Postsecondary Faculty Attitudes and Beliefs about Writing-Based Pedagogies in the STEM Classroom

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ABSTRACT

Writing is an important skill for communicating knowledge in science, technology, engineering, and mathematics (STEM) and an aid to developing students' communication skills, content knowledge, and disciplinary thinking. Despite the importance of writing, its incorporation into the undergraduate STEM curriculum is uneven. Research indicates that understanding faculty beliefs is important when trying to propagate evidence-based instructional practices, yet faculty beliefs about writing pedagogies are not yet broadly characterized for STEM teaching at the undergraduate level. Based on a nationwide cross-disciplinary survey at research-intensive institutions, this work aims to understand the extent to which writing is assigned in undergraduate STEM courses and the factors that influence faculty members' beliefs about, and reported use of, writing-based pedagogies. Faculty attitudes about the effectiveness of writing practices did not differ between faculty who assign and do not assign writing; rather, beliefs about the influence of social factors and contextually imposed instructional constraints informed their decisions to use or not use writing. Our findings indicate that strategies to increase the use of writing need to specifically target the factors that influence faculty decisions to assign or not assign writing. It is not faculty beliefs about effectiveness, but rather faculty beliefs about behavioral control and constraints at the departmental level that need to be targeted.

INTRODUCTION

The National Research Council (2012) and others have called on institutions to increase the amount and type of writing included in science, technology, engineering, and mathematics (STEM) courses to support and develop student learning and disciplinary thinking (Keys, 1999; Wallace *et al.*, 2004; Klein and Boscolo, 2016). These calls are supported by multiple studies within STEM that indicate that writing can be used to support a range of learning goals, including learning to write, conceptual understanding, developing critical-thinking skills, fostering disciplinary thinking, and cultivating the feeling of being part of a community of practice (Keys, 1999; Wallace *et al.*, 2004; Klein and Boscolo, 2016; Slade and Miller, 2017). However, the use of writing in STEM classrooms is limited in scope (Stroumbakis *et al.*, 2016; Trafimow *et al.*, 2017), and where it is assigned, it tends to be used by localized practitioners rather than systemically adopted across disciplines (Rivard, 1994; Poock *et al.*, 2007; Reynolds *et al.*, 2012; Russell, 2013). This trend aligns with the slow adoption of other evidence-based practices and a continued prevalence of traditional teaching practices (Henderson and Dancy, 2007; Brownell and Tanner, 2012; Corbo *et al.*, 2016; Stains *et al.*, 2018). For stakeholders—those interested in increasing the use of writing practices in STEM undergraduate classrooms—it is important to understand and address

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the factors behind faculty uptake of, or resistance to, increased incorporation of writing activity in their courses.

Research identifying factors that impede the widespread use of evidence-based practices in STEM shows that low levels of adoption do not arise from faculty being unaware of the pedagogical developments; rather, faculty identity and beliefs, as well as existing social and cultural factors, tend to act as constraints (Henderson and Dancy, 2007; Ebert-May *et al.*, 2011; Corbo *et al.*, 2016; Gibbons *et al.*, 2018). In particular, traditionally oriented beliefs are shown to inhibit change in practice (Gess-Newsome *et al.*, 2003; Luft *et al.*, 2004; Smith and Southerland, 2007), because such instructors more easily revert to traditional methods following a professional development intervention (Gallos *et al.*, 2005). Studies examining STEM faculty beliefs and practices related to evidence-based practices focus broadly on evidence-based practices as a whole (Sunal *et al.*, 2001; Henderson and Dancy, 2007, 2008; Henderson *et al.*, 2012; Quardokus and Henderson, 2015; Bathgate *et al.*, 2019), or, if focusing on a specific instructional practice, are set within a specific discipline (Dancy *et al.*, 2016; Manduca *et al.*, 2017). In addition, current efforts to increase the adoption of high-impact instructional practices focus less on social and cultural environments than is warranted (Sunal *et al.*, 2001; Wieman *et al.*, 2010; Henderson *et al.*, 2011; Quardokus and Henderson, 2015).

With the importance of aligning change strategies with faculty beliefs (Henderson *et al.*, 2011; Corbo *et al.*, 2016; Flash, 2016, 2021; Gibbons *et al.*, 2018), efforts to foster the adoption of specific instructional practices should consider instructor beliefs specific to that practice. This may be especially important for examining faculty use of writing practices in undergraduate STEM classrooms due to the unique relationship STEM faculty have with writing, in part characterized by the constructive role they view it playing in building scientific knowledge as part of the research process (Yore *et al.*, 2004; Moon *et al.*, 2018a). However, there is an even greater dearth of research focused on faculty beliefs about using writing in STEM undergraduate classrooms; what does exist suggests that faculty assignment of writing is also more tied to beliefs and attitudes than to awareness of research regarding effective classroom use (Salem and Jones, 2011; Trafimow *et al.*, 2017). Thus, understanding the attitudes and beliefs held by postsecondary instructors across STEM specifically about writing, for both those who do and do not assign writing, can direct efforts to accelerate the adoption of writing pedagogies in STEM.

Within the context of a project to examine factors influencing faculty practices with regard to assignment of writing in undergraduate STEM courses at research-intensive institutions, two separate and complementary studies were conducted. Using the overall data set, the studies examined different factors potentially influencing faculty assignment of writing, drew on different theoretical frameworks and literatures, addressed different research questions, and employed different data analysis approaches and methods. One study (Thompson *et al.*, 2021) employed an ecological systems perspective (Bronfenbrenner, 1976) and examined the independent and combined contributions of faculty demographic characteristics and faculty beliefs about the effectiveness of specific writing practices, beliefs about contextual resources and constraints, and epistemic beliefs on the assignment of writing. The current study employs the theory of planned behavior framework (Ajzen and Madden, 1986) and examines the types of writing STEM faculty report assigning in their courses and whether faculty attitudes, subjective norms, and beliefs about factors that may influence perceived behavioral control differ between faculty who do and do not assign writing in their courses.

THEORETICAL FRAMEWORK

This study is guided by the theory of planned behavior (Figure 1), which connects attitudes, subjective norms, and perceived behavioral control to predict intention to perform a behavior and, ultimately, the behavior itself (Ajzen and Madden, 1986; Ajzen, 1991). The theory of planned behavior builds upon the theory of reasoned action (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980), in which the intention to perform a behavior incorporates the motivational factors of attitudes and subjective norms about a behavior. However, Ajzen and Madden (1986) posited that the degree to which a person's intentions translate into behavior is also impacted by the control they perceive having over their own actions. Thus, they developed the theory of planned behavior to incorporate perceived behavioral control as a factor that can influence behavior (Ajzen, 1991; Ajzen and Madden, 1986). Through hierarchical regression modeling, they determined that perceived behavioral control can both directly and indirectly, through intention, influence behavior when a person does not have complete control over a situation (Ajzen and Madden, 1986) Since its inception, the theory of planned behavior has been used to examine the relationship between behavior and beliefs in a large array of contexts (Ajzen, 1991, 2011), including connecting the instructional practices and beliefs of STEM teachers (Crawley, 1990; Veal *et al.*, 2015) and faculty (Bathgate *et al.*, 2019).

Ajzen and Madden (1986) define the constructs of attitudes and subjective norms similarly to how they are defined in the theory of reasoned action (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980). Attitudes capture personal beliefs about a behavior and encapsulate how favorably or unfavorably a person views the behavior, where attitudes may arise from beliefs about the outcomes of the behavior and personal costs of performing the behavior. Subjective norms capture the perceived social views about engaging or not engaging in a behavior. The subjective norms are informed by the normative beliefs, what a person believes those who are important to them think about performing a specific behavior. Finally, perceived behavior control is the ease or difficulty with which a person believes they can perform a specific behavior (e.g., incorporate writing into their classroom). Ajzen and Madden (1986) describe perceived behavioral control as influenced by factors such as an individual's past experiences with the behavior, the experiences of the people they interact with, and perceived resources or impediments to performing the behavior (e.g., time constraints). Perceived behavioral control becomes increasingly important to consider as the control a person has over their behavior in a specific context decreases. It is beneficial to examine faculty's implementation of writing pedagogies through the lens of the theory of planned behavior, because it provides an organizational framework for analyses of faculty intentions and the personal and contextual factors that influence intention (Crawley, 1990; Veal *et al.*, 2015; Bathgate *et al.*, 2019).

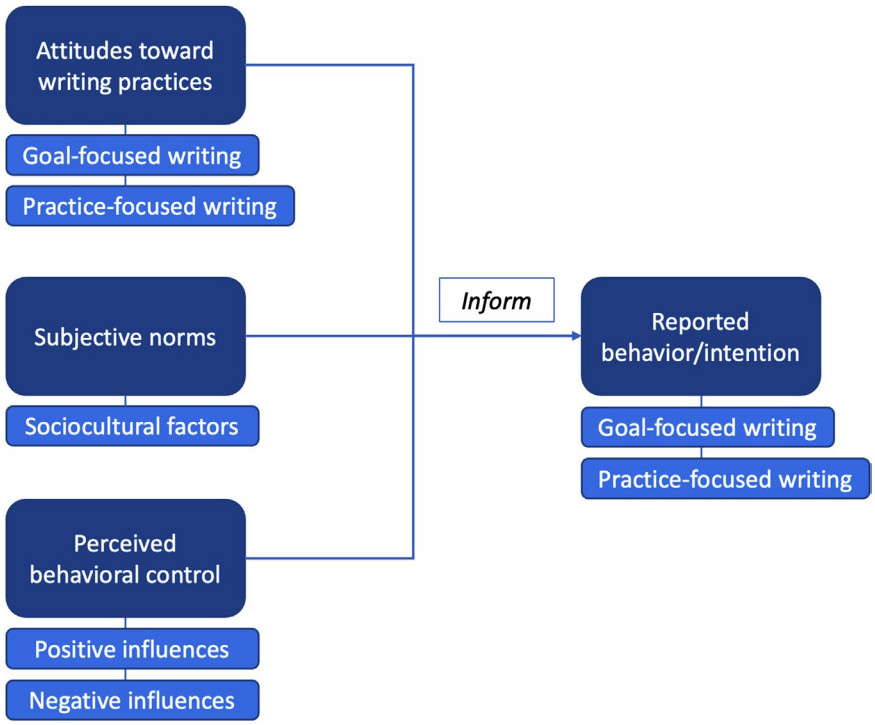

FIGURE 1. Alignment of the theory of planned behavior with the survey elements. Attitudes, subjective norms, and perceived behavioral control indirectly inform behavior through intention. Perceived behavioral control also directly informs behavior. The dark blue rectangles indicate the elements of the theory of planned behavior, and the light blue rectangles indicate the survey elements aligned with each element.

Specifically, instructors learn and develop their beliefs through social interactions with others (Vygotsky, 1978; Kelly, 2006; Russ *et al.*, 2016) and the values and context that are part of the culture of the organization in which they are situated (Amundsen and Wilson, 2012; Kezar, 2013; Elrod and Kezar, 2016). Cultural factors may be especially impactful on an instructor's perceived behavioral control at the postsecondary level due to the strong disciplinary and departmental environments in which instructors are embedded. For example, in some departmental environments, a traditionalist view—that subject matter knowledge is sufficient for effective teaching—dominates (Luft *et al.*, 2004; Henderson *et al.*, 2011; Brownell and Tanner, 2012). Thus, to direct the development and implementation of writing-based pedagogies, we must characterize not only instructors' attitudes about writing pedagogies, but also the subjective norms and perceived behavioral control influencing their instructional use of writing. This research provides insights that can help bridge the gap between what faculty view as effective and their actual instructional behaviors.

RESEARCH QUESTIONS

This work seeks to provide further insights into faculty assignment of writing by answering the following research questions, which can guide efforts to promote the wider adoption of writing in STEM through targeting faculty beliefs that influence their use of writing.

1. What types of writing do STEM faculty at research-intensive institutions report assigning in their courses?
2. To what extent do STEM faculty at research-intensive institutions believe writing is an effective tool for learning STEM content knowledge?
3. Do the attitudes and subjective norms differ between faculty who do and do not assign writing in their courses?
4. Do faculty beliefs about factors that may influence perceived behavioral control differ between faculty who assign and do not assign writing?

METHODS

Study Plan

To address these questions, we undertook a study with two components: obtaining a study sample of STEM faculty at research-intensive institutions and developing a survey to identify faculty practices and beliefs. Survey development was guided by the need to characterize faculty practices and research evidence of the importance of beliefs in shaping faculty practices. The framework provided by the theory of planned behavior was used during analysis as a way to make meaning of the findings.

Study Sample

This study focuses specifically on STEM faculty at research-intensive institutions. We chose to focus on a specific institution type, as faculty behaviors and beliefs may be distinct at, and thus not comparable across, various types of postsecondary institutions dues to their distinct cultures. The distinct culture of research-intensive institutions (e.g., the higher relative emphasis placed on research compared with teaching, typically large introductory classrooms, the availability and role of teaching assistants [TAs]) paired with the large number of undergraduate students who attend this type of institution merits a focus on this institution type. A collaborative effort was undertaken with the Reinvention Collaborative, a consortium of research-intensive institutions, to identify faculty in STEM departments. A list of faculty in STEM departments at 63 research-intensive institutions located in the United States was generated and served as the participant base from which the sample for the pilot study and study sample were drawn. The final version of the survey was sent to 29,430 faculty via an online survey system. Faculty received two reminders to complete the survey and no incentives were provided to faculty for completing the survey. Following survey cleaning (described in the Supplemental Material, "Survey Cleaning"), there were 4891 "complete" surveys, with a response rate of 17%. This response rate is similar to that of other studies surveying the nationwide STEM faculty population, for example, Gehrke and Kezar (2017) and Apkarian *et al.* (2021).

Survey Development and Structure

This study was primarily quantitative in nature, focusing on the analysis of survey responses, as its purpose was to broadly characterize the existing beliefs of STEM faculty about using writing in undergraduate STEM classrooms. The survey (see Supplemental Material) was jointly designed by the authors, who consist of both STEM and writing studies faculty. Participants were first asked about their behaviors (indicating yes/no), i.e., whether they assigned specific writing practices, and attitudes (from very effective to not effective) related to the writing practices. "Writing" itself was not defined for faculty, but descriptions of the writing practices were defined for faculty in the survey and divided into two categories: goal-focused practices and process-focused practices. The goal-focused practices are characterized by the goal(s) for incorporating writing and include learning to writing in a scientific style, writing to learn concepts and principles, and writing to demonstrate mastery of concepts and principles. The process-focused practices are characterized by the process(es) students undergo during the writing assignments. They include writing that incorporates peer review between students, revision of writing in response to feedback, and scaffolding sections of a long piece of writing by dividing it into smaller supported sections. Faculty were then asked about factors that may influence their subjective norms and perceived behavioral control beliefs about writing (strongly agree to strongly disagree), consisting of social and contextual factors the research literature has identified as potential resources and constraints to STEM instructional practices. Additionally, participants were asked about their disciplinary epistemic beliefs, but those responses are analyzed in Thompson *et al.* (2021).

A subset of the survey questions included an open-response option so that participants could expand on factors influencing their writing beliefs. After faculty responded to the given items surrounding how they think about using writing in their classroom, they were asked if there were other factors shaping their pedagogical use of writing. Respondents who selected "yes" to the open-response questions were given space to expand on the additional factors. In the final section of the survey, all participants were asked demographic questions (see Supplemental Table S1 for the collected demographics). Initial questions were developed based on previously identified factors that influence pedagogical change (Henderson and Dancy, 2007; Henderson *et al.*, 2011). The survey included logic to sort faculty based on two identifiers (i.e., whether they teach undergraduates and whether they use writing); the logic flow of the questions covered in this analysis is presented in a flowchart in Supplemental Figure S1. The study was approved by the University of Michigan review board, and respondents indicated their consent before beginning the survey.

To establish response-process validity for the survey, cognitive interviews were conducted with five STEM faculty (including two biologists, two chemists, and one physicist) from two research universities. The cognitive interviews used a verbal probing technique to elicit participants' reasoning processes as they reflected on the survey questions and their own responses (Collins, 2003). Audio recordings of the interviews were transcribed verbatim and discussed by the study team; the survey questions and format were refined to address interpretation issues and add response categories not previously included. The resultant survey was piloted with a subset of 200 STEM faculty randomly selected from 63 research-intensive institutions (Carnegie Classification of Institutions of Higher Education, http://carnegieclassifications.iu.edu). Following the pilot data collection, a preliminary analysis was performed to identify questions that were not performing well and account for the average time spent responding. Results were discussed with the project team, and some questions in the epistemology section of the survey, not analyzed in this article, were modified or excluded for the scale-up distribution of the survey.

Data Collection and Cleaning

The survey was conducted in partnership with the survey institute at the University of Michigan. Survey distribution, collection, and cleaning were performed by the survey institute at the lead author's home institution. Details are described in the Supplemental Material. To increase the likelihood that the sample was representative of the population of STEM instructors at research-intensive institutions in the United States and not biased from a higher response rate by a particular institution or discipline, we applied post-stratification weights during data analysis to account for differential response rates across institutions and between disciplines within institutions. The data were post-stratified using an iterative proportional fitting, or raking, approach (Heeringa *et al.*, 2010), described in the Supplemental Material ("Post-stratification Approach"). Weights were used during analysis when determining relative frequencies to help account for error sampling and nonresponse bias (Heeringa *et al.*, 2010).

Data Analysis

An analysis of how demographic factors, discipline, and faculty beliefs relate to the assignment of writing have previously been reported in Thompson *et al.* (2021). The study presented here expands on the importance of attitudes toward writing practices, subjective norms, and perceived behavioral control identified in Thompson *et al.* (2021). This study provides an analysis of participant responses to all the questions focused on the behaviors and attitudes toward the six writing practices presented in the survey, all the questions probing the subjective norms surrounding use of writing in instruction, and all the questions pertaining to perceived behavioral control for using writing in instruction. The responses are compared between the faculty who report assigning and not assigning writing. To facilitate analyses, survey items were organized in accordance with the theory of planned behavior framework as reflected in Figure 1.

Analysis was performed with Stata SE (StatCorp, 2017) on de-identified data, using the weights created by the survey institute. Faculty indicated their beliefs about writing pedagogies on a scale of not effective (1) to very effective (4) and the impact of social and cultural factors on a scale of strongly disagree (1) to strongly agree (5). Responses were represented numerically when working with the data in Stata. When average responses were interpreted, the level of belief or agreement presented herein corresponds to the closest whole number (e.g., if an average agreement of 3.75 was calculated, the impact would be considered to correspond to "agree"). Statistical analysis was performed on the weighted data using linear regressions with significance assigned at $\alpha < 0.05$. Specifically, the differences in responses between the writing assigners and non-assigners for attitudes about effectiveness of writing practices and beliefs informing the ways in which faculty think about assigning of

writing were analyzed for statistically significant differences. In addition, post hoc multiple comparisons tests were also performed to identify differences within a group (e.g., between the factors constraining writing for writing assigners). These differences are either indicated by superscripted letters in the tables presented in the body of the article or as *p* values provided in Supplemental Tables S5, S6, S8, and S9. Effect size was also calculated; omega-square (ω^2) effect size is reported in alignment with the use of regression analysis, where values between 0.01 and 0.058 are considered small, 0.059 to 0.137 as medium, and above 0.138 as large (Kirk, 1996; Olejnik and Algina, 2003; Rodriguez, 2006; Khalilzadeh and Tasci, 2017). Medium and large effect sizes are considered to indicate a meaningful difference.

The open responses were collected and thematically analyzed based on frequently occurring themes (Cohen *et al.*, 2011). The analysis is presented in the Supplemental Material ("Open Response Analysis") and themes are summarized in Supplemental Table S13.

RESULTS

Faculty-Reported Behavior about Using Writing-Based Pedagogies

We first examined general faculty use of writing in STEM undergraduate courses. From the weighted responses, 69% of faculty who teach undergraduates reported using writing in their classrooms (n_w = 3121 of 4497). We refer to this group as writing assigner (WA) faculty throughout the subsequent analysis, with the remaining 31% referred to as writing non-assigner (WNA) faculty. Of the WA faculty, 14% teach introductory-level courses only, 43% teach advanced-level courses only, and 43% teach at both course levels (n_w = 3121; Supplemental Table S2). The WA faculty were asked to consider a course they regularly teach in which they use writing. Fifty-five percent of faculty identified a course enrolling fewer than 50 students, and less than 1% of WA faculty identified a course with greater than 500 students (Supplemental Table S3). For the courses that they identified, faculty identified which of the provided goal-focused and process-focused writing practices they used in a course. For each of the goal-focused practices, the majority of faculty reported using at least one writing assignment with each of the goals of "writing to learn" and "writing to demonstrate mastery" (Table 1). Approximately half of the faculty reported using "learning to write" in their identified courses (Table 1). A smaller percentage of writing users reported using process-focused practices in their identified courses (Table 1). Forty-seven percent of faculty reported using "revision based on feedback" in their courses, with "peer review between students" and "scaffolding a long piece of writing" each reported as being used by only about a third of faculty.

TABLE 1. Faculty use of writing practices in courses in which they regularly teach and use writing[a]

	Percent of WA who assign the practice
Goal-targeted practices	
Learning to write	52%
Writing to demonstrate mastery	71%
Writing to learn	74%
Process-directed practices	
Scaffolding a long piece of writing	28%
Peer review between students	30%
Revision based on feedback	47%

[a]The n_w varied for each question, with the values presented in Supplemental Table S4.

Faculty Attitudes and Subjective Norms about Writing-Based Pedagogies

Comparison of WA and WNA faculty attitudes about the relative effectiveness of each writing practice indicated that both groups viewed all writing practices as somewhat effective for developing students' conceptual knowledge and understanding of principles in STEM (Table 2). For WA faculty, "writing to learn" and "revision based on feedback" had the highest average effectiveness ratings for their ability to support student learning, followed by "writing to demonstrate mastery." Conversely, peer review had the lowest average rating for faculty attitudes about the effectiveness of the practices. Similar to their counterparts, the WNA faculty rated peer review as the least effective practice; however, they viewed revision as the most effective writing practice (Table 2). Comparison between

TABLE 2. Faculty attitudes about the effectiveness of writing practices[a]

	Attitudes for faculty who assign writing (WA)	Attitudes for faculty who do not assign writing (WNA)	F^b	Effect size (ω^2)
Goal-targeted practices				
Learning to write	3.1 ± 0.0[†]	2.9 ± 0.0[§,ß]	25.06	0.005
Writing to demonstrate mastery	3.3 ± 0.0	3.0 ± 0.0[§]	95.68	0.021
Writing to learn	3.4 ± 0.0[‡]	3.0 ± 0.0[§,ß]	227.99	0.049
Process-directed practices				
Scaffolding a long piece of writing	3.1 ± 0.0[†]	2.9 ± 0.0[ß]	37.28	0.008
Peer review between students	2.9 ± 0.0	2.8 ± 0.0	10.95	0.002
Revision based on feedback	3.4 ± 0.0[‡]	3.2 ± 0.0	55.68	0.012

[a]For each practice, the average attitude about how effective the practice is for promoting student learning of STEM content knowledge, for both WA and WNA, is presented. Attitudes about effectiveness are on a scale of 1 (not effective) to 4 (very effective) with standard error of the mean.

[b]Differences in the attitudes between faculty who use and do not use writing are all statistically significant with $p \leq 0.001$ and effect sizes indicate the magnitude of the difference. Superscript symbols indicate practices where the attitudes are equivalent within a group (e.g. within WA or WNA) as determined by post-hoc analysis (e.g. writing user views of 'Learning to write' and 'Scaffolding a long piece of writing' are not significantly different, as indicated by '†'). All effect sizes were small or negligible in magnitude. The n_w varied for each question, with the values presented in the SI (Table S5).

TABLE 3. Factors that influence the subjective norms of writing practices with the average agreement presented for both WA and WNA faculty[a]

	Faculty who assign writing (WA)	Faculty who do not assign writing (WNA)	F[b]	Effect size (ω^2)
Subjective norms				
Writing is not important in my discipline.	1.4 ± 0.0	2.1 ± 0.0	423.10	0.086[c]
Faculty in my department are not encouraged to incorporate writing in their courses.	2.9 ± 0.0	3.4 ± 0.0	213.49	0.045

[a]Agreement with each statement was on a scale of 1 (strongly disagree) to 5 (strongly agree) with standard error of the mean.
[b]Differences in the agreement between WA and WNA groups are all statistically significant, with $p \leq 0.001$. The p values between factors within the WA and WNA groups were < 0.001.
[c]Medium effect sizes. The n_w varied for each question, with the values presented in the Supplemental Table S6.

the two groups of faculty primarily showed negligible or small effect sizes across each of the practices (Table 2), which indicates that the differences between attitudes about the effectiveness of writing practices for faculty who do and do not assign writing do not appear to be meaningful.

Two survey questions gauged how disciplinary and departmental social interactions might impact faculty subjective norms about the pedagogical use of writing. Overall, both groups of faculty disagreed with the sentiment that "writing is not important in my discipline" impacted their pedagogical use of writing, where the WA faculty indicated stronger disagreement with a medium effect size (Table 3). Both groups of faculty indicated neutral agreement to the sentiment that "faculty in my department are not encouraged to incorporate writing in their courses" impacted their use of writing (Table 3). Thus, differences between the influence of subjective norms on WA and WNA faculty may be due more to disciplinary than departmental culture.

Factors Influencing Perceived Behavioral Control of Use of Writing

We first present faculty responses to the factors that may inform the ways in which faculty think about how writing can be incorporated into instruction, which could increase perceived behavioral control. The average responses fell between disagree and neutral, where each of the two social factors "experience as a student" and "colleagues sharing strategies" showed the highest agreement rating for one of the WA and WNA groups (Table 4) with small effect sizes. The difference in agreement between the two social factors for the WA and WNA faculty had a small effect size. Similarly, across the external resources about pedagogical writing use, the WA faculty reported higher agreement than the WNA faculty, with only small effect sizes (Table 4).

The factors that may decrease faculty's perceived behavioral control for incorporating writing showed average responses ranging from "disagree" to "agree." The WNA group, on average, reported higher agreement that these factors limit their use of writing in the classroom, with small to medium effect sizes between the two groups (Table 5). Four of the factors had medium effect sizes for the differences in average agreement between the two groups. Of these, three were instructional constraints and one was a personal factor. The two factors with the largest effect sizes between agreement of WA and WNA groups were limited course time ($\omega^2 = 0.118$)

TABLE 4. Factors that could increase perceived behavioral control of assigning writing in the classroom, with the average agreement presented for both WA and WNA faculty[a]

		Faculty who assign writing (WA)	Faculty who do not assign writing (WNA)	F[b]	Effect size (ω^2)
Social factors					
1	I use teaching practices for writing that are very similar to those that I experienced as a student.	2.8 ± 0.0	3.2 ± 0.0	102.79	0.022
2	I have colleagues who share with me strategies and ideas about incorporating writing.	3.1 ± 0.0	2.6 ± 0.0	218.17	0.046
External resources about pedagogical writing use					
3	I read literature regarding the incorporation of writing in my discipline.	2.7 ± 0.0[†]	2.2 ± 0.0[‡]	177.37	0.038
4	I communicate with our campus center for teaching and learning about incorporating writing in my classes.	2.4 ± 0.0	2.0 ± 0.0[§]	168.16	0.036
5	Professional development opportunities have helped me learn how to incorporate writing.	2.7 ± 0.0[†]	2.2 ± 0.0[‡]	176.38	0.038
6	I communicate with our campus writing center about using writing in the classroom.	2.3 ± 0.0	1.9 ± 0.0[§]	121.01	0.026

[a]Agreement with each statement was on a scale of 1 (strongly disagree) to 5 (strongly agree) with standard error of the mean. Error is standard error of the mean.
[b]Differences in the agreement between WA and WNA are all statistically significant with $p \leq 0.001$. Superscript symbols indicate views that are equivalent within a group (e.g. the factors 'reading literature' and 'professional development' were not significantly different between writing users, as indicated by '†'). The n_w varied for each question, with the values presented in the SI (Table S7). See Tables S8 and S9 for p values between factors within the WA and WNA groups. All effect sizes were small or lower in magnitude.

TABLE 5. Factors that may decrease perceived behavioral control of assigning writing in the classroom, with the average agreement for each factor presented for both WA and WNA faculty[a]

		Faculty who assign writing (WA)	Faculty who do not assign writing (WNA)	F[b]	Effect size (ω^2)
Instructional factors					
1	My schedule is too full to develop materials and modify my course to include writing.	2.9 ± 0.0	3.4 ± 0.0	219.67	0.047
2	Covering all the material in my course does not leave instructional time to incorporate writing.	2.8 ± 0.0	3.7 ± 0.0	602.32	0.118[c]
3	My course is too large to incorporate writing.	2.6 ± 0.0	3.5 ± 0.0	616.33	0.121[c]
4	I don't have sufficient resources (e.g. TAs) to incorporate writing in my course.	3.0 ± 0.0	3.3 ± 0.0	370.68	0.076[c]
5	I cannot incorporate writing because my TAs are not prepared to assess writing.	2.9 ± 0.0	3.5 ± 0.0	255.10	0.054
Personal experience factors					
6	I don't feel confident about using writing in my class.	2.0 ± 0.0	2.6 ± 0.0	333.98	0.069[c]
7	My previous attempts to incorporate writing were not successful.	2.2 ± 0.0	2.6 ± 0.0	209.15	0.045
8	I am not aware of the research on the effectiveness on incorporating writing in my course to enhance student learning.	2.7 ± 0.0	3.3 ± 0.0	276.76	0.058

[a]Agreement with each statement was on a scale of 1 (strongly disagree) to 5 (strongly agree) with standard error of the mean.
[b]Differences in the agreement between WA and WNA groups are all statistically significant, with $p \leq 0.001$. The n_w varied for each question, with the values presented in the Supplemental Table S10. See Supplemental Tables S11 and S12 for p values between factors within the WA and WNA groups.
[c]Medium effect sizes.

and course size ($\omega^2 = 0.121$), both instructional factors. This aligns with the general trend that the instructional factors had higher average agreement than the factors falling under personal experience. However, the average agreement with each of the factors was at or below the level of "neither agree nor disagree" for both groups.

Faculty responses to two open-ended questions on the survey provided further insight into additional factors guiding faculty behaviors for using writing in the classroom (themes and exemplars are presented in the Supplemental Table S13). The open-ended responses primarily expanded on factors included in the survey—namely time, course size, personal experience, and feedback and advice—which supports our use of survey methodology for this study. Twenty percent of those responding to the open-ended questions elaborated on factors that positively influenced their beliefs about incorporating writing in their courses, where responses primarily aligned with the factors presented in the survey but provided more detail. A subset of the responses described incorporating writing because of recognizing benefits for students or using writing as a way to measure student engagement and understanding. Some of the respondents attributed these beliefs to factors including field experience, research, mentorships, and workshops. Faculty also expanded on factors that could reduce their perceived behavior control for using writing in their course. Time constraints made up 18% of the combined open-ended responses; most commonly identified time constrains were grading student work, providing feedback on student writing, planning assignments, and incorporating writing instruction in their classes. Furthermore, some of the responses focused on the connection between the limitations of time and class size, aligning with quantitative results, wherein 20% of faculty cited both as inhibiting writing use. For example, the write-in responses indicated that using writing in large classes was challenging due to lack of time to provide feedback to all students, especially with limited TA support (as also seen in the survey results presented in Table 5).

DISCUSSION

Faculty-Reported Behavior

The majority of faculty reported that they assign some form of writing in their classes, primarily in smaller courses. Additionally, some faculty reported using multiple practices, implying that they view writing as a multifaceted tool. Both findings align with work by Moon *et al.* (2018a) in their analysis of interviews with faculty about their conceptions of writing. Faculty primarily reported using goal-focused practices in the course in which they regularly use writing. This finding may suggest that, while STEM faculty at research-intensive institutions are incorporating writing into their classes, they are not necessarily also incorporating writing practices that could alleviate the need for instructor feedback, such a peer review (Topping, 2009). Not only could using such practices alleviate the burden on instructors to provide feedback, but they have also been found to support STEM students during the writing process. For example, studies on peer review of writing in STEM courses have demonstrated that students can successfully provide their peers with substantive feedback that they can then use to make meaningful content-focused revisions (Halim *et al.*, 2018; Moon *et al.*, 2018b; Finkenstaedt-Quinn *et al.*, 2021).

Influence of Attitudes and Subjective Norms

Both the WA and WNA faculty viewed goal-focused and process-focused writing practices as somewhat effective at promoting student learning of concepts in STEM, with no meaningful differences between the two groups. While the theory of planned behavior posits that attitudes influence behavior (i.e., writing use), our findings are consistent with prior research on uptake of evidence-based pedagogies, which shows that positive attitudes about effectiveness are not necessarily aligned with actual usage (Henderson and Dancy, 2007; Corbo *et al.*, 2016). Our results are also comparable to the findings of Stroumbakis *et al.* (2016), who focused on STEM faculty at a community college. Those authors found that, while faculty viewed writing

as a method to support student learning and writing skills, they did not perceive the benefits as sufficient to warrant the work required to include writing in non–writing intensive courses. Thus, the lack of meaningful differences in attitudes about the effectiveness of the writing practices between the WA and WNA groups indicates that the other constructs informing intention and behavior (i.e., subjective normative beliefs and perceived behavioral control) are important to consider. We see a similar misalignment between attitudes and behavior when examining just the WA faculty. Less than half of WA faculty reported assigning process-focused writing practices, but they do not necessarily believe these practices are less effective than goal-focused practices. This warrants further investigation into why fewer faculty report using process-focused practices.

Relatedly, there is a misalignment between faculty attitudes of effectiveness and the research literature focused on writing practices. For example, peer review was viewed by both groups as the least effective writing practice, yet there is substantial work demonstrating its benefits for supporting student writing at the undergraduate level (Cho and Schunn, 2007; Cho and MacArthur, 2010; Lundstrom and Baker, 2009) and for learning STEM concepts and disciplinary thinking specifically (Halim *et al.*, 2018; Moon *et al.*, 2018b; Finkenstaedt-Quinn *et al.*, 2020, 2021). To further complicate this, Thompson *et al.* (2021) found that positive attitudes toward peer review and scaffolding practices were negatively associated with assigning writing, positing that this is due to a higher difficulty for implementing the practices. Together, these reports could indicate that faculty do not believe these practices can be effective in their own course contexts. These results may indicate that greater exposure to the research findings focused on writing processes may be necessary to influence the beliefs of faculty and that researchers should consider describing how writing practices may be successfully incorporated into different contexts.

Overall, the potential subjective norms that could decrease intention to incorporate writing did not appear important to faculty assignment of writing. However, there was a higher average agreement by the WNA group that writing is not important to their disciplines. This finding suggests that, if faculty do not believe that writing is important to their disciplines they will be less likely to assign it in their courses. Thus, disciplinary culture may be an important consideration for subjective norms influencing intention and behavior to use writing practices. This aligns with prior research that tied disciplinary culture to the relationship between writing use and beliefs at the high school level (Horn, 2005; Gillespie *et al.*, 2014), but indicates that further investigation is merited due to the low agreement found in this study.

Influences on Perceived Behavioral Control

For the factors that may positively influence the perceived behavior control of incorporating writing practices, both WA and WNA faculty reported higher agreement with social factors than the external resources about pedagogical writing use. While our findings align with the importance of social factors on instruction (Sandi-Urena *et al.*, 2011; Andrews and Lemons, 2015) and adoption of evidence-based practices in STEM (Khatri *et al.*, 2016), the differences have only a small effect size. However, Thompson *et al.* (2021) identified a positive relationship between colleagues sharing strategies and assignment of writing, which is paralleled by the findings of Bathgate *et al.* (2019) on the implementation of evidence-based practices in general. Further research is needed to identify the relative importance of social factors and how they may or may not differ between WA and WNA faculty. In addition, the differences in agreement between WA and WNA groups on the external resources that may positively influence the perceived behavior control surrounding pedagogical writing use (e.g., reading education literature and taking part in professional development opportunities on incorporating writing) merits further investigation, as our findings differ somewhat from those of Henderson *et al.* (2012), who found that those two resources distinguish faculty who use evidence-based practices, while we only found small effect sizes for the difference in agreement between the two groups. This difference in our findings compared with prior literature about the uptake of evidence-based practices indicates that the ideal modes for propagating research findings related to the instructional use of writing may be different from other evidence-based practices.

The differences between WA and WNA faculty on factors that may negatively influence the perceived behavioral control were more distinct. Overall, the WA group indicated that the factors had a lower impact on their use of writing than their WNA counterparts. For one of the personal experience factors, lack of confidence in incorporating writing, there was a meaningful difference between the two groups with a medium effect size. This finding suggests that, on average, faculty who do not assign writing are less confident in their ability to incorporate writing, which could decrease their perceived behavioral control. Thus, despite the minimal differences in the attitudes and subjective norms reported by WA and WNA faculty, the difference in personal experiences could be reducing the perceived behavioral control of the WNA faculty, such that they are not motivated to surmount the barriers to incorporating writing.

Instructional constraints appear to negatively impact perceived behavioral control for both WA and WNA faculty, with meaningfully higher agreement for WNA faculty exemplified by differences in agreement of a medium effect size for three of the five factors. In addition to instructional factors previously identified as constraining faculty assigning writing—their schedules being too full or having limited instructional time to incorporate writing—at the high school (Horn, 2005) and undergraduate (Thompson *et al.*, 2021) level, we identified insufficient resources as a constraint. Such constraints could be due to the culture within departmental or institutional settings and might necessitate top-down cultural change or resources that increase the perceived behavior control for incorporating writing. Resources could describe how instructional constraints can be mitigated through the writing process itself. Incorporating process-focused practices into writing assignments—such as peer review between students—may alleviate the workload and other assessment-related issues that may be reducing the perceived behavioral control.

Directions for Change

The primary differences between WA and WNA STEM faculty at research-intensive institutions appear to lie in factors influencing their perceived behavior control. Our results extend those of Thompson *et al.* (2021) by indicating a further focus on

instructional constraints as inhibiting the assignment of writing. The focus on instructional constraints seen here and in STEM education literature on the uptake of evidence-based instructional practices in general (Sunal *et al.*, 2001; Henderson and Dancy, 2007) indicates that efforts to increase the use of writing practices in STEM undergraduate courses may require reducing factors that constrain faculty's perceived behavioral control. This could involve changes at the departmental, college, or institutional levels to build a supportive environment, which may in turn positively influence subjective norms, as has been suggested for evidence-based instructional practices generally (Quardokus and Henderson, 2015; Corbo *et al.*, 2016;). This proposition also aligns with the perspective that stakeholders should consider the departmental or institutional values and the environment they create. For example, consideration of institutional and departmental values are at the center of the Writing-Enriched Curriculum model developed at the University of Minnesota. In this model, departmental faculty members engage in a series of structured discussions and data analysis with the purpose of collectively identifying, addressing, and at times transforming faculty beliefs about locally relevant modes of both writing and writing instruction (Flash, 2021).

Alternatively, efforts to increase the use of writing practices in STEM at research-intensive institutions could leverage the attitudes faculty have about the positive effects writing has on their students, captured by the short-answer responses to our survey, by placing a greater emphasis on the evidence in STEM education research that demonstrates the effectiveness and best use of instructional writing practices to support student outcomes. While much research focused on the effectiveness of writing already exists (Reynolds *et al.*, 2012; Anderson *et al.*, 2015; Klein, 2015; Gere *et al.*, 2019), the social factors should be harnessed to promote cultural change, and researchers should consider and be explicit about how to incorporate writing practices into diverse classroom environments in ways that mitigate the instructional constraints.

Limitations

Despite the valuable information derived from our survey analysis, this study has a few limitations. Although weighting was used, there is still potential for sampling bias in our data set due to the low response rate. For example, faculty who view writing as important to their disciplines may have been more likely to respond to the survey. This could explain the disagreement of both WA and WNA faculty with the survey question stating that "writing is not important in my discipline" and would minimize the importance of subjective norms on the assignment of writing in STEM classrooms. Thus, the large nonresponse bias may mean that we are not capturing certain influences on faculty behavior. In addition, for many questions, the average responses were around neutral, this arose from the broad distribution of responses by the two groups that then averaged close to neutral. This may indicate that the factors influencing faculty assignment of writing are individualized or that the survey did not capture primary factors. Relatedly, participant responses were limited to the questions included, and there was minimal room for in-depth responses. However, the quantitative approach used herein aligns with this study's aim of developing a large-scale understanding of faculty behaviors, attitudes, and beliefs about using writing pedagogies. Additionally, some of the differences between WA and WNA beliefs may be due to the courses they teach. However, we have limited information about the types of courses that WNA and WA faculty teach. An additional challenge, as indicated by Kezar (2013), is that not all members of an organization view or interact with the beliefs of the culture in the same way, indicating the importance of exploring differences arising from disciplinary culture. Finally, we did not do correlational analyses that incorporate variables such as course size and demographics, which limits our findings.

CONCLUSION AND IMPLICATIONS

This study contributes to the STEM education literature focused on the uptake of evidence-based instructional practices by providing an overview of the types of writing practices that STEM faculty at research-intensive institutions report using in their undergraduate courses and their attitudes and beliefs surrounding writing as a pedagogical practice. Our analysis serves as a starting point for future studies focused on developing a more nuanced understanding of the specific practices or beliefs of this population with regard to writing. While there exists literature that examines the general uptake of practices in STEM, the orientation of this work can direct the efforts of stakeholders specifically interested in increasing STEM faculty integration of writing during instruction. Overall, faculty view a range of writing practices as at least somewhat effective for supporting student conceptual learning, yet a significant portion of faculty indicated that they do not assign writing. In addition, when considering a course that they regularly teach in which they use writing, faculty primarily reported on using writing in smaller courses. Usage limited to smaller courses may reduce the number of students who can benefit from the writing practices being incorporated into STEM classrooms. This suggests that work is merited in promoting the implementation of writing practice in STEM for a range of learning goals and course environments. One approach is to develop faculty's understanding of the effectiveness and versatility of writing practices and use knowledge of the factors that influence faculty use of writing when advocating for change.

Our work further substantiates the importance of considering faculty's perceived behavioral control, specifically perceived instructional constraints at both the departmental and institutional levels. We suggest that stakeholders can work to minimize these constraints, either by providing external supports or taking the difficulties into account when designing specific writing practices. External supports can span from promoting organizational change to helping individual faculty develop strategies that address the constraints hindering their use of writing. While some of the constraints may be addressable through cultural change, it is necessary to acknowledge that writing practices can increase the instructional demand on faculty and to address that demand when designing and propagating practices. When designing writing practices, stakeholders can intentionally develop or promote practices that minimize the constraints that could reduce instructors' perceived behavioral control, such as time constraints associated with providing feedback to large classes. Designing writing assignments that minimize instructor workload while also supporting learning and then clearly outlining how to successfully incorporate the assignment may serve to increase the adoption of writing-based instructional practices.

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