Reflections on the introduction of quantitative assessment in persuasive writing classes. *Numeracy: Advancing Education in Quantitative Literacy, 7*(1), 1-11. doi:10.5038/1936-4660.7.1.5

Hillyard, Cinnamon. (2012). Comparative study of the numeracy education and writing across the curriculum movements: Ideas for future growth. *Numeracy: Advancing Education in Quantitative Literacy, 5*(2), 1-19. doi:10.5038/1936-4660.5.2.2

Hoffman, Kathleen, Leupen, Sarah, Dowell, Kathy, Kephart, Kerrie, & Leips, Jeff. (2016). Development and assessment of modules to integrate quantitative skills in introductory biology courses. *CBE-Life Sciences Education, 15*(Summer), 1-12. doi:10.1187/cbe.15-09-0186

Kinkead, Joyce. (2018). Engaging undergraduate researchers in the assessment of communication across the curriculum courses. A*cross the Disciplines: A Journal of Language, Learning, and Academic Writing, 15*(2), 15-30. Retrieved from https://wac.colostate.edu/docs/atd/articles/kinkead2018.pdf

Kosko, Karl W. (2016). Writing in Mathematics: A survey of K-12 teachers' reported frequency in the classroom. *School Science and Mathematics, 116*(5), 276–285. doi:10.1111/ssm.12177

Lutsky, Neil. (2008). Arguing with numbers: Teaching quantitative reasoning through argument and writing. In Bernard L. Madison & Lynn Arthur Steen (Eds.), *Calculation vs. context: Quantitative literacy and its implications for teacher education* (pp. 59-74). Washington, D.C.: Mathematical Association of America.

Markus, Hazel, & Nurius, Paula. (1986). Possible selves. *American Psychologist, 41*(9), 954-969. doi:10.1037/0003-066X.41.9.954

McLeod, Susan H. (1992/2000). Writing across the curriculum: An introduction. In Susan H. McLeod & Margot Soven (Eds.), *Writing across the curriculum: A guide to developing programs* (pp. 1-8). Fort Collins, CO: The WAC Clearinghouse.

Meisels, Gerry G. (2010). Science literacy: Hand in glove with numeracy. *Numeracy: Advancing Education in Quantitative Literacy, 3*(2), 1-3. doi:10.5038/1936-4660.3.2.1

Méndez-Carbajo, Diego. (2016). Quantitative reasoning and information literacy in economics. In Barbara J. D'Angelo, Sandra Jamieson, Barry Maid, & Janice R. Walker (Eds.), *Information literacy: Research and collaboration across disciplines* (pp. 317-334). Fort Collins, CO: The WAC Clearinghouse.

Miller, Jane E. (2010). Quantitative literacy across the curriculum: Integrating skills from English composition, mathematics, and the substantive disciplines. *Educational Forum, 74*(4), 334-346. doi:10.1080/00131725.2010.507100

Norton, Bonny. (2001). Non-participation, imagined communities and the language classroom. In Michael P. Breen (Ed.), *Learner contributions to language learning: New directions in research* (pp. 159-171). London, United Kingdom: Longman/Pearson Education.

Nunnally, Jum C. (1967). P*sychometric theory*. New York, NY: McGraw-Hill.

Paxton, Moragh, & Frith, Vera. (2015). Transformative and normative? Implications for academic literacies research in quantitative disciplines. In Theresa Lillis, Kathy Harrington, Mary R. Lea, & Sally Mitchell (Eds.), *Working with academic literacies: Case studies towards transformative practice* (pp. 155-162). Fort Collins, CO: The WAC Clearinghouse.

Rutz, Carol, & Grawe, Nathan D. (2009). Pairing WAC and quantitative reasoning through portfolio assessment and faculty development. *Across the Disciplines: A Journal of Language, Learning, and Academic Writing, 6*, Retrieved from http://wac.colostate.edu/atd/assessment/rutz_grawe.cfm.

Scheurer, Erika. (2015). What do WAC directors need to know about "coverage"? *The WAC Journal, 26*, 7-21.

Stroumbakis, Kostas. D., Moh, Namjong, & Kokkinos, Dimitrios. (2016). Community college STEM faculty views on the value of writing assignments. *The WAC Journal, 27*, 142-154. Retrieved from https://wac.colostate.edu/journal/vol27/stroumbakis.pdf

Tinto, Vincent. (2015). Through the eyes of students. *Journal of College Student Retention: Research, Theory, and Practice*, 1-16. doi:10.1177/1521025115621917

Vacher, H. L. (2014). Looking at multiple meanings of numeracy, quantitative literacy, and quantitative reasoning. *Numeracy: Advancing Education in Quantitative Literacy, 7*(2), 1-14. doi:10.5038/1936-4660.7.2.1

Wenger, Etienne. (1998). *Communities of practice: Learning, meaning, and identity*. New York, NY: Cambridge University Press.

Wilkins, Jesse L. (2000). Preparing for the 21st century: The status of quantitative literacy in the United States. *School Science and Mathematics, 100*(8), 405-418. doi:10.1111/j.1949-8594.2000.tb17329.x

Wilkins, Jesse L. (2010). Modeling quantitative literacy. *Educational and Psychological Measurement, 70*(2), 267-290.

Wilkins, Jesse L. (2016). An assessment of the quantitative literacy of undergraduate students. *The Journal of Experimental Education*. doi:10.1080/00220973.2015.1111854

Wolfe, Joanna. (2010). Rhetorical numbers: A case for quantitative writing in the composition classroom. *College Composition and Communication, 61*(3), 452-475.

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