UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

SCIENCE WRITING INSTRUCTION EFFICACY BELIEFS OF SECONDARY AND POST-SECONDARY SCIENCE INSTRUCTORS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

DOCTOR OF PHILOSOPHY

By

CARRIE J. MILLER-DEBOER
Norman, Oklahoma
2015

SCIENCE WRITING INSTRUCTION EFFICACY BELIEFS OF SECONDARY AND POST-SECONDARY SCIENCE INSTRUCTORS

A DISSERTATION APPROVED FOR THE
DEPARTMENT OF INSTRUCTIONAL LEADERSHIP AND ACADEMIC CURRICULUM

BY

____
Dr. Timothy Laubach, Chair

____
Dr. Edmund Marek

____
Dr. Michele Eodice

____
Dr. Priscilla Griffith

____
Dr. Kerry Magruder

© Copyright by CARRIE J. MILLER-DEBOER 2015
All Rights Reserved.

To Julie Ambler, who started me down this road; Tim Laubach, who helped me finally reach this milestone; and Silas DeBoer, who continues to walk with me along the way.

Acknowledgements

My deepest appreciation to my committee, Timothy A. Laubach (Chair), Michele Eodice, Priscilla Griffith, Kerry V. Magruder, and Edmund A. Marek. Without their encouragement and faith in my ability, I could not have finished my Ph.D. I especially want to thank Tim Laubach for his mentorship, patient guidance, and willingness to go the distance in helping me achieve my goals at the University of Oklahoma.

My sincere thanks go to my parents, Darrell and Paula Miller, who unceasingly supported and encouraged my endeavors. The prayers of my mother and all those who have interceded on my behalf are much appreciated. I am also happy to once again graduate alongside my father, who understands completely the challenge of a blank page. Special thanks to my husband, Silas DeBoer, who not only eased my transition into the social sciences but made sure I ate at appropriate times and found infinite ways to bring a smile to my face when I needed it most. Thank you Kay Thaden-DeBoer for bringing him and your cheer into my life.

Regrettably, I can't possibly thank everyone who has been part of this eight-year journey. Thank you to all of the people from the Biology Department, Writing Center, and Geology and Geophysics Department without whom, I never would have thought much about science writing. Thank you especially to Heather and Paul Ketchum, Mariëlle Hoefnagels, Megan Elwood-Madden, Moira Ozias, Jennifer Dorsey, Jeff Patterson, Kristy Brugar, Kate Roberts, Stacy Reeder, and Wendy Martin. Finally, thank you to the 118 teachers and instructors who contributed their time to make this study a reality.

Table of Contents

List of Tables

List of Figures

Dissertation Abstract

Discipline-specific writing standards at the secondary level and writing intensive course requirements at the post-secondary level require science teacher and science instructors to teach science writing skills. However, many do not feel equipped in this area, often from lack of professional development or poor perceptions of themselves as writers. Thus, this study investigated science teacher and science instructor science writing instruction efficacy beliefs and identified antecedents to high efficacy. During the first phase, quantitative data were collected from 46 secondary science teachers and 72 post-secondary college instructors using an online survey that included the Teacher Sense of Efficacy Scale and the Writer Self-Perception Survey. The results of the quantitative phase guided the development of the second, qualitative phase, which included analysis of responses to two sets of two open-ended statements and interviews with eight educators: four secondary science teachers and four post-secondary instructors identified as having high science writing efficacy beliefs. Secondary science teachers had a mid- to high-range of efficacy beliefs (M = 6.9, SD = 0.85), whereas post-secondary science instructors had low- to high-range efficacy beliefs (M = 6.3, SD = 1.3). Within both groups, the educators with the highest efficacy beliefs valued science writing, used writing to learn strategies, had experience teaching and integrating writing into their science classes, and faced barriers. Unique to secondary science teachers were having an inner locus of control, being self-directed learners and collaborating with colleagues. Post-secondary science instructors also implemented writing in the discipline strategies and received positive feedback from students regarding writing.

Manuscript I

Secondary Science Teacher Science Writing Instruction Efficacy Beliefs

This manuscript is prepared for submission to the peer-reviewed journal *The Journal of Science Teacher Education*.

Abstract

Writing instruction is often emphasized throughout the curriculum, including the science classroom. However, low writing instruction efficacy, sometimes attributed to teachers' writing histories, often blocks educators from teaching writing confidently and efficiently. This explanatory sequential mixed methods study investigated science teacher writing instruction efficacy beliefs and identified antecedents to high writing instruction efficacy beliefs. Quantitative data from an online survey that included the Teacher Sense of Efficacy Scale (TSES) and the Writer Self-Perception Scale (WSPS) were collected from 46 secondary science teachers and analyzed in the first phase. The results of the quantitative phase then guided the development of the second, qualitative phase, which also included data collection and analysis. Responses from the 46 science teachers to two sets of two open-ended statements were coded into themes during the second phase and, using TSES scores, four teachers with high science writing instruction efficacy beliefs were identified and interviewed. Science writing instruction efficacy beliefs of these science teachers ranged from mid- to high-levels. Thus, the lowest efficacy teachers felt that they had at least some influence when teaching science writing and the highest efficacy teachers felt they had a great deal of influence when teaching science writing. Science teachers with the highest science writing instruction efficacy beliefs valued science writing, used writing to learn strategies, had experience teaching and integrating writing into their science classes, faced but were not focused on barriers to integrating science writing, displayed an inner locus of control, were self-directed learners and collaborated with colleagues.

Keywords

science writing, writing to learn, science instruction, efficacy beliefs

Introduction

Currently, emphasis is on implementing writing instruction throughout the K-12 curriculum, including the science classroom. To date, 43 states have adopted the Common Core State Standards (CCSS), along with Washington D.C., 4 territories, and the Department of Defense Education Activity (Common Core State Standards Initiative, 2015). The CCSS are divided into Mathematics and English Language Arts (ELA) & Literacy in History/Social Studies, Science and Technical Subjects. The ELA and Literacy standards are combined into one set of standards for grades K-5 and divided into separate standards for grades 6-12. Given the need for secondary ELA teachers to focus primarily on teaching reading, writing, speaking and listening, and language, content area teachers in history/social studies, science and technical subjects are thus expected to provide instruction in reading and writing within their respective discipline. Although the expectation exists that writing be part of secondary science classrooms, many science teachers lack confidence integrating writing instruction into their science curricula (Street & Stang, 2008).

In many disciplines and at any level, low writing instruction efficacy often blocks educators from teaching writing to students confidently and efficiently (Street & Stang, 2008, 2009). To be successful and persistent in a new pedagogy, teachers must judge themselves capable of producing favorable outcomes in their classrooms or courses (Bandura, Barbaranelli, Caprara, & Pastorelli, 1996; Tschannen-Moran & Hoy, 2001). Therefore, integration of writing instruction into science curricula requires that teachers change their role expectations and view of science (Gaskins et al., 1994).

Knowledge of science alone is no longer sufficient; science teachers must also understand reading, writing, and thinking processes (Gaskins et al., 1994).

Regrettably, science teachers often lack experience and development in writing and instituting writing to learn strategies into their classrooms (Holliday, Yore, & Alvermann, 1994). They are often unfamiliar with writing norms within the scientific community and do not feel as well prepared to write (grammatically and mechanically) or teach writing as English teachers (Sullenger, 1990). Thus, many science teachers perceive skill in writing as a student responsibility and writing skill development as the purview of the English department (Sullenger, 1990). These beliefs are not fixed, however. In a study of five secondary school teachers (two science, one social studies, and two ELA), professional development on writing instruction in the content areas increased teacher perception of writing instruction efficacy beliefs while teacher definitions of writing instruction became more complex (Landon-Hays, 2012).

Not all professional development seems to work equally for science teachers as for other disciplines, however. Using the National Writing Project professional development model, Street and Stang (2009) found that most of the twenty in-service teachers representing a variety of disciplines increased their self-confidence as writers, while the five science teachers in the class did not. Akkus, Gunel, and Hand (2007) also noted that despite two days of professional development using the Science Writing Heuristic (SWH), some science teachers had trouble shifting from a traditional method of teaching to using the more student-centered SWH. Thus, a better approach to understanding the relationship between science teachers and writing is within the context of writing in science.

Within the context of science, few studies exist that are focused on efficacy beliefs of science teachers in regards to writing instruction within their classrooms. Holliday and colleagues (1994) reviewed the existing literature on learning science through reading and writing, focusing on then-current breakthroughs, barriers, and promises. In what Holliday and colleagues referred to as a text-driven and fragmented field of research, Sullenger (1990) sought to include the perspectives of teachers on writing in science. Two decades later, many studies that explore science teacher writing instruction efficacy beliefs do so only as the concept intersects with the main focus of the study. Recognizing science learning as process-based rather than content-based, researchers teamed with middle school teachers to build and assess a new science curriculum (Gaskins et al., 1994). Whereas the body of the study focused on student performance after two units of an integrated science and reading/writing program using a performance-based assessment, the researchers also interviewed the two teachers and their two supervisors at the end of the instruction to understand their experiences during development and implementation of the units.

Landon-Hays (2012) sought to identify teachers' perceptions of writing and themselves as writing instructors through ten focus-group interviews with five high school teachers (two science, one social studies, and two ELA). The Landon-Hays study sets precedent for my own research, which differs in a few critical ways, including a broader sample population of middle and high school teachers, a larger sample population through the use of mixed methods, and a finer context focus of science teachers alone.

Given the paucity of research in this area and in the face of new writing standards in the science content area, we first need a baseline understanding of science teacher writing instruction efficacy beliefs to provide the most appropriate and targeted professional development opportunities. Therefore, the goal of this explanatory sequential mixed methods study (Creswell & Plano Clark, 2011) was to investigate science teacher writing instruction efficacy beliefs to create that baseline for implementation of appropriate professional development in science writing instruction for secondary science teachers. This includes understanding the antecedents to high writing instruction efficacy beliefs among science teachers such that these factors can be included in professional development plans. Thus, I asked the following questions: What are science teacher science writing instruction efficacy beliefs? What characterizes individuals with high science writing instruction efficacy beliefs?

Theoretical Framework

The theoretical framework for this study is based primarily on self-efficacy, which is defined as the personal belief in one's ability to negotiate a stressful task. Unlike a general sense of self-confidence or self-esteem, self-efficacy depends on context and is affected by four factors (antecedents): perception of mastery (personal) experiences, vicarious experiences, verbal persuasion, and physiological state. These four factors are antecedents of efficacy beliefs and will often be referred to by the term *antecedents* throughout the remainder of this paper. Among these antecedents to efficacy beliefs, mastery experiences are the most powerful. Additionally, watching peer models (vicarious experience) allows an observer to visualize personal success and receiving encouragement or praise (verbal persuasion) from a respected person to undertake or continue in a task can also increase self-efficacy. Beyond these social factors, an individual's physiological state can also influence self-efficacy, depending upon how it is interpreted by the individual (Bandura, 1977).

It is important to note that these antecedents are merely a source of information. None directly affect self-efficacy beliefs; rather, it is the perception and cognitive processing of each that influences efficacy expectations (Bandura, 1977). Processing also includes situational and environmental factors of individual experiences. Thus, efficacy beliefs can be generalized to other circumstances, but usually only if the context is similar and lasting change in efficacy belief is a result of experience in a variety of contexts over an extended period of time (Bandura, 1977). In addition, within a particular context, the magnitude, generality, and strength of efficacy expectations predict engagement, effort, and perseverance towards a task (Bandura, 1977; Bandura et al., 1996).

Extending Bandura's model, Tschannen-Moran and colleagues explained situational differences as part of a cyclical model of teacher efficacy (Tschannen-Moran, Hoy, & Hoy, 1998). Whereas the cyclical model of teacher efficacy begins with consideration and interpretation of sources of efficacy information, Tschannen-Moran and colleagues posited that this interpretation alone does not lead to teacher efficacy belief. Rather, teachers also analyze the requirements and context of the task at hand. Among other things, this includes student factors, resources, administration relationships, and school culture (Tschannen-Moran et al., 1998). Further, Tschannen-Moran and colleagues separated current perception of teaching (an efficacy antecedent) from teaching efficacy, which is defined as the perception of future functioning.

Self-efficacy is such a powerful variable that it can and will affect academic performance (Bandura et al., 1996). Students need help cultivating efficacy beliefs in metacognition, self-regulation, and writing literacy. Promoting these tools help students apply skills and information from one context to another, persevere in learning, and experience mastery in academic settings (Bandura et al., 1996). Hence, students require teachers with a strong sense of self-efficacy, as these teachers are more likely to create environments that support student learning.

Explanatory Sequential Mixed Methods

This study employed an explanatory sequential mixed methods design (Creswell & Plano Clark, 2011), which was comprised of a two-phase project. Quantitative data were collected and analyzed in the first phase. The results of the quantitative phase then guided the development of the second, qualitative phase, which also included data collection and analysis. The overall intent of this design was to have the qualitative data provide more depth and more insight of the quantitative data. Thus, a benefit of this design is combining the strengths of quantitative and qualitative analyses to investigate the research questions (Creswell & Plano Clark, 2011).

Context and Participants

The present study sought to investigate science teacher writing instruction efficacy beliefs to create a baseline for implementation of appropriate professional development in science writing instruction for secondary science teachers in Oklahoma. For academic year 2014-2015, there were 521 public school districts across 77 counties in Oklahoma with enrollments ranging from less than 250 to over 25,000 students (Office of Educational Quality and Accountability, 2014). Of these districts, 420 were classified as rural (U.S. Department of Education, National Center for Education Statistics, 2004). In 2012-2013, 61.9% of students qualified for Free or Reduced Lunch (Office of Educational Quality and Accountability, 2014). Teachers in Oklahoma are primarily white (85.5%) females (78%) with average teaching experience of 12.5 years (Office of Educational Quality and Accountability, 2014; U.S. Department of Education, National Center for Education Statistics, 2012).

Nearly 1,500 middle and high school science teachers from across the state of Oklahoma representing 495 urban, suburban, and rural public school districts were invited to participate in this study. Email addresses were obtained from school websites that publicly listed teacher contact information. An initial mass email inviting participation in an online survey was sent to these email addresses using Qualtrics. Two weeks later, those who had not yet begun or completed the survey were sent a reminder email. Out of this population, 71 teachers volunteered to participate in the study, but only 46 teachers provided complete responses and were considered participants in this study.

The schools represented by these teachers included 28% with student populations under 350 and 74% with student populations over 350. One teacher taught online and another currently teaches adults in addition to secondary students. The majority of respondents were long-term teachers. Thirty-six percent have taught for over twenty years, 20% eleven to twenty years, 10% six to ten years, 13% one to five years, and 6% less than one year. Out of the 46 teachers, 65% teach or have taught high school and 61% teach or have taught middle school. Additionally, 24% have also taught intermediate grades, 11% have taught primary grades, and 13% have taught adult populations.

Phase One Instruments

Modified TSES

Whereas the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs & Enochs, 1990) is commonly used to measure science teaching efficacy beliefs, the Teacher's Sense of Efficacy Scale (TSES; Tschannen-Moran & Hoy, 2001) uses language recommended by Bandura (2006). The TSES was designed to better understand the kinds of things that create difficulties for teachers in their school activities. The instrument consists of 24 items and uses a 9-point Likert scale that measures "How much can you do" from *Nothing* to *A Great Deal*. The possible range of scores on the TSES is 1(*Nothing*) to 9 (*A Great Deal*) as it is scored using unweighted means rather than cumulative scores. The TSES includes measures of teaching efficacy beliefs in three areas: Student Engagement (SE; item 1, 2, 4, 6, 9, 12, 14, 22), Instructional Strategies (SI; item 7, 10, 11, 17, 18, 20, 23, 24) and Classroom Management (CM; item 3, 5, 8, 13, 15, 16, 19, 21), (Tschannen-Moran & Hoy, 2001). The TSES has been found to be consistently reliable ($\alpha = .87$) (Tschannen-Moran & Hoy, 2001).

When modifying the TSES for this study, the number of items, response scale, and scoring procedure were maintained. To make the measure applicable for this study, each questions began with the phrase "When teaching science writing" to direct respondents toward the appropriate context. Despite the modification, items separated largely onto the same factors found by Tschannen-Moran and Hoy (2001). Reliability was determined for the total modified TSES (α = .94) and for each subscale: SE (α = .85), IS (α = .86), and CM (α = .93).

Teacher Survey

A 19-item survey was developed and administered to the 46 secondary school science teachers (see Appendix A). The survey included closed-ended questions related to demographic information (item 1, 2, 3, 14), as well as writing experiences (item 4, 6, 7, 8) and teaching experiences (item 5, 9, 10, 11, 12, 14, 15). It also included two sets of two open-ended statements, “I believe/doubt I am a good teacher of science writing because…” and “I can/cannot teach science writing because….” Responses to the last four statements were later analyzed qualitatively.

Modified WSPS

The Writer’s Self-Perception Survey (WSPS; Bottomley, Henk, & Melnick, 1997) consists of 38 items and uses a 5-point Likert scale from *Strongly Disagree* (rating of 1) to *Strongly Agree* (rating of 5), such that the possible range of scores on the WSPS is 38 to 190. Originally designed to estimate how children feel about themselves as writers, the WSPS includes measures of General Performance (GPR; item 3, 6, 12, 14, 17, 18, 19, 20), Specific Performance (SPR; item 22, 25, 29, 31, 34, 36, 38), Observational Comparison (OC; item 1, 4, 8, 11, 16, 21, 23, 26, 30), Social Feedback (SF; item 5, 9, 10, 13, 28, 33, 27), and Physiological States (PS; item 2, 7, 24, 27, 32, 25) and No Subscale (NS = item 15) (Bottomley et al., 1997). Reliability measures for the original WSPS are above .87 for each of the five scales and factor loadings for each item was .40 or greater (Bottomley et al., 1997). Correlations among the scales ranged from .51 to .76 (Bottomley et al., 1997).

When modifying the WSPS for this study, the number of items, response scale, and scoring procedure were maintained (see Appendix B). To make the measure applicable for teachers, observational comparisons referred to "other teachers" vs. "other kids" and "people in my life" vs. "people in my family." Finally, references to "my teacher" were replaced with "those who supervise or evaluate me." For this study, reliability was determined for the total modified WSPS ($\alpha = .97$) and for each subscale: GPR ($\alpha = .96$), SPR ($\alpha = .89$), SF ($\alpha = .92$), OC ($\alpha = .92$) and PS ($\alpha = .94$). Factor loadings for each item were above 0.40, although not all of the items separated to the same factors as the original WSPS. In particular, the GPR items and SPR items did not separate for adults in this study as they did for children in a previous study (Bottomley et al., 1997).

Phase One Data Collection

Modified TSES

To begin scoring the TSES, a response of *Strongly Disagree* was assigned a value of 1 and a response of *Strongly Agree* was assigned a value of 5. Unweighted means of the items that loaded on each of the three factors: Efficacy in Student Engagement (SE), Efficacy in Instructional Strategies (IS), and Efficacy in Classroom Management (CM) were then calculated (see Table 1).

Table 1

Modified TSES Scores

Measure	*i*	*M*	*SD*	Median	Range
TSES	24	6.9	0.85	7.0	5.0-8.6
SE	8	6.2	0.96	6.3	4.3-8.3
IS	8	7.2	0.94	7.3	5.0-9.0
CM	8	7.2	1.14	7.3	5.0-9.0

Note. TSES = Teacher's Sense of Efficacy Scale; SE = Student Engagement; IP = Instructional Strategies; CM = Classroom Management. *i* = number of items for that particular measure. Scores represent the unweighted mean for each measure.

Teacher Survey

Demographic questions on the teacher survey were coded according to the American College Personnel Association's (ACPA) guidelines (Moody, Obear, Gasser, Cheah, & Fechter, 2013). For this particular population, gender preferences were coded as male (n = 15), female (n = 29), or no response (n = 2). All teachers reported English as their primary language and few (n = 3) reported proficiency in a language other than English. Also, given the small number of individuals with a doctoral degree (n = 1), teachers were identified as either having (n = 19) or not having (n = 27) a graduate degree.

Teacher responses to college writing courses varied and were quantified as a sum of the number of writing courses reported, ranging from 0 – 3 courses. Of the 46 teachers, 19 did not respond or reported not taking writing courses in college, 7 took one writing course, 15 took two writing courses, and 5 reported taking three writing courses. Few teachers reported having published any work (n = 11). Therefore, questions on the number of publications by type [research (n = 8), pedagogy (n = 4) and books (n = 1)] were each condensed first into binary variables and ultimately into a single binary variable for use in analysis.

The schools represented by these teachers were public schools with student populations under 350 (n = 13) or with student populations over 350 (n = 34), with one teacher who reported teaching at both sizes of institutions. One teacher also taught online and another taught adults in addition to secondary students. The majority of respondents were long-term teachers. Nineteen taught for over twenty years, 12 eleven to twenty years, 6 six to ten years, 6 one to five years, and 3 less than one year. Most teach or have taught high school (n = 32) and/or middle school (n = 33) and some have taught elementary (n = 11) and adult populations (n = 3).

Of these science teachers, most teach a science class that includes writing (n = 34), but few reported teaching classes with a significant writing component (n = 9), that are writing intensive by design (n = 1), or that teach writing for the subject (n = 4). A few science teachers also reported teaching another type of course (n = 6). Regarding professional development in teaching writing, 21 teachers reported having participated in some type of professional development and most (n = 30) reported belonging to at least one professional organization. As the question for professional organization membership was open-ended, responses were quantified by summing the number of local, regional, and national/international teaching organizations listed by each teacher. Membership ranged from 0 – 5 organizations, with most teachers with a professional organization membership belonging to one (n = 11) organization. Nine teachers reported belonging to two organizations, 8 reported belonging to three organizations, and 2 reported belonging to five organizations. Finally, teachers were also asked to report other significant experiences with regards to teaching writing, to which only 13 teachers responded with additional and specific information generally covered by other questions.

Modified WSPS

To score the WSPS, a response of *Strongly Disagree* was assigned a value of 1 and a response of *Strongly Agree* was assigned a value of 5. Since each subscale is associated with a different number of questions, the highest possible score for each is as follows: GPR = 40; SPR = 35; OC = 45; SF = 35; and PS = 30. According to Bottomley and colleagues (1997), average values for each subscale are GPR = 35, SPR = 29, OC = 30, SF = 27, and PS = 22 and low values for each subscale are GPR = 30, SPR= 24, OC = 23, SF = 22, and PS = 16. Table 2 presents the total modified WSPS score, the scores for each of the subscales, and the scores for the single question not linked to a subscale for the 46 teachers in this study.

Table 2

Modified WSPS Scores

Measure	*i*	*M*	*SD*	Median	Range
WSPS	38	140.3	20.9	141.0	81-190
GPR	8	31.0	5.4	32.0	9-40
SPR	7	27.1	3.2	27.5	21-35
OC	9	30.4	6.0	29.0	19-45
SF	7	27.3	4.1	27.0	19-35
PS	6	20.8	5.5	20.5	6-30
NS	1	3.7	0.9	4.0	1-4

Note. WSPS = Writer's Self-Perception Survey; GPR = General Progress; SPR = Specific Progress; OC = Observational Comparison; SF = Social Feedback; PS = Physiological State; NS = No Subscale. *i* = number of items for that particular measure. Scores represent the cumulative score for each measure.

Phase One Data Analysis

The explanatory sequential design began with a quantitative focus in data collection and analysis to provide a generalized picture of science teacher writing instruction efficacy beliefs and a framework for the interview protocol and participant selection. The quantitative data were also used to identify cases for the interview. The primary data source for the quantitative data was the online survey that included the modified TSES, teacher survey, and modified WSPS. Where three or fewer responses were missing from a subscale, I replaced the missing data with the mean score of the available data for that subscale as the WSPS is scored cumulatively and the complete data set was already limited in size. This data replacement affected WSPS data for six teachers and TSES data for four teachers.

Modified TSES

To identify science teacher science writing efficacy beliefs among secondary educators, I analyzed the modified TSES data, dividing teachers into two groups, *high* (n = 26) and *low* (n = 20). *High* was defined as any TSES score above the group mean and *low* as any TSES score below the group mean. Independent *t*-tests were performed to compare the TSES scores of the two teacher groups.

Teacher Survey

Frequency tables were created for each of the items on the teacher survey and variables were condensed to meet the requirements for a reliable Chi-Square analysis. Simple open or multiple response items were quantified into either dichotomous or ratio variables and dichotomous variables were created from multiple choice questions with the exception of *Years Teaching*, which retained three categories: less than 1 to 5 years, 6 – 20 years, and over 20 years of experience. Questions 2 and 3 were not used from the survey because all teachers spoke English and only 3 teachers spoke an additional language, which rendered the Chi-Square test unreliable. Question 9 was also not used as the responses to this question were too varied to quantify for analysis. Thus, for the final analysis, eleven variables were created from the original fifteen questions on the teacher survey (see Table 3). Of these variables, gender and school size were considered demographic and teaching context variables, respectively. Completion of a graduate degree, publication experience, and number of college writing courses were counted as variables related to teachers' *writing histories* (Street & Stang, 2009). With regards to the four antecedents of self-efficacy (Bandura, 1989), years of teaching experience, number of grade bands taught, and the type of writing a teacher reported were considered *personal mastery* experiences (Tschannen-Moran & Hoy, 2007). Finally, participation in professional development and membership in professional organizations likely had aspects of both *vicarious experience* and *verbal persuasion* (Tschannen-Moran et al., 1998).

Table 3

Final Variables for Analysis

Variable used in Analysis	Item
Gender preference (male/female)	1
Teaches at a public school with fewer than 350 students (yes/no)	14
Teaches at a public school with more than 350 students (yes/no)	14
Has at least one publication	6, 7, 8
Completed a graduate degree	13
College writing courses (ratio)	4
Years teaching (less than 1 – 5, 6 – 20, over 20)	10
Type of writing reported for science class (high/low)	15
Grade bands taught (ratio)	11
Participation in writing instruction professional development (yes/no)	5
Professional organization membership (ratio)	12

To begin exploring the antecedents of high efficacy beliefs (Bandura et al., 1996) regarding science writing instruction, Pearson's Chi-Square tests for independence were performed to compare the relation between *high* and *low* modified TSES groups and demographics (gender preference, school size), writing histories (publications, graduate degree), and teaching experience (years teaching, type of writing reported for science class, participation in professional development). Where contingency tables were 2 x 2, Yate's continuity correction was used. Independent *t*-tests were also used to compare the relation between *high* and *low* modified TSES groups and writing histories (number of college writing courses) and teaching experiences (number of grade bands taught, number of professional organization memberships).

Modified WSPS

The modified WSPS scores for these teachers were used primarily as an interval variable during analysis as many argue that teachers' perceptions of themselves and experiences as writers influence their ability to teach students how to write (Lavelle, 2006; Street & Stang, 2008, 2009; Usher & Pajares, 2008). To gain a broad perspective as to how secondary-level science teachers perceive themselves as writers, I did calculate descriptive statistics for the WSPS scores and ran tests of normality, specifically Shapiro-Wilk, and measures of skewness and kurtosis.

To test the assertion that teachers with low perceptions of themselves as writers are blocked from effectively teaching their students to write (Street & Stang, 2009), independent *t*-tests were performed to compare the relation between *high* and *low* TSES groups and WSPS scores.

Phase One Results

Modified TSES

According to science teacher modified TSES scores, participants ranged from having *some influence* (5.0) to *a great deal of influence* (8.6) in their classrooms when thinking of science writing instruction (see Figure 1). On average, teachers had a TSES score of 6.9 $\pm$ 0.85. Participant TSES score distribution was slightly skewed towards higher efficacy values (skewness, -0.3) and peaked (kurtosis, -0.2), but did not significantly differ from normal distribution [Shapiro-Wilk(46) = 0.977, p = .485].

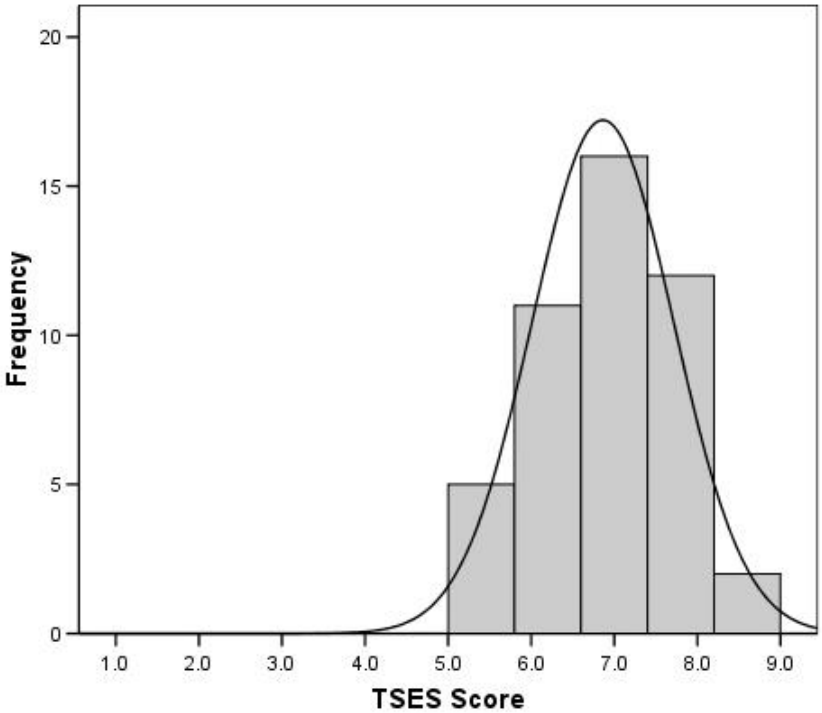

Figure 1. Distribution of TSES scores among participating secondary level science teachers (*M* = 6.9, *SD* = 0.85).

For the subsequent statistical analyses, modified TSES scores were separated into *high* (n = 26) and *low* (n = 20). A comparison between the unweighted mean showed differences in the Total TSES score. Results from an independent *t*-test indicated that teachers who were categorized as having high efficacy (*M* = 7.5, *SD* = 0.45) scored significantly higher on the TSES than teachers who were categorized as having low efficacy (*M* = 6.1, *SD* = 0.55), $t(1) = 9.39$, $p < .001$. This difference was seen for all subscales: SE, (*M* = 6.7, *SD* = 0.76), (*M* = 5.5, *SD* = 0.78), $t(1) = 5.17$, $p < .001$; IS, (*M* = 7.8, *SD* = 0.60), (*M* = 6.4, *SD* = 0.67), $t(1) = 7.49$, $p < .001$; CM, (*M* = 7.9, *SD* = 0.82), (*M* = 6.3, *SD* = 0.81), $t(1) = 6.64$, $p < .001$.

Teacher Survey

When comparing categorical distributions using the Chi-square test, separating TSES scores into *high* (n = 26) and *low* (n = 20) was most reliable. From these results, there was no relationship between demographic variables such as gender or school size and teachers grouped according to modified TSES scores. There were also no significant relationships between variables representing teacher writing histories, personal mastery experience, or vicarious experience/verbal persuasion and teachers grouped according to modified TSES scores. Categorical variables expected to identify sources of personal mastery experiences included, years of teaching experience and type of writing reported for science class. Chi-square tests were unreliable for publication experience and type of writing instruction reported because over 20% of the cells contained less than five counts. Participation in professional development about the teaching of science writing included aspects of both vicarious experience and verbal persuasion antecedents.

Results of independent *t*-tests indicated no significant differences between teachers grouped by *high* and *low* TSES scores and number of writing courses taken in college or membership in professional organizations. However, teachers categorized as having high efficacy had experience teaching across more grade bands (M = 1.92, SD = 0.89) than participants categorized as having low efficacy, (M = 1.45, SD = 0.61), $t(1)$ = 2.038, p = .048.

Modified WSPS

Teacher perceptions of themselves as writers ranged from *low* (81) to *high* (190) with a mean of slightly below *average* (M = 140.3, SD = 20.9) according to WSPS scores (see Figure 2). The WSPS score distribution was slightly skewed toward lower self-perceptions (skewness, 0.010) and flattened (kurtosis, 1.351), likely because of four outliers: one score less than or equal to 81 and three scores greater than or equal to 185. However, the distribution did not significantly differ from normal distribution [Shapiro-Wilk(46) = 0.961, p = 0.123].

Independent t-tests comparing means of WSPS and subscale interval data according to two efficacy levels indicated no significant differences between groups. For this analysis, WSPS scores were considered variables representing a teacher's perception of his or her writing history.

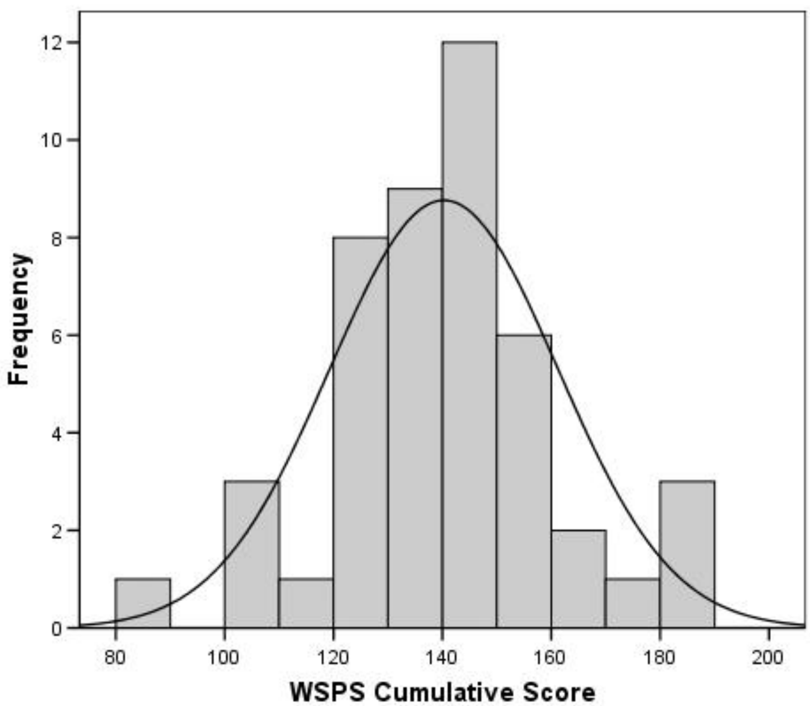

Figure 2. Distribution of WSPS scores among participating secondary level science teachers (M = 140.3, SD = 20.9).

Phase One Planning for Phase Two

Using Rogers Diffusion of Innovation Model (Sandholtz, Ringstaff, & Dwyer, 1997; Schrum & Levin, 2012) as a framework, I identified teachers two standard deviations or higher above the group modified TSES mean as *Innovators* (n = 2), teachers less than two standard deviations but greater than one standard deviation above the TSES mean as *Early Adopters* (n = 3), teachers less than one standard deviation but greater than the TSES mean as *Early Majority* (n = 21), teachers less than the mean but greater than one standard deviation below the TSES mean as *Late Majority* (n = 13), and teachers less than or equal to one standard deviation above the TSES mean as *Late Mass* (n = 7). Whereas Rogers Diffusion of Innovation often describes trends in technology adoption and use, in a general sense *Innovators* and *Early Adopters* engage most readily with new ideas, and have higher efficacy beliefs (Anderson, Varnhagen, & Campbell, 1998). Thus, I purposefully selected these two groups as potential interview candidates.

Phase Two Interview Questions

In a review of literacy integration into the science classroom, Holliday and colleagues (1994) adapted five questions from Rosaen (1989) to investigate teacher attitudes and interactions with writing in the sciences. Additionally, Sullenger (1990) identified seven perceptions that describe teachers' writing practices in science. Borrowing from both of these sources, I pre-identified eight interview questions (see Figure 3), adding probing questions throughout the interview as appropriate.

How do you define science writing?
How do you currently incorporate science writing into your classroom?
How do you evaluate your students' science writing?
What resources do you have for teaching science writing in your classes?
How have you been prepared to teach science writing in your classes?
What barriers do you face when teaching science writing in your class? How do you overcome those barriers?
What aspects of improving your science writing instruction are most interesting to you?

Figure 3. Pre-identified interview questions for teachers with high science writing instruction efficacy belief scores on the TSES. Probing questions were added as appropriate.

Phase Two Data Collection

Teacher Survey

Qualitative data from the online teacher survey consisted of teacher responses to two sets of two open-ended statements: *I believe I am a good teacher of writing because…* (n = 35), *I doubt I am a good teacher of writing because…* (n = 28), *I can teach science writing because…* (n = 39), and *I cannot teach science writing because…* (n = 21). All 46 teachers responded to at least one of the statements; however, not all teachers responded to every statement.

Interviews

Four interview candidates, one teacher identified as an Early Adopter and three teachers identified as Early Majority were selected using a random number generator. Of the teachers having TSES scores above the group mean, neither of the 2 Innovators, only 2 of 3 Early Adopters and 13 of 21 Early Majority teachers had agreed to further contact and provided contact information. Potential interview candidates were contacted at least twice, either by phone, email, or both. Interview candidates who did not volunteer to participate further in the study were replaced with another randomly selected teacher that fit the initial criteria. Interview candidates were emailed the pre-identified questions in advance of the interview to give them time to consider their answers in preparation for the interview. Interviews were conducted over the phone and all teachers interviewed agreed to have their interview audio recorded and transcribed.

Phase Two Data Analysis

Teacher Survey

Teacher responses to the two sets of two open-ended statements were coded as one data set. All teachers responded to at least one of the open-ended statements, but not necessarily all four statements. These statements included the following: *I believe I am a good teacher of writing because…* (n = 35), *I doubt I am a good teacher of writing because…* (n = 28), *I can teach science writing because…* (n = 39), and *I cannot teach science writing because…* (n = 21). I read over responses to the open-ended statements on the survey several times and took notes on common response categories, developing several codes. Once these codes were well established, I condensed them in no particular order into six themes (see Table 4), which were then reviewed by an independent coder. Cohen's kappa was computed for each coder pair and then averaged. Pre-discussion, inter-rater reliability was moderate ($\kappa = 0.54$). After discussing each case and reconciling the differences between teachers as instructors and teachers as writers, coders were able to reach agreement such that inter-rater reliability was excellent ($\kappa = 0.94$).

Table 4

Open-ended Statement Themes

Theme	Description
Value of writing (1)	Writing is part of science Writing is an important skill Teacher understands science writing Teacher mentions or illustrates misunderstanding of science writing
Mastery experience and skill development in teaching science writing (2)	Teacher has experience or practice teaching science writing as evidenced by direct mention of teaching, evaluating, or creation of resources Teacher has experienced professional development in science writing instruction Teacher has not had direct instruction/professional development in science writing instruction
Ethos in science writing (3)	Teacher has prior personal experience with writing or science writing or mentions lack thereof Teacher mentions feelings about writing (enjoys/dislikes) Teacher mentions personal writing proficiency or limitations thereof
Writing part of curriculum (4)	Teacher assigns or uses some kind of writing in his/her class Teacher mentions using writing to learn strategies Teacher feels s/he does not use enough or the right type of writing in class
Time (5)	There is not enough time to teach/assign/evaluate writing as part of the curriculum
Student Response (6)	Students show evidence of progress in writing, or lack thereof Mention of student motivation Students are too distracted to write well (e.g. by technology)

Interviews

With interviewee permission, I audio recorded each interview and then transcribed each recording. Following the data spiral (Creswell, 2007), I listened to and read each interview several times, making notes on each response. As I read each interview, I took notes on each teacher’s responses such that I could identify certain categories or codes that were prevalent. After considering these codes, I condensed them into five main themes, again in no particular order (see Table 5).

Table 5

Interview Themes

Theme	Description
Writing to Learn	Values science writing Treats writing as a process Encourages revision Uses peer review
Evaluation and Feedback	Provides feedback to students Uses set criteria for grading (rubric)
Self-Directed Learner	Draws from past experience (e.g. college) Finds or creates own resources Seeks out additional professional development
Collaborative	Within the science department Cross curricular Vertical and/or horizontal alignment
Barriers	Extrinsic Student motivation or preparation Poverty Cultural Content

Phase Two Results

Teacher Survey

After reading science teacher responses to the four open-ended statements on the online survey, six themes repeated themselves throughout with both positive and negative aspects, depending upon the question. In this case, positive indicates teachers reporting understanding, comfort, or power to act whereas negative connotes a lack of understanding, comfort, or power to act as reported by teachers, not any judgment upon the teachers themselves. These themes included an inherent value in writing as part of science, experience and development in teaching science writing, personal experience and development as a writer, including writing as part of the science curriculum, time barriers to including writing in the science class, and direct or indirect student responses to writing in science (see Table 4).

Many teachers reported *valuing writing* as an important skill for students and as an important part of science. One teacher wrote, “Scientists communicate with other scientists in writing, so it is a critical skill” (0116) whereas another indicated, “I believe that each subject that is taught needs a writing component” (0112). Other teachers did not have a strong definition of science writing, reporting “I have no experience actually teaching others how to write scientifically or actually understand what ‘science writing’ is and how it is different from ‘writing’ in general” (0108).

Teachers with *experience and development in teaching science writing* often reported personal mastery experiences, “I am able to model” (0124) professional development experiences, “I have had several staff development sessions which focused on helping students use writing skills and how to implement writing activities in my classroom” (0103) and access to or development of science writing resources, “I evaluate all student writing with grading rubrics that I develop with assistance from both other teachers and online rubric builders” (0103). Many teachers indicated a lack of specific development in teaching science writing, “I have had no training in it. In university it is not covered. We have one two hour class that covers actually teaching science and that is it” (0104), and few personal mastery experiences, “I have always struggled to scale my expectations with writing” (0110).

With regards to their *personal experience and development as writers*, some teachers identified themselves as proficient and comfortable with writing, “I feel pretty confident in teaching science writing only because I have done it myself so many times and do rather well in it” (0121), whereas others felt their writing experience was inadequate or painful, “I can’t teach writing because I HATE to write myself and I avoid it as much as possible!” (0117).

Teachers who *included writing in their science classrooms* reported doing so in a variety of ways ranging from “I require complete sentences when students answer questions” (0120) to “The students write detailed descriptions in their science journals about what they are learning and how it impacts them in an everyday way” (0139). Many teachers seemed to feel their efforts at including writing were inadequate however, explaining “I don’t make them write enough nor take the time to correct all their mistakes as well as I should” (0129).

Time was reported as a significant barrier to integrating writing. Many teachers mentioned issues similar to, “There is a certain amount of material to be covered for state testing so there isn’t a lot of extra time to have students completing a large number of extensive reports” (0125) or “It takes so long to grade and give proper assistance because I have too many students in my class” (0129).

Regarding *direct or indirect student responses* to science writing, student success was often evidence of personal mastery in science writing instruction as teachers reported believing themselves good teachers of writing because “of the ability my students have gained at writing lab reports by the end of the year” (0113). However, student proficiency in and motivation towards writing were often cited as barriers, making some teachers feel overwhelmed. One teacher reported, “My students struggle with writing in general coming to me, and struggle with writing when they leave” (0102). Another teacher reported,

> My students put in the minimum effort and then try to use their electronic devices. They want to finish quickly and do nothing. Many are not motivated to try to more than what will keep them from failing. Many have not yet learned the patience it takes to do a good job. There are also too many distractions for their attention, and their attention span is short. (0127)

When considering teacher responses to *I believe I am a good teacher of writing…* according to their science writing efficacy score (TSES), a general pattern emerged from the 35 teachers who responded (see Table 6). Innovators and Early Adopters believed themselves to be good teachers of writing because they value writing, have experience teaching science writing, and use writing with their students, giving students specific criteria, e.g. “write using evidence” (0109) or “integrating claims, evidence and reasoning” (0111). Teachers classified as Early Majority generally expressed positive experience as writers, used specific writing assignments in class, e.g. “In my classroom, student are assigned projects as well as lab reports to help them focus and develop their ability to write scientific literature” (0121). Early Majority teachers also acknowledged the importance of teaching writing and provided models of good writing to their students. Late Majority teachers believed themselves to be good teachers of writing because they include specific writing assignments as part of their science curriculum and have personal experience as a writer. Finally, teachers classified as Late Mass typically included writing as part of their science curriculum. Late Mass teachers also reported specific teaching skills, but also indicated a lack of formal training in teaching students how to write.

Table 6

Teacher Responses to I believe I am a Good Teacher of Writing Because… Enumerated by Theme.

		Theme					
RDI Classification	*n*	1	2	3	4	5	6
Innovator	2	2	0	0	1	0	0
Early Adopter	3	1	2	0	3	0	0
Early Majority	15	4	4	7	7	0	1
Late Majority	10	2	1	3	7	0	1
Late Mass	5	1	2	0	4	0	0

Note. RDI = Rogers Diffusion of Innovation.

Fewer teachers (28) responded to *I doubt I am a good teacher of writing because…* (see Table 7). Innovators and Early Adopters generally did not respond to this statement or specifically indicated that they had no doubts. The single innovator that did respond wrote, “I do not have a ton of experience with writing for major publications” (0109). Early Majority teachers generally expressed a desire for additional or lack of professional development in science writing instruction or indicated a feeling of not giving students enough instruction or feedback on grammar, e.g. “I don’t reinforce the mechanics of good writing (syntax, grammar, etc.)” (0123). Teachers classified as Late Majority also indicated a lack of professional development and a feeling of not assigning enough or the *right kind* of writing, e.g. “I don’t have many assignments; they write paragraphs” (0106). Late Majority teachers were also more apt to cite time as a barrier to integrating writing into their science class and some indicated a lack of clarity regarding science writing. Both of these barriers are indicated in the following comment, “There is a certain amount of material to be covered for state testing so there isn’t a lot of extra time to have students completing a large number of extensive reports” (0125). Teacher classified as Late Mass reported a lack of student progress in writing, time constraints within the classroom, and little personal experience as a writer, and feeling that they do not implement enough writing in science class.

Table 7

Teacher Responses to I Doubt I am a Good Teacher of Writing Because… Enumerated by Theme.

		Theme					
RDI Classification	*n*	1	2	3	4	5	6
Innovator	1	0	0	1	0	0	0
Early Adopter	1	0	0	0	0	0	0
Early Majority	14	1	6	1	6	2	3
Late Majority	8	3	3	1	3	2	0
Late Mass	4	0	0	1	1	1	1

Note. RDI = Rogers Diffusion of Innovation.

Thirty-nine teachers completed the statement *I can teach science writing because…* (see Table 8). Of these, Innovators and Early Adopters indicated they could teach science writing because of their experience as science writers and their experience and ability as a teacher of science writing. These teachers also indicated that their students have the ability and expectation to write in science. Early Majority teachers also indicated experience as science writers. Although many felt that they lack experience and training as teachers of science writing, they were overwhelmingly positive in their ability to develop this skill and integrate writing in their science classrooms. One teacher reported, "…it is a subject, like any other, and in time, with proper preparation and planning, I can handle almost any subject" (0110). Another teacher wrote, "I can find ways to show how writing in the discipline of science is necessary and valuable" (0122). Many Early Majority teachers also indicated that they already incorporate writing in their science class and that they view writing as important to student learning, e.g. "Science writing helps lay out a logical sequence of thought…" (0128). Late Majority teachers also indicated the value of writing as a learning tool and expressed specific ways they can teach science writing, e.g. "I can help those who are having difficulties getting started" (0136) and "I… have numerous examples to show what is good writing and what is poor writing" (0142). Late Majority teachers also focused on student enjoyment of activities and the relationship between enjoyment and writing. One teacher wrote, "I also feel that if the students enjoy the activity they are doing then they will feel good about writing about it" (0136). Another mentioned, "They enjoy sharing their thoughts and ideas verbally in class, so why not document those thoughts, ideas and experiences in written form for them to read years later?" (0118). Finally, Late Mass teachers indicated the value of writing as a communicative tool, willingness to implement writing in their science class, some experience as a writer, and use of writing activities in their science class. One teacher also noted a potential resource that might improve student motivation and perseverance in writing,

> I feel comfortable with the written word. I know that good writing is a process. The finished product has been altered along the way. You do not just turn in the first thoughts that enter your brain. This is why I like writing on a computer. I can alter my words to better capture my thoughts without the frustration of having to write the sentences over and over. I think that my students would also be less apt to just "turn it in" if they were able to compose on a computer.

Table 8

Teacher Responses to I Can Teach Science Writing Because… Enumerated by Theme.

		Theme					
RDI Classification	*n*	1	2	3	4	5	6
Innovator	2	0	1	2	0	0	0
Early Adopter	3	1	2	1	1	0	2
Early Majority	18	6	7	9	5	0	2
Late Majority	11	5	6	2	3	0	3
Late Mass	5	2	2	2	2	0	1

Note. RDI = Rogers Diffusion of Innovation.

Finally, only 21 teachers completed the statement *I cannot teach science writing because…* (see Table 9). Of these, only one innovator gave a response, again focused on a lack personal experience with science writing. Early Majority teachers generally indicated a desire for additional development in science writing instruction and a lack of time to teach, grade, or include science writing assignments in their class. One teacher mentioned, “Sometimes it takes a lot of valuable class time to get students to write for a specific purpose” (0123) and another indicated, “I can’t teach writing as much as I would like due to the time demands of required objectives” (0119). Late Majority teachers focused primarily on their perceived shortcomings as writers, noting “I am not a good writer myself” (0106) and “I cannot spell very well” (0140). Finally, teachers classified as Late Mass reported limited personal experience in science writing and barriers of student motivation and time.

Table 9

Teacher Responses to I Cannot Teach Science Writing Because… Enumerated by Theme

		Theme					
RDI Classification	*n*	1	2	3	4	5	6
Innovator	1	0	0	1	0	0	0
Early Adopter	0	0	0	0	0	0	0
Early Majority	12	0	5	2	0	4	0
Late Majority	5	0	1	2	1	1	0
Late Mass	3	0	0	1	0	1	1

Note. RDI = Rogers Diffusion of Innovation.

High Efficacy Case Studies

Sarah was a middle school science and English Language Arts teacher identified as an Early Adopter according to her TSES score (*TSES* = 8.1). According to the WSPS, Sarah's perception of herself as a writer was slightly above average (*WSPS* = 157). She has taught science for over twenty years at a small K-8 school in a rural, high poverty district. At the time of the interview, she taught 7^{th} and 8^{th} grade, although she has taught elementary students in the past. Ten years ago, she returned to school for a master's degree in English, in addition to her double major in science, and when interviewed, taught writing and reading along with her science classes. Sarah's class sizes were relatively small – she had less than 25 students – and she taught the same groups of students for three hours a day, divided equally among science, reading, and writing. Because she had this three-hour block with her students, Sarah reported having the freedom to incorporate research-reading-writing assignments focused on science as long as she meets state learning objectives.

Seth also taught middle school science to 7^{th} and 8^{th} graders at a school located in a suburb near a larger city. According to his TSES score (*TSES* = 7.6), Seth was identified as an Early Majority teacher. Seth's WSPS score (*WSPS* = 136) placed his perception of himself as a writer slightly below average. At the time of the interview, Seth had been teaching for ten years and was alternatively certified, having a bachelor's degree in zoology and herpetology coming from a career in zoology, which included international experience and research publications from his work in zoos. At the time of the interview, Seth taught life science, including pre-AP life science, and an environmental science elective that incorporated service learning. As part of his pre-AP responsibilities, Seth attended professional development every other year, which included embedded literacy within science courses. He was also a member of several regional and national professional teaching organizations. Seth typically taught 160 – 180 students per year with a strong focus on interactive science notebooks. Many of Seth's classes were inclusion classrooms such that he reported a wide range of student abilities within any given class. He also noted that there are high rates of student transfer at his school and that many of his students come from low socioeconomic families and may be first-generation college students.

At the time of the interview, Carl taught 6^{th} – 8^{th} grade science, although he has also taught elementary, high school, and post-secondary students. According to his TSES score, Carl was identified as Early Majority (*TSES* = 7.5) and was among those who had a high perception of themselves as writers (*WSPS* = 185). Carl had a bachelor's degree in science education but returned to school for a master's in biology, and a doctorate in science education. Given his post-graduate degrees, Carl had several publications in research and pedagogical journals. At the time of the interview, Carl was the only middle school science teacher at a small dependent district PreK-8 school. In this environment, Carl reported feeling fairly isolated. To combat this, he continued to seek learning opportunities both formal and informal and maintained membership in several regional and national professional teaching organizations. In his classes, Carl implemented science notebooks and emphasized using these notebooks to create lab reports. Carl also asked his students to present material digitally in creative ways as his school went paperless and had one-to-one laptops for grades 5 and above.

Jessica, a high school teacher, was identified as an Early Majority teacher (*TSES* = 6.9) and according to her WSPS score (*WSPS* = 133) had a perception of herself as a writer slightly below average. Jessica was a first-year teacher with little professional development in the realm of science writing instruction, even from her bachelor's degree in secondary science education. Most of the classes Jessica taught were part of a freshman program to help academically at-risk students succeed in their classes. These students were taught by a core team of teachers, much like a middle school approach. In addition to these classes, Jessica also taught biology for sophomores, juniors, and seniors. Out of her approximately 130 students, around 100 of them were freshmen. Jessica reported spending approximately two months working specifically on writing science reports with her freshman, in partnership with the core ELA teacher, who proofread each paper as part of the students' report grade. In contrast, Jessica was unable to do much writing instruction with her upper level biology class; her primary goal was to cover course materials prior to state testing, per her administration's instructions, and add a research paper assignment towards the end of the class if she had time.

Common among all four teachers were *writing to learn strategies*. Carl and Seth both use open-format science notebooks in their classes. For Seth, the notebook was also a way to teach his students about the nature of science and implement their own creativity to their projects.

> I show them at the beginning of the year what scientists did. I showed them about Charles Darwin and his notebook, what he did on the *Beagle* and Marie Curie's notebooks that are still radioactive, and that's kind of mind-blowing to them. I said, "Everything you can think of, all of your thoughts… don't be afraid to put it down because you just have to get that out. Even if it's not a complete thought, just write it down." And we do drawings… or find a picture and glue it in there…. [The] notebook is a kind of timeline of our year…. There are also some examples that the kids find on Pinterest or they will share with others and they're creating slit pages or making their notebook more of a reflection of like a scrapbook of what they're doing.

When writing formal lab reports, Seth and Carl both have their students reference their notebooks to provide evidence for the claims that they make. For Carl, notebooks and reports are very process-driven, following the structure of scientific investigation. Likewise, Sarah is very process-driven with her students, with one assignment building on and contributing to another. To explain the kind of writing she asks her students to do, Sarah described a project she had previously done with her 3rd grade students.

> So, we watched the Ken Burns documentary on bridges… that was informative. Then from that, we built the balsa wood bridges. They had to write a formal proposal for it; they had to do a technical writing report basically. They had to write the proposal, they had to do cost, they had to put the scientific method into it, like what was their hypothesis, and they had to put research into it, like what they learned about bridges…. Then they did the experiment to see how much weight the bridge would hold… Then they had to write a conclusion, so they basically wrote a report over their experiment. And at the same time, they were doing reading because they did research on it. And they were doing science

> because they did a project using engineering, math, and the other parts of science. That's basically kind of how I do things.

Similarly, Jessica helped her students to build their reports through a step-by-step process that breaks down each stage of the writing process. For her process, Jessica described beginning with a list of questions to help guide her students through the research process. From these notes, the students write their initial report, have it proofread by their English teacher, and then go back to the computer lab to revise their paper before turning in their final product.

When *evaluating student writing*, all four teachers also used a rubric. Carl and Sarah looked primarily toward state learning standards to develop their rubrics. Sarah even found a checklist for informational writing on the state department's website that included both content and writing components. Jessica's criteria focused on specific criteria including addressing the topic, including research citations, writing in third person tense, and writing concisely, "without a lot of frill" (Jessica). Seth uses rubrics to assess work, but primarily discussed having students self-assess through reflection. He also used peer-review, including having partners read each other's writing out loud so that students can hear what they wrote "and when they read it out loud…it either makes sense or it doesn't… they can realize, 'Oh geez, that doesn't make any sense'" (Seth). Seth also chooses several notebooks daily to give feedback to students by making notes and asking questions to help guide their writing.

Among these teachers, Sarah, Carl, and Seth were extremely *self-directed learners*. During our interview, Carl mentioned considering finding materials from and attending a seminar given by "one of the foremost authorities for teaching teachers how to help their students notebook effectively in the science class" (Carl). He also talked about his education, saying, “It wasn’t always just about sticking more letters onto the end of my name, it was… modeling the lifelong learner and trying to stay current” (Carl). Sarah also described her love for learning and how she applies it to her classroom.

> I love to learn new things.... I like to analyze and I’ll look at things and find out where there’s like a hole in something and I’ll work to plug that hole. I’m very goal oriented… I don’t like to stop until I meet the goal and if there’s something that my kids need or something that I think they need to learn, I will do what it takes to find what they need to learn. (Sarah)

During our conversation, Seth detailed a life of goal setting and experience in science and research, which he brought into the classroom. The day of our interview however, he had just received ten Chromebooks from a grant and was considering how to use them in his classroom.

> Does that mean that the science notebooks now can go digital? …the kids are going to choose what format, what works for them and I think I’m just going to have to adapt and roll with it and see what happens. But, it’s taking it to that next level… It’s a challenge and it’s a big responsibility, so I’m a little scared, but hey – that’s okay, anxiety is good because stressful modes can produce some really good stuff. (Seth)

Jessica also showed evidence of self-directed learning explaining that she had to find her own resources for teaching science writing, but as this was her first year teaching, she faced a number of challenges. “I felt like beginning of this year I was kind of thrown into, ‘okay, here’s the classroom, here’s some kids, biology, here’s some groups for environmental, teach whatever, make sure they don’t kill each other’” (Jessica).

Not only were the high efficacy teachers self-directed, most also *collaborated* with their colleagues. At Seth’s school, among the science teachers, expectations for the lab report were vertically aligned, “we all created a 6th, 7th, 8th grade lab report” (Seth). There was also cross-curricular collaboration, especially with Seth’s service learning class. While his students were doing research and collecting data on recycling, another teacher decided to engage his students in a simulated protest to illustrate a historical concept. “We started a little war… we had the recyclists and the anti-recyclists... Then we started sending little letters back and forth… and the kids were heavily engaged in writing” (Seth). Likewise, Sarah described a consistent and collaborative group of teachers at her school.

> So I work in an environment where like, the social studies teacher expects them to write well and the science kids are expected to write well. It’s not just in their writing class where they’re expected to write well…. We all kind of work together and come up with new ideas and this is a really cool place to work. (Sarah)

Within her freshman program, Jessica experienced collaboration that benefited both her students and her teaching. Working with the English teacher

> really shows [the students] that what they’re learning in one class can apply to another one and…I think it helps them to see the fact that there is continuity in their teachers….Talking to each other…helps us in general. If I’m talking to the English teacher and say, “Okay, who really struggles with writing? Who do I need to help through this process?” I think that makes a big difference and can really help. (Jessica)

Not all of the teachers were in collaborative environments however. Among the science teachers, Jessica indicated a lack of integration and collaboration, as did Carl in regards to his school. In his case, being at a small school had an isolating effect. “I feel like I’m teaching in a vacuum in that there’s not a lot of vertical and horizontal integration and collaboration and so forth...” (Carl).

Regardless of their personal success and positive environment, each teacher faced common *barriers* to teaching science writing. Carl and Jessica both talked about lack of student preparation. To overcome these barriers, Carl used the revision process and asked students to verbalize their thoughts because, “if they can verbalize it then maybe then that will help them translate it into written form" (Carl). For Jessica, one of the biggest barriers was teaching students to cite research and understand plagiarism. "They're not exposed to that and so I introduce it and they freak out and automatically start saying, 'I can't do this. I can't do this. This is too hard, I can't do this'" (Jessica). In this case, Jessica broke each project down and helped her students through each step to ease them into a new way of writing. For Seth, one of the biggest problems he faced was discipline, likely because students "would rather cut up and get in trouble than just show that [they] don't know how to do something" (Seth). In these instances, Seth works toward building trust and relationships with students, and that "a lot of times they just need an advocate. They just need to have someone that says, 'You know, I remember middle school. It sucked, it was horrible, but you know what? It's also kind of fun" (Seth). Specific to her classroom, Sarah felt that she did not face barriers because of the time and freedom she had with her students. On a school-wide level however, she mentioned that a district-wide concern is poverty and neglect such that "getting them to have value in themselves… that is probably more of a challenge than the science aspect of it, just having them learn what they need to learn within themselves and bring it out" (Sarah). Faced with this type of challenge, she banded together with her colleagues and made sure to give students opportunity to learn from mistakes.

> We don't give up on kids. When they do something writing for me, I'll tell them when they make a mistake and they can go back and fix it… Because it's important to show them the mistakes that they make, tell them the things that they did do well, but show them the mistakes that they made and they can go back and fix it. The worst thing I think that you can do as someone that teaches something in writing, is to not show them what, not let them go back and fix their mistakes… I think that's one of the biggest challenges is to get them to realize that, hey – you need to go back and fix this. You need to learn. (Sarah)

Discussion

The goal of this study was exploration of secondary science teacher science writing instruction efficacy beliefs to provide a framework for future professional development, given the need for secondary science teachers to provide writing instruction within their area of study. Identifying antecedents to high science writing instruction efficacy beliefs and testing the theory that low self-perception as a writer blocks teachers from successfully implementing writing instruction will aid in creating effective professional development opportunities. To this end, I asked: What are science teacher science writing instruction efficacy beliefs? and What characterizes individuals with high science writing instruction efficacy beliefs?

Phase One

Modified TSES.

In seeking science teacher science writing instruction efficacy beliefs, I found that those science teachers that responded to the online teacher survey encompassed a range of mid- to high-range beliefs. Since the survey was not compulsory, it is possible that only teachers interested in or already using writing in their science classrooms responded. However, the scores on the modified TSES and its subscales are not dissimilar from those reported by Tschannen-Moran and Hoy (2001, 2007) during their construction of the original instrument or subsequent uses of the instrument in their studies.

Teacher Survey.

Compared to the general population of teachers in Oklahoma (Office of Educational Quality and Accountability, 2014), larger schools were overrepresented in this study, as were teachers having advanced degrees. The majority of districts (81%) in Oklahoma are rural, with district populations of 2,000 students or less (divided among elementary, middle, and high school). However, when gathering email addresses from school and district web sites, small rural districts were less likely to have email addresses available and typically had only one or two science teachers at a school, unlike large districts that had several science teachers per grade level.

When examining the quantitative data for differences between science teachers with high and low science writing instruction efficacy beliefs, demographic, contextual, personal mastery, vicarious experience, and verbal persuasion variables from the teacher survey were not related to high science writing instruction efficacy beliefs, with the exception of number of grade bands taught. In this case, science teachers with high science writing instruction efficacy beliefs had generally taught across more grade bands than those with low efficacy beliefs, potentially because of a personal mastery experiences across a wider range of contexts. Teaching students how to write scientifically in elementary school, middle school, high school and college requires different instructional methods that would increase a teacher's range of instructional strategies with a variety of learners. Elementary teachers, who already teach across several domains, use academic, personal, child-oriented, and practical criteria when gauging integration of literacy and science (Baker & Saul, 1994). The Science Writing Heuristic (SWH), designed for use with secondary level students, focuses on eight stages that prepare students for the laboratory activity, guide them through the laboratory, and ultimately, make evidence-supported claims from their data (i.e., write an argument) (Keys, Hand, Prain, & Collins, 1999). Finally, at the post-secondary level, writing is marked by the process and purpose of writing (e.g. claims and evidence, logical structure, citation) (Brammer, Amare, & Campbell, 2008).

Modified WSPS.

The range of teachers' perceptions of themselves as writers on the WSPS were distributed similarly to what Street and Stang (2009) found via qualitative analysis. However, whereas they and others argue that previous writing experience and lack of confidence in writing often blocks educators in any discipline from teaching writing to students confidently and efficiently (Lavelle, 2006; Street & Stang, 2008, 2009; Usher & Pajares, 2008), teachers with high science writing instruction efficacy beliefs did not have significantly higher perceptions of themselves as writers (WSPS) than teachers with low science writing instruction efficacy beliefs. Neither did teachers with high science writing instruction efficacy beliefs have more publication experience or graduate-level experience than teachers with low science writing efficacy beliefs, other potential indicators of writing history from the teacher survey.

Phase One Planning for Phase Two

As context is crucial to self-efficacy beliefs (Bandura et al., 1996; Tschannen-Moran & Hoy, 2001), it is not surprising that demographic and contextual variables from the online survey were unable to capture those elements most common to science teachers with high science writing instruction efficacy beliefs. Additionally, it is not the mastery experiences, vicarious experiences, verbal persuasions, and physiological states themselves that influence efficacy beliefs, but an individual's interpretation of those antecedents (Bandura, 1989), underscoring the importance of also collecting qualitative data to provide a richer picture of individual efficacy beliefs. For instance, both Carl and Sarah taught at small, rural schools. In Sarah's case, she viewed her colleagues as a network of support and ideas, whereas Carl felt relatively isolated. Thus, the quantitative data were valuable in identifying cases of high science writing efficacy belief that merited in-depth exploration.

Phase Two

Teacher Survey.

As predicted by Bandura (1989; 1996), teachers with high science writing instruction efficacy beliefs largely reported personal *mastery experiences* with science writing. Innovators, Early Adopters, and Early Majority teachers cited experience as a teacher of science writing, described specific writing assignments, and mentioned positive personal experience as a writer. Those who described specific assignments and criteria potentially indicate established writing integration, rather than beginning writing integration, as changing curriculum can temporarily lower efficacy (Tschannen-Moran et al., 1998).

Teachers indicated little opportunity to gain *vicarious experience* in science writing instruction as many teachers mentioned lack of professional development both as pre-service and in-service teachers. Thus, little may have changed since Holliday and colleagues (1994) suggested more attention be paid to writing to learn strategies within science teacher preparation programs and professional development opportunities. Indeed, the National Writing Project (NWP), one of the largest and longest-running professional development programs in writing instruction addressed the needs of teachers in the classroom by developing a peer-to-peer professional development system (Gray, 2000).

Verbal persuasion mentioned by teachers was nonexistent but perhaps subtly present in their discussions of time as a barrier. Many teachers felt the need to cover content based on state testing and comments by their administrations. Rather than a positive form of persuasion, this feedback was largely negative. Tschannen-Moran and Hoy (1998) found that teacher efficacy increased with principals who provided resources and autonomy and in school cultures with abundant opportunities for collaboration. Within the open-response items, teachers rarely mentioned working with colleagues, suggesting that most feel relatively isolated within their classrooms, consistent with later findings of Tschannen-Moran and Hoy (2007).

Few teachers discussed their *physiological state* in regards to teaching, but many teachers did mention the value of science writing, similar to Sullenger's (1990) findings. Perhaps the most striking commonality among high science writing efficacy teachers however, was an apparent internal locus of control rather than a focus on barriers to implementation of writing within the science classroom. For Landon-Hays (2012), teachers developed an internal locus of control as efficacy increased. Prior to increased efficacy, teachers in Landon-Hays's population focused more on external barriers. The same was true in my study; lower efficacy teachers were more apt to cite challenges of student preparation, progress, and motivation than those with high science writing efficacy beliefs. Instead, high efficacy teachers focused primarily on their desire for additional professional development in the area of science writing instruction, indicating a desire to continue learning.

Interviews.

Sarah, Carl, and Seth were each career teachers who described a wealth of *mastery experiences*. Each provided examples of well-established science writing curriculum, indicating a stable curriculum connected to high efficacy beliefs (Gaskins et al., 1994; Tschannen-Moran et al., 1998). Carl and Seth also had history as professional writers via research publications. Whereas they did not necessarily draw upon this experience to teach writing to their students, they did use these experiences to provide evidence for the value of science writing. Sarah also made use of her writing history, drawing upon her experiences writing in college science courses and relying on her English degree to inform her instructional practices across the curriculum. Thus, unlike the science teachers Sullenger (1990) interviewed, Carl, Seth, and Sarah were familiar with disciplinary genres and felt prepared to write and teach writing to their students. Being a new teacher, Jessica mentioned a specific lack of personal mastery not only as her science writing resources are in their infancy, but also because she did not have much experience or instruction with science writing or teaching science writing during her bachelor's program.

Consistent with Tschannen-Moran and Hoy's (2007) findings, Jessica perhaps depended more on *verbal persuasion* particularly from her English Language Arts colleague. Schriver and Czerniak (1999) note that middle school science teachers have higher science teaching efficacy beliefs than their junior high counterparts, perhaps because of the support provided by team-based teaching in middle schools. This was also likely true for Jessica, given the team-based teaching approach to her freshmen courses, something she did not experience as part of her biology class. As novice teachers are still building a repertoire of teaching experience, this social aspect of efficacy can have a stronger impact on novice teacher efficacy beliefs than career teacher efficacy beliefs (Tschannen-Moran & Hoy, 2007). Thus, despite the lack of verbal persuasion in Carl's teaching context, he maintained a high level of science writing instruction efficacy belief because of his extensive classroom experience. For Sarah and Seth, the collaborative atmospheres of their schools point to high collective efficacy (Goddard, Hoy, & Hoy, 2000), which can help create a positive feedback loop among teachers and students. Not only does high collective efficacy maintain the efficacy beliefs of these two groups, but it can also mitigate impacts of low socioeconomic status on the efficacy beliefs of teachers and students within a school (Bandura, 1989; Tschannen-Moran & Hoy, 2001), a barrier that both Sarah and Seth mentioned. Additionally, Seth and Sarah indicated having a sense of instructional autonomy, allowing them to exercise an internal locus of control (Goddard, Hoy, & Hoy, 2004).

The collaborative atmosphere of Seth and Sarah's school environments also likely provided opportunities for *vicarious experience* as they discussed science writing strategies and instruction with their colleagues. Likewise, the workshops and conferences that Seth and Carl attended also provided peer models of science writing instruction that for Carl, were not achieved within his school context. Targeted professional development typically aids in developing student-centered methods (Akkus et al., 2007; Soven, 1988) and educators gain the most from successful implementation of ideas and strategies clarified during professional development (Palmer, 2011; Ross & Bruce, 2007). Thus, Jessica also would have benefited from further instruction in teaching science writing, an apparent point of frustration for her as during her first year of teaching she felt largely unprepared, in general.

Regarding *physiological states,* Seth briefly mentioned the impact of fatigue and illness not only on himself, but on his students as well. Of greater impact however, was the value Sarah, Carl and Seth placed on writing as part of science. Additionally, Sarah, Carl, and Seth repeatedly discussed themselves as lifelong learners, as did Jessica, who expressed a desire to learn more from and collaborate with her colleagues. This finding coincides with Baker and Saul (1994) who noted that elementary teachers focused on learning had a strong internal locus of control, exhibiting passion for science. Likewise, Bratcher and Stroble (1994) noted that the progression from comfort to confidence to competence in science writing instruction included periods of discomfort and disequilibrium that teachers addressed through collaboration and self-directed learning.

Phase Two Relating to Phase One

Alone, the quantitative results largely indicate only whether or not a science teacher had a particular experience, not how experiences were perceived. Thus, many low and high efficacy teachers shared similar experiences, but as Bandura (1989) pointed out, perception and processing of experiences is what influences efficacy beliefs. The qualitative findings of this study achieved what the quantitative results did not: teacher perceptions of the issues surrounding science writing instruction within their classrooms. These themes and perceptions can perhaps contribute to future quantitative studies, especially if questions are phrased similar to those in Tschannen-Moran and Hoy (2007) in which teachers were asked to rate mastery experiences and verbal persuasion/support on a nine-point Likert scale. As several commonalities occurred among this study and others (e.g., Landon-Hays, 2012; Sullenger, 1990; Tschannen-Moran & Hoy, 2007) perhaps a more robust survey can soon be developed to look for patterns in efficacy belief antecedents across a larger population.

Conclusion

What are Science Teacher Science Writing Instruction Efficacy Beliefs?

Although new curriculum changes are often met with trepidation and decreases in efficacy beliefs (Gaskins et al., 1994; Tschannen-Moran & Hoy, 2007), science writing instruction efficacy beliefs among the Oklahoma science teachers who took part in this survey ranged from mid- to high-levels. Thus, the lowest efficacy teachers in this group felt that they had at least some influence when teaching science writing and the highest efficacy teachers felt they had a great deal of influence when teaching science writing.

What Characterizes Individuals with High Science Writing Instruction Efficacy Beliefs?

Those middle and high school science teachers with the highest science writing instruction efficacy beliefs valued science writing as a means of doing and learning science. They were most characterized by a breadth of experience teaching and integrating writing into their science classes, having developed specific assignments and rubrics to evaluate student writing. These high efficacy teachers were faced but were not focused on barriers to integrating science writing. Instead, they displayed an inner locus of control, having an attitude of willingness and desire to continue learning new ways to teach writing within their classrooms. Much of the learning these teachers were self-directed learners and collaborated with colleagues to find and develop their own resources for integrating writing into their science classrooms.

Overwhelmingly, the science teachers surveyed expressed a lack of and desire for professional development in science writing instruction. This underscores the need for not only professional development opportunities for in-service teachers, but also an increased emphasis on using writing to learn strategies within science teacher education classes. This may include establishing a common definition of science writing, pointing out current uses of writing to learn strategies in professional development and teacher preparation programs, encouraging collaboration among peers, and increasing teachers' capacity to be self-directed learners, rather than merely providing specific science writing strategies and resources.

References

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry-based approach known as the Science Writing Heuristic to traditional science teaching practices: Are there differences? *International Journal of Science Education*, *29*(14), 1745–1765.

Anderson, T., Varnhagen, S., & Campbell, K. (1998). Faculty adoption of teaching and learning technologies: Contrasting earlier adopters and mainstream faculty. *The Canadian Journal of Higher Education*, *28*(2,3), 71–98.

Baker, L., & Saul, W. (1994). Considering science and language arts connections: A study of teacher cognition. *Journal of Research in Science Teaching*, *31*(9), 1023–1037.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191.

Bandura, A. (1989). Regulation of cognitive processes through perceived self-efficacy. *Developmental Psychology*, *25*(5), 729.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In T. Urdan & F. Pajares (Eds.), *Self-Efficacy Beliefs of Adolescents (PB)* (pp. 307–337). Information Age Publishing.

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (1996). Multifaceted impact of self-efficacy beliefs on academic functioning. *Child Development*, *67*(3), 1206–1222.

Bottomley, D. M., Henk, W. A., & Melnick, S. A. (1997). Assessing children's views about themselves as writers using the Writer Self-Perception Scale. *The Reading Teacher*, *51*(4), 286–296.

Brammer, C., Amare, N., & Campbell, K. S. (2008). Culture shock: Teaching writing within interdisciplinary contact zones. *Across the Disciplines*, *5*.

Bratcher, S., & Stroble, E. J. (1994). Determining the progression from comfort to confidence: A longitudinal evaluation of a National Writing Project site based on multiple data sources. *Research in the Teaching of English*, *28*(1), 66–88.

Common Core State Standards Initiative. (2012). In the States. Retrieved March 12, 2013, from http://www.corestandards.org/in-the-states

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Los Angeles: Sage.

Gaskins, I. W., Guthrie, J. T., Satlow, E., Ostertag, J., Six, L., Byrne, J., & Connor, B. (1994). Integrating instruction of science, reading, and writing: Goals, teacher development, and assessment. *Journal of Research in Science Teaching*, *31*(9), 1039–1056.

Goddard, R. D., Hoy, W. K., & Hoy, A. W. (2000). Collective teacher efficacy: Its meaning, measure, and impact on student achievement. *American Educational Research Journal*, *37*(2), 479–507.

Goddard, R. D., Hoy, W. K., & Hoy, A. W. (2004). Collective efficacy beliefs: Theoretical developments, empirical evidence, and future directions. *Educational Researcher, 33*(3), 3–13.

Gray, J. (2000). *Teachers at the center: A memoir of the early years of the National Writing Project*. Berkeley, CA: National Writing Project.

Holliday, W. G., Yore, L. D., & Alvermann, D. E. (1994). The reading–science learning–writing connection: Breakthroughs, barriers, and promises. *Journal of Research in Science Teaching, 31*(9), 877–893.

Keys, C. W., Hand, B., Prain, V., & Collins, S. (1999). Using the Science Writing Heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching, 36*(10), 1065–1084.

Landon-Hays, M. (2012, October 22). *I would teach it if I knew how: Inquiry, Modeling, Shared Writing, Collaborative Writing, and Independent Writing (IMSCI), a model for increasing secondary teacher self-efficacy in integrating writing instruction in the content areas* (Unpublished doctoral dissertation). Utah State University, Logan, UT.

Lavelle, E. (2006). Teachers' self-efficacy for writing. *Electronic Journal of Research in Educational Psychology, 4*(1), 73–84.

Moody, C., Obear, K., Gasser, H., Cheah, S., & Fechter, T. (2013). ACPA standards for demographic questions. ACPA Governing Board. Retrieved from http://www.myacpa.org/sites/default/files/Proposal-Demographic-Questions-and-Responses-2.pdf

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards (English Language Arts)*. Washington D.C.: National Governors Association Center for Best Practices, Council of Chief State School Officers. Retrieved from http://www.corestandards.org/ELA-Literacy

Office of Educational Quality and Accountability. (2014). *Oklahoma Educational Indicators Program: Profiles 2013 State Report*. Publications Clearinghouse of the Oklahoma Department of Libraries.

Palmer, D. (2011). Sources of efficacy information in an inservice program for elementary teachers. *Science Education*, *95*(4), 577–600.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an efficacy belief instrument for elementary teachers. *Science Education*, *74*(6), 625–637.

Rosaen, C. L. (1989) Writing in the content areas: Reaching its potential in the learning process. In J. Brophy (Ed.), *Advances in research on teaching, Volume 1. Teaching for Meaningful Understanding and Self-Regulated Learning* (pp. 153-194). Greenwich, CT: JAI Press.

Ross, J., & Bruce, C. (2007). Professional development effects on teacher efficacy: Results of randomized field trial. *The Journal of Educational Research*, *101*(1), 50–60.

Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: Creating student-centered classrooms*. New York: Teachers College Press.

Schriver, M., & Czerniak, C. M. (1999). A comparison of middle and junior high science teachers' levels of efficacy and knowledge of developmentally appropriate curriculum and instruction. *Journal of Science Teacher Education*, *10*(1), 21–42.

Schrum, L., & Levin, B. B. (2012). Strategic leadership: Encouraging and assessing technology integration. In L. Schrum (Ed.), *Educational technology for school leaders* (pp. 41–58). Thousand Oaks, CA: Corwin Press.

Street, C., & Stang, K. (2008). Improving the teaching of writing across the curriculum: A model for teaching in-service secondary teachers to write. *Action in Teacher Education*, *30*(1), 37–49.

Street, C., & Stang, K. K. (2009). In what ways do teacher education courses change teachers' self confidence as writers? *Teacher Education Quarterly*, *36*(3), 75–94.

Sullenger, K. S. (1990). *Science teachers' perspectives about writing in science* (Unpublished doctoral dissertation). University of Georgia, Athens, Georgia.

Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education, 17*(7), 783–805.

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, *23*(6), 944–956.

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, *68*(2), 202–248. http://doi.org/10.3102/00346543068002202

Tschannen-Moran, M., & MacFarlane, B. (2011). I know I can! Teacher self-efficacy in the English language arts classroom. In D. Lapp & D. Fisher (Eds.), *Handbook* *of research on teaching the English language arts* (pp. 218–223). New York: Routledge.

U.S. Department of Education, National Center for Education Statistics. (2004). *Common Core of Data (CCD)*. Retrieved from http://nces.ed.gov/ccd/TableDisplay.asp?TablePath=tables/table_01.asp

U.S. Department of Education, National Center for Education Statistics. (2012). *Schools and Staffing Survey (SASS)*. Retrieved from http://nces.ed.gov/surveys/sass/tables/state_2004_18.asp

Usher, E. L., & Pajares, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of Educational Research*, *78*(4), 751–796.

Appendix A – Manuscript I: Teacher Survey

Items:	Response Type:
1. How do you describe your gender identity?	*open*
2. What is your primary (most proficient/fluent) language?	*open*
3. In what other languages are you proficient/fluent?	*open*
4. Name any college level courses you have taken on writing or the teaching of writing(list titles).	*open*
5. Have you ever participated in any workshops/inservice or professional development about the teaching of writing?	Yes, No, Other
6. In my primary science field, I have published approximately ___ research articles.	0, 1 – 5, 6 – 20, Over 20
7. I have published approximately ___ articles on my teaching (in a pedagogy journal, for example).	0, 1 – 5, 6 – 20, Over 20
8. I have published ___ books.	0, 1 – 5, 6 – 10, Over 10
9. Please describe any other experiences you consider significant with regards to the teaching of writing.	*open*
10. How many years of teaching experience do you have?	Less than 1, 1 – 5, 6 – 10, 11 – 20, Over 20
11. Which student populations have you taught? Select all that apply, please indicate subject in the box provided for each selection.	PreK – K, 1st – 2nd , 3rd – 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, Other
12. To what professional organizations do you belong?	*open*
13. Degrees and Concentrations:	B.A., B.S., M.A., M.S., Ed.D., Ph.D., Specialist, Other
14. At what type of institution do you currently teach? Please choose all that apply.	Public (under 350 students), Public (over 350 students), Private (under 350 students), Private (over 350 students), CareerTech, Online, Other
15. I teach (please select all that apply):	Courses within my subject that include writing, Have a significant writing component, A course that teaches writing for the subject, All the courses I teach are writing intensive by design, Other

Appendix B – Manuscript I: Modified WSPS

Directions: Listed below are statements about writing. Please read each statement carefully. Then circle the letter that shows how much you agree or disagree with the statement.	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1. I write better than other teachers.	SA	A	U	D	SD
2. I like how writing makes me feel inside.	SA	A	U	D	SD
3. Writing is easier for me than it used to be.	SA	A	U	D	SD
4. When I write, my organization is better than other teachers.	SA	A	U	D	SD
5. People in my life think I am a good writer.	SA	A	U	D	SD
6. I am getting better at writing.	SA	A	U	D	SD
7. When I write, I feel calm.	SA	A	U	D	SD
8. My writing is more interesting than other teachers' writing.	SA	A	U	D	SD
9. Those who supervise or evaluate me think my writing is fine.	SA	A	U	D	SD
10. Other teachers think I am a good writer.	SA	A	U	D	SD
11. My sentences and paragraphs fit together as well as other teachers' sentences and paragraphs.	SA	A	U	D	SD
12. I need less help to write well than I used to.	SA	A	U	D	SD
13. People in my life think I write pretty well.	SA	A	U	D	SD
14. I write better now than I could before.	SA	A	U	D	SD
15. I think I am a good writer.	SA	A	U	D	SD
16. I put my sentences in order better than other teachers.	SA	A	U	D	SD
17. My writing has improved.	SA	A	U	D	SD
18. My writing is better than before.	SA	A	U	D	SD
19. It's easier to write well now than it used to be.	SA	A	U	D	SD
20. The organization of my writing has really improved.	SA	A	U	D	SD
21. The sentences I use in my writing stick to the topic more than the ones other teachers use.	SA	A	U	D	SD
22. The words I use in my writing are better than the ones I used before.	SA	A	U	D	SD
23. I write more often than other teachers.	SA	A	U	D	SD
24. I am relaxed when I write.	SA	A	U	D	SD
25. My descriptions are more interesting than before.	SA	A	U	D	SD
26. The words I use in my writing are better than the ones other teachers use.	SA	A	U	D	SD
27. I feel comfortable when I write.	SA	A	U	D	SD
28. Those who supervise or evaluate me think I am a good writer.	SA	A	U	D	SD
29. My sentences stick to the topic better now.	SA	A	U	D	SD
30. My writing seems to be more clear than other teachers' writing.	SA	A	U	D	SD
31. When I write, the sentences and paragraphs fit together better than they used to.	SA	A	U	D	SD
32. Writing makes me feel good.	SA	A	U	D	SD
33. I can tell that those who supervise or evaluate me think my writing is fine.	SA	A	U	D	SD
34. The order of my sentences makes better sense now.	SA	A	U	D	SD
35. I enjoy writing.	SA	A	U	D	SD
36. My writing is more clear than it used to be.	SA	A	U	D	SD
37. Other teachers would say I write well.	SA	A	U	D	SD
38. I choose the words I use in my writing more carefully now.	SA	A	U	D	SD

Manuscript II

Post-Secondary Science Instructor Science Writing Instruction Efficacy Beliefs

This manuscript is prepared for submission to the peer-reviewed journal *Across the Disciplines*.

Abstract

Writing is integral to disciplinary discourse in the sciences and is a way for students to process new concepts and experiences. However, many science faculty do not see themselves as proficient writers and are largely unprepared to teach science writing. This explanatory sequential mixed methods study investigated science instructor science writing instruction efficacy beliefs and identified antecedents to high efficacy. Quantitative data from an online survey that included the Teacher Sense of Efficacy Scale (TSES) and the Writer Self-Perception Scale (WSPS) were collected from 72 science instructors. The results of the quantitative phase guided the development of the second, qualitative phase. Responses from the 72 science instructors to two sets of two open-ended statements were coded into themes during the second phase and, using TSES scores, four instructors with high science writing instruction efficacy beliefs were identified and interviewed. Science writing instruction efficacy beliefs among the instructors who took part in this survey ranged from low- to high-levels. Thus, the lowest efficacy instructors felt that they could do nothing when teaching science writing and the highest efficacy teachers felt they had a great deal of influence when teaching science writing. Those instructors with the highest efficacy beliefs valued science writing, had experience teaching writing, integrated writing into their courses, used writing to learn and writing in the discipline strategies, received positive feedback and faced barriers to integrating science writing in their courses.

Keywords

science writing, writing to learn, writing across the curriculum, writing in the disciplines, science instruction, efficacy beliefs

Introduction

Although disciplinary ideas of good writing vary, Writing across the Curriculum (WAC) is marked by commonalities, especially when considering the process and purpose of writing (e.g. claims and evidence, logical structure, citation) (Brammer, Amari, & Campbell, 2008). Thus, the initial stages of WAC within a university are often characterized by cross-disciplinary interest in student learning and best approaches to teaching (McLaren, Dyche, Altidor-Brooks, & Devonish, 2011). Eventually, many universities developed writing-intensive (WI) courses in an effort to link writing within the general education curriculum (Russell, 2002). Within many WI courses in the sciences, focus shifts to writing like a scientist rather than writing to learn, placing emphasis on rhetorical differences among disciplinary genres, a movement known as writing in the disciplines (WID) (Monroe, 2003). As a simplification, whereas WAC is *writing to learn*, WID is perhaps *writing to become a professional* (Carter, 2007). The WID focus is specialized rhetoric for a niche audience, after students have completed their general education requirements and become part of a particular discourse community (Stock, 1986). Therefore, writing in post-secondary science can take a myriad of forms, often depending on perceived student needs, course goals, and instructor pedagogy.

Demand for incorporation of writing in college science courses continues (Russell, 2002; Walvoord, 1996), as a Google search for *writing intensive courses* and *university* returns 41,500 hits. Writing is not only integral to disciplinary discourse in the sciences, it is also a way for students to process and make sense of new concepts and experiences encountered within a science class (Bruner, 1996; Emig, 1977; Moffett, 1965). However, many students have difficulty recognizing writing as part of *doing science* (Yates, Williams, & Dujardin, 2005). Additionally, science instructors often become correctors of student work rather than collaborators in the thinking and learning process by turning writing into a grammar exercise rather than discourse central to the nature of science (Bratcher & Stroble, 1994; Chinn & Hilgers, 2000). This fallback to traditional and familiar structures may indicate low self-efficacy in the instructor's own ability to implement a new approach to learning (Bratcher & Stroble, 1994; Tschannen-Moran, Hoy, & Hoy, 1998).

According to the literature, college-level science faculty are largely unprepared to teach science writing skills (Holliday, Yore, & Alvermann, 1994; Labianca & Reeves, 1985) and although many post-secondary science educators see themselves as proficient writers (Harbke, 2007) this is not reflected in their science writing instruction efficacy beliefs (Ross, Burgin, Aitchison, & Catterall, 2011). As instructor efficacy beliefs can affect student performance (Bandura, 1989; Tschannen-Moran et al., 1998), providing opportunities for instructors to increase their efficacy beliefs is essential to student success in science fields.

Whereas the links between self-efficacy and writing instruction within disciplines has been recognized previously, there are few studies providing information on the antecedents of science instructor's science writing instruction efficacy beliefs, focusing on secondary-level science teachers instead (Gaskins, Guthrie, Satlow, Ostertag, Six, Byrne, & Connor, 1994; Holliday et al., 1994; Landon-Hays, 2012; Sullenger, 1990). One such study focuses on the relationship between major advisors and their graduate students (Ross et al., 2011). Recognizing that learning how to *write* *like a scientist* is a transformation and that many students find themselves becoming stuck in various stages of this transformation, Ross and colleagues sought to discover what tasks students and their advisors find difficult and what strategies within the sciences can aid in moving students through their transformation into becoming a member of their disciplinary discourse community. Students and supervisors came from a variety of disciplines, including health sciences, sciences, engineering, and math and computing. However, the majority of responses came from the sciences (Ross et al., 2011). Students indicated that their advisor was the main source of support for writing their dissertations and that this support was either insufficient or nonexistent. According to Ross and colleagues, these advising professors expressed low writing efficacy beliefs themselves and unable to explain their role in writing beyond feedback (often negative) and encouragement, expected students to learn science writing through mimicry (Ross et al., 2011). As many science faculty learned science writing via enculturation, they often have trouble making the tacit explicit and forget their own slow evolution and development as a writer, something that Holliday and colleagues (1994) also observed among most literate individuals.

Ross and colleagues (2011) ultimately indicated a need to create a culture of mindfulness within the sciences. Given the results of their study, the writing experiences of graduate students are extremely stressful and often traumatic, perhaps leading to low writing efficacy beliefs as professors. Since low writing efficacy belief influences writing instruction efficacy belief (Landon-Hays, 2012; Tschannen-Moran & MacFarlane, 2011), this creates a potential negative feedback loop that continues to hinder science instructors from incorporating writing into their science courses.

Given the minimal research in this area, my study will fit into the current gap in the literature to provide data on the antecedents of science instructor science writing instruction efficacy beliefs. Within the remainder of this study, *instructor* is used to refer to any individual teaching a college course at a post-secondary institution, regardless of professional level. This information will be useful to provide effective professional development for instructors integrating writing intensive requirements into their courses. Thus, this explanatory sequential mixed methods study (Creswell & Plano Clark, 2011) investigated science instructor science writing instruction efficacy beliefs to create a baseline for implementation of appropriate professional development in science writing instruction for science faculty. This includes understanding the antecedents to high writing instruction efficacy beliefs among science faculty such that these factors can be included in professional development plans. Thus, I asked the following questions: What are science instructor science writing instruction efficacy beliefs? What characterizes individuals with high science writing instruction efficacy beliefs?

Literature Review

Writing in post-secondary science education

In instances of student writing interventions (e.g. workshops, seminars, etc.) there seems to be little reported improvement in student science writing skills. Kroen (2004) described implementing an assignment to help students analyze and interpret authentic data. Throughout the semester, Kroen offered specific instruction, opportunities for peer review, and assigned journal articles to serve as both content source and writing models. Students saw the assignment as a requirement for a grade, rather than part of their education as a professional. Like the findings from Yates and colleagues (2005), many students are not viewing writing as part of the scientific process and a means to learning. They have not wholly entered into an awareness of science as a discourse community conversing across time and space (Chinn & Hilgers, 2000). This suggests that writing is not an important part of students' science experience within their college courses.

Considering this continued disassociation, information and sporadic practice alone may not provide students with the connection to the scientific process that Kroen (2004) and Yates and colleagues (2005) sought. Instead, we should perhaps focus on "how students are acculturated and socialized into the world of scientists" (Chinn & Hilgers, 2000, p. 7) primarily through modeling by professors. To this end, Chinn and Hilgers examined WI course requirements to determine how the professor's approach to writing and writing assignments within science classes would impact student outcomes. Chinn and Hilgers reported that the role of instructor as *corrector* was predominate in writing intensive courses, meaning that students wrote for the instructor as audience, the assignment represented a product rather than process, and students viewed the writing process as editing. Instructors as *collaborators* created a discourse community within the course, providing students with real-world audiences and assignments. Students were often part of research teams for these assignments, using writing to communicate and learn. Students vastly preferred courses taught by collaborative instructors and left with a greater understanding of and preparation for their careers as scientists (Chinn & Hilgers, 2000). What Chinn and Hilgers did not indicate in their study were the underlying reasons that cause instructors to gravitate toward one end of the corrector-collaborator spectrum over another.

Preparing instructors to give meaningful feedback on writing assignments is of key importance. In a study tracking self-reported growth in critical thinking skills from 24,837 students at 392 colleges over a four-year period, instructor feedback on papers had the greatest positive effect on students' ability to think critically (Tsui, 1999). In a smaller study of 82 biology students, final research paper scores did not correlate with number of college-level writing courses taken, technical writing courses taken, or number of years in college (Jerde & Taper, 2004). Rather, prior experience in science writing and according to student comments, instructor feedback, helped students refine their final paper (Jerde & Taper, 2004).

Much of the literature however, especially that encountered in science-specific databases and journals (e.g. Web of Science, *Journal of College Science Teaching*), focuses on specific writing assignments or courses aimed at helping students either engage with content or write like a professional scientist. In one example, Lankford and vom Saal (2012) walked readers through the creation of a writing-intensive biology capstone course, including examples of assignments, case studies, article critiques, peer evaluation guides, rubrics, and grading schemes. Of note in this case, the graduate teaching assistant (GTA) collaborating with the course professor "held extensive experience as a former high school biology teacher" (Lankford & vom Saal, 2012, p. 21). Prior to her experience with this particular course, the GTA had likely received professional development in instructional techniques and curriculum design, which may be possible antecedents to high science writing instruction efficacy beliefs. Practitioner articles such as the example highlighted here certainly demonstrate instructors as collaborators as defined by Chinn and Hilgers (2000), but the question remains: What aided the development of these individuals as confident (as evidenced by their willingness to publish) science writing instructors?

Self-efficacy beliefs

Self-efficacy is the personal belief in one's ability to negotiate a stressful task (Bandura, 1977). Unlike self-confidence or self-esteem, self-efficacy depends on context and is affected by an individual's perception of the following antecedents: personal mastery experiences, vicarious experiences, verbal persuasion, and physiological. Of these, personal mastery experiences are the most powerful antecedent to efficacy beliefs. However, observing successful peer models (vicarious experience) can allow an individual to picture themselves being successful and encouragement or praise from a respected person (verbal persuasion) regarding a specific task can also increase self-efficacy. Finally, an individual's physical and emotional responses to a situation can also influence self-efficacy, depending upon their interpretation of their physiological reaction (Bandura, 1977).

The antecedents themselves do not directly affect self-efficacy beliefs; rather, it is the perception and cognitive processing of each antecedent as information, as well as situational and environmental factors, that influence efficacy expectations (Bandura, 1977). Thus, efficacy beliefs are generalizable, but usually only to similar contexts with lasting change in efficacy belief resulting from repeated experiences across varied contexts (Bandura, 1977). Within a specific context however, the magnitude, generality, and strength of efficacy expectations predict engagement, effort, and perseverance towards a task (Bandura, 1977; Bandura et al., 1996).

As an extension of self-efficacy, teacher efficacy beliefs were developed to explain individual efficacy within the context of education (Tschannen-Moran et al., 1998). This model is cyclical, beginning with a teacher's interpretation of efficacy antecedents and adding teacher analysis of their specific requirements and context, including student factors, resources, administration relationships, and school culture (Tschannen-Moran et al., 1998). As this model of teacher efficacy was developed in the K-12 setting, only few studies apply this theory to post-secondary education (e.g., Fives & Looney, 2009; Shavaran, Rajaeepour, Kazemi, & Zamani, 2012). Shavaran and colleagues (2012) created their own measure of faculty efficacy that included a teaching subscale and found no significant difference among faculty from public universities in Iran based on gender or professional level. However, whereas Fives and Looney reported no significant differences in efficacy beliefs based on teaching level, they did find that instructors from the college of education had higher efficacy beliefs than those from the college of behavioral and social sciences and that female instructors exhibited higher teaching efficacy beliefs than male instructors. Further, Fives and Looney (2009) expanded self-efficacy theory to faculty and GTAs at a Research I university in the mid-Atlantic regions of the United States by using an online survey based on a modified Teacher Sense of Efficacy Scale (TSES) (Tschannen-Moran & Hoy, 2001) and Collective-Efficacy Scale (Goddard et al., 2000). Thus, this particular study created precedent for use of the TSES with university faculty.

Explanatory Sequential Mixed Methods

This study employed an explanatory sequential mixed methods design (Creswell & Plano Clark, 2011), which was comprised of a two-phase project. Quantitative data were collected and analyzed in the first phase. The results of the quantitative phase then guided the development of the second, qualitative phase, which also included data collection and analysis. The overall intent of this design was to have the qualitative data provide more depth and more insight of the quantitative data. Thus, a benefit of this design is combining the strengths of quantitative and qualitative analyses to investigate the research questions (Creswell & Plano Clark, 2011).

Context and Participants

The present study sought to investigate science instructor science writing instruction efficacy beliefs to create a baseline for implementation of appropriate professional development in science writing instruction for post-secondary science educators in Oklahoma. For academic year 2011-2012, there were 25 public institutions across Oklahoma consisting of 10 regional universities, 1 public liberal arts university, 12 community colleges, 11 constituent agencies, and 2 university centers with enrollments ranging from 1,191 to 45,271 students (Oklahoma State Regents for Higher Education, 2014). There were also 14 private institutions with enrollments ranging from 166 to 4,185 students and 4 proprietary institutions in Oklahoma. In 1999-2000, 81.7% of students attended college via financial aid (Oklahoma State Regents for Higher Education, 2001). In 2007, faculty in Oklahoma were primarily white (76.7%) males (64.7%) with tenure (40.9%) (National Center for Education Statistics, 2007).

Nearly 1,300 science instructors from across the state of Oklahoma representing 63 public and private colleges and universities were invited to participate in this study. Email addresses were obtained from institution websites that publicly listed instructor contact information by department. Only instructors from departments including physical, earth, health, or natural sciences were selected for participation; science instructors within education departments were not specifically included. Because mathematics and computer science faculty are included within science departments, especially at smaller institutions, some mathematics and computer science faculty were included in the sample population. Emails were imported into Qualtrics, where an initial mass email inviting instructors to participate in an online survey was sent, followed by a reminder email to instructors who had not yet completed the survey two weeks after the initial invitation. Out of the initial instructor population, 112 instructors elected to participate in the study. However, only 72 instructors provided complete responses and thus were included as participants for this study.

The institutions represented by these instructors included 21% public with student populations under 10,000, 44% public with student populations over 10,000, 13% private with student populations under 10,000, and 2% private with student populations over 10,000. Of these, 19% were two year institutions and 3% of instructors taught online. The majority of respondents were long-term faculty. Twenty-eight percent have taught for over twenty years, 26% eleven to twenty years, 23% six to ten years, 14% one to five years, and 1% less than one year. Out of the 72 instructors, 24% were full professors, 26% associate professors, and 30% assistant professors. Additionally, 6% were non-tenure track instructors, 5% were adjunct instructors, and

1% were professor emeritus. Disciplines represented by these instructors included biology (33%), health sciences (10%), earth sciences (11%), physics (11%), chemistry (10%), math (8%), and computer science (1%). Several instructors who responded to the survey did not list their discipline.

Phase One Instruments

Modified TSES

Whereas the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs & Enochs, 1990) is commonly used to measure science teaching efficacy beliefs, the Teacher's Sense of Efficacy Scale (TSES) (Tschannen-Moran & Hoy, 2001) uses language recommended by Bandura (2006). The TSES was designed to better understand the kinds of things that create difficulties for K-12 teachers in their school activities. The instrument consists of 24 items and uses a 9-point Likert scale that measures "How much can you do" from *Nothing* to *A Great Deal*. The possible range of scores on the TSES is 1 (*Nothing*) to 9 (*A Great Deal*) as it is scored using unweighted means rather than cumulative scores. The TSES includes measures of teaching efficacy beliefs in three areas: Student Engagement (SE; item 1, 2, 4, 6, 9, 12, 14, 22), Instructional Strategies (IS; item 7, 10, 11, 17, 18, 20, 23, 24) and Classroom Management (CM; item 3, 5, 8, 13, 15, 16, 19, 21), (Tschannen-Moran & Hoy, 2001). The TSES has been found to be consistently reliable ($\alpha = .87$) (Tschannen-Moran & Hoy, 2001). A 19-item modified version used with 117 college instructors was also found to be reliable ($\alpha = .88$) (Fives & Looney, 2009); however, this measure had subscale reliabilities of SE ($\alpha = .82$), IS ($\alpha = .77$), and CM ($\alpha = .61$). Based on these results, Fives and Looney posited potentially unclear language in the TSES, based on lack of formal pedagogical training.

When modifying the TSES for this study, the number of items, response scale, and scoring procedure were maintained. To make the measure applicable for this study, each question began with the phrase "When teaching science writing" to direct respondents toward the appropriate context. Given Fives and Looney's (2009) concerns over pedagogical jargon, I also modified questions dealing with student behavior to focus instead on *disruptive technologies* (see Appendix A). Despite the modification, items separated largely onto the same factors found by Tschannen-Moran and Hoy (2001). Reliability was determined for the total modified TSES (α = .97) and for each subscale: SE (α = .92), IS (α = .92), and CM (α = .94).

Instructor Survey

A 20-item survey was developed and administered to the 72 post-secondary science instructors (see Appendix B). The survey included closed-ended questions related to demographic information (item 1, 2, 3, 14), as well as writing experiences (item 4, 6, 7, 8) and teaching experiences (item 5, 9, 10, 11, 12, 14, 15). It also included two sets of two open-ended statements, "I believe/doubt I am a good teacher of science writing because…" and "I can/cannot teach science writing because…." Responses to the last four statements were later analyzed qualitatively.

Modified WSPS

The Writer's Self-Perception Survey (WSPS) (Bottomley, Henk, & Melnick, 1997) consists of 38 items and uses a 5-point Likert scale from *Strongly Disagree* (rating of 1) to *Strongly Agree* (rating of 5), such that the possible range of scores on the

WSPS is 38 to 190. Originally designed to estimate how children feel about themselves as writers, the WSPS includes measures of General Performance (GPR; item 3, 6, 12, 14, 17, 18, 19, 20), Specific Performance (SPR; item 22, 25, 29, 31, 34, 36, 38), Observational Comparison (OC; item 1, 4, 8, 11, 16, 21, 23, 26, 30), Social Feedback (SF; item 5, 9, 10, 13, 28, 33, 27), and Physiological States (PS; item 2, 7, 24, 27, 32, 25) and No Subscale (NS = item 15) (Bottomley et al., 1997). Reliability measures for the original WSPS are above .87 for each of the five scales and factor loadings for each item was .40 or greater (Bottomley et al., 1997). Correlations among the scales ranged from .51 to .76 (Bottomley et al., 1997).

When modifying the WSPS for this study, the number of items, response scale, and scoring procedure were maintained (see Appendix C). To make the measure applicable for instructors, OC items referred to "other instructors" vs. "other kids" and "people in my life" vs. "people in my family." Finally, references to "my teacher" were replaced with "those who supervise or evaluate me." For this study, reliability was determined for the total modified WSPS ($\alpha = 0.96$) and for each subscale: GPR ($\alpha = 0.93$), SPR ($\alpha = 0.94$), SF ($\alpha = 0.93$), OC ($\alpha = 0.96$) and PS ($\alpha = 0.96$). Factor loadings for each item were above 0.40, although not all of the items separated to the same factors as the original WSPS. In particular, the GPR items and SPR items did not separate for adults in this study as they did for children in a previous study (Bottomley et al., 1997).

Phase One Data Collection

Modified TSES

To begin scoring the TSES, a response of *Strongly Disagree* was assigned a value of 1 and a response of *Strongly Agree* was assigned a value of 5. Unweighted means of the items that loaded on each of the three factors: Efficacy in Student Engagement (SE), Efficacy in Instructional Strategies (IS), and Efficacy in Classroom Management (CM) were then calculated (see Table 1).

Table 1

Modified TSES Scores

Measure	*i*	*M*	*SD*	Median	Range
TSES	24	6.3	1.33	6.5	1.0-8.6
SE	8	5.7	1.36	5.6	1.0-9.0
IS	8	6.7	1.40	6.8	1.0-9.0
CM	8	6.5	1.60	6.6	1.0-9.0

Note. TSES = Teacher's Sense of Efficacy Scale; SE = Student Engagement; IP = Instructional Strategies; CM = Classroom Management. *i* = number of items for that particular measure. Scores represent the unweighted mean for each measure.

Instructor Survey

Demographic questions on the instructor survey were coded according to the American College Personnel Association's (ACPA) guidelines (Moody et al., 2013). For this particular population, gender preferences were coded as male (n = 38), female (n = 31), queer (n = 1), heterosexual (n = 1), or no response (n = 1). Most instructors reported English as their primary language (n = 69). Other primary languages spoken included Romanian (n = 1) and Russian (n = 2). Several instructors (n = 19) reported proficiency in a language (n = 17) or languages (n = 2) other than their primary language. All instructors had at least one graduate degree; some had a masters only (n = 13), others doctorate only (n = 29), and many had both a masters and doctoral degree (n = 30).

Instructor responses to college writing courses varied and were quantified as a sum of the number of writing courses reported, ranging from 0 – 9 courses. Of the 72 instructors, 30 did not respond or reported not taking writing courses in college, 13 took one writing course, 16 took two writing courses, and 13 reported taking three or more writing courses. Out of the 42 instructors that did take at least one writing course, 19 mentioned taking a science or technical writing course. Instructors published research primarily within their own field. Only eleven instructors had not published research, 21 published between one and five articles, 13 published between six and twenty articles, and 27 published over twenty articles. Fewer instructors published articles on their teaching (n = 22) and only one had published more than five articles, so this measure was reduced to a dichotomous variable. Approximately the same number of instructors (n = 19) had published books, with only two having published more than five, thus this measure was also reduced to a dichotomous variable.

The institutions represented by these teachers were both public (n = 50) and private (n = 11) with student populations under 10,000 (n = 26) or with student populations over 10,000 (n = 35), with nine instructors not reporting the type of institution at which they teach. The majority of respondents were long-term teachers. Twenty-two taught for over twenty years, 20 eleven to twenty years, 18 six to ten years, 11 one to five years, and 1 less than one year. Most taught courses for majors (n = 63), and courses for non-majors or general education requirements (n = 57), while some taught graduate-level courses (n = 34) or other populations, including post-doctoral researchers, middle and high school students, and medical, dental or nursing students (n = 9). Most instructors taught more than one type of student population (n = 67).

Of the 72 instructors, most teach a course within their discipline that includes writing (n = 60), but few reported teaching the writing intensive course for the department (n = 2), courses with a significant writing component (n = 28), courses that are writing intensive by design (n = 5) or that teach writing for the major (n = 4). A few science instructors also reported teaching another type of course that presumably did not include writing (n = 7). Regarding professional development in teaching writing, 21 instructors reported having participated in some type of professional development and most (n = 60) report belonging to at least one professional organization, although only 24 reported belonging to a professional teacher's organization. As the question for professional organization membership was open-ended, responses were quantified by summing the number of local, regional, and national/international teaching organizations listed by each instructor. Membership ranged from 0 – 8 organizations; 17 instructors reported belonging to one organization, 10 reported belonging to two organizations, 12 reported belonging to three organizations, 12 reported belonging to four organizations, and 9 reported belonging to five or more organizations. Finally, instructors were also asked to report other significant experiences with regards to teaching writing, to which 37 instructors responded with additional and specific information generally covered by other questions.

Modified WSPS

To score the WSPS, a response of *Strongly Disagree* was assigned a value of 1 and a response of *Strongly Agree* was assigned a value of 5. Since each subscale is associated with a different number of questions, the highest possible score for each is as follows: GPR = 40; SPR = 35; OC = 45; SF = 35; and PS = 30. According to Bottomley and colleagues (1997), average values for each subscale are GPR = 35, SPR = 29, OC = 30, SF = 27, and PS = 22 and low values for each subscale are GPR = 30, SPR= 24, OC = 23, SF = 22, and PS = 16. Table 2 presents the total modified WSPS score, the scores for each of the subscales, and the scores for the single question not linked to a subscale for the 72 instructors in this study.

Table 2

Modified WSPS Scores

Measure	*i*	*M*	*SD*	Median	Range
WSPS	38	141.7	20.3	143.0	102-190
GPR	8	30.7	5.9	32.0	17-40
SPR	7	26.6	4.5	27.0	14-35
OC	9	31.7	5.9	30.0	18-45
SF	7	28.5	4.7	28.0	19-35
PS	6	20.3	5.8	22.0	6-30
NS	1	4.0	0.9	4.0	2-5

Note. WSPS = Writer's Self-Perception Survey; GPR = General Progress; SPR = Specific Progress; OC = Observational Comparison; SF = Social Feedback; PS = Physiological State; NS = No Subscale. *i* = number of items for that particular measure. Scores represent the cumulative score for each measure.

Phase One Data Analysis

The explanatory sequential mixed methods design began with a quantitative focus in data collection and analysis to provide a generalized picture of science teacher writing instruction efficacy beliefs and a framework for the interview protocol and participant selection. The quantitative data were also used to identify cases for the interview. The primary data source for the quantitative data was the online survey that included the modified TSES, instructor survey, and modified WSPS. Where three or fewer responses were missing from a subscale, I replaced the missing data with the mean score of the available data for that subscale as the WSPS is scored cumulatively and the complete data set was already limited in size. This data replacement affected WSPS data for three instructors and TSES data for seven instructors.

Modified TSES

To identify science writing efficacy beliefs among post-secondary science instructors, I analyzed the modified TSES data, dividing instructors into two groups, *High* ($n = 37$) and *Low* ($n = 35$). *High* was defined as any TSES score above the group mean and *Low* as any TSES score below the group mean. Independent *t*-tests were performed to compare the TSES scores of the two instructor groups.

Instructor Survey

Frequency tables were created for each of the items on the instructor survey and variables were condensed to meet the requirements for a reliable Chi-Square analysis. All items were quantified into either dichotomous, categorical, or ratio variables. Questions 2 and 11 were not used from the survey because only three teachers did not speak English and only nine instructors were non-tenure track, which rendered the Chi-

Square tests unreliable. Question 9 was also not used as the responses to this question were too varied to quantify for analysis. Thus, for the final analysis, twenty-three variables were created from the original fifteen questions on the instructor survey (see Table 3). Of these variables, gender and additional languages spoken size were considered demographic variables. Instructors choosing not to self-identify or identifying as queer or heterosexual were not included in the analysis because the number of individuals was too low for a Chi-Square test to remain reliable. Variables regarding institution type and student populations taught were considered context variables and coded into dichotomous yes/no variables because some instructors taught at both public and private institutions or large and small institutions. Type of graduate degree, publication experiences, and number of college writing courses were counted as variables related to teachers' *writing histories* (Street & Stang, 2009). Pedagogy and book publications were collapsed into a dichotomous yes/no variable to meet the assumptions of the Chi-Square test. With regards to the four antecedents of self-efficacy (Bandura, 1989), years of teaching experience, number of different student populations taught, and the type of writing a teacher reported were all considered *personal mastery* experiences (Tschannen-Moran & Hoy, 2007). Albeit, Fives and Looney (2009) found evidence to the contrary that years of teaching experience has a professional mastery impact for post-secondary instructors. Finally, participation in professional development and membership in professional and teaching organizations likely had aspects of both *vicarious experience* and *verbal persuasion* (Tschannen-Moran et al., 1998).

Table 3

Final Variables for Analysis

Variable used in Analysis	Item
Gender preference (male/female)	1
Additional language proficiency (ratio)	3
Teaches at a private institution (yes/no)	15
Teaches at a public institution (yes/no)	15
Teaches at an institution with less than 10,000 students (yes/no)	15
Teaches at an institution with over 10,000 students (yes/no)	15
Teaches at a two-year institution (yes/no)	15
Teaches at a four-year institution (yes/no)	15
Teaches non-majors or general education course (yes/no)	11
Teaches graduate-level course (yes/no)	11
Graduate Degree (masters alone, doctorate alone, masters & doctorate)	14
Number of research publications (0, 1 – 5, 6 – 20, over 20)	6
Has at least one pedagogy publication (yes/no)	7
Has published at least one book (yes/no)	8
Had a course in science or technical writing (yes/no)	4
College writing courses (ratio)	4
Years teaching (less than 1, 1 – 5, 6 – 10, 11 – 20, over 20)	10
Type of writing reported for science class (none, low, high)	16
Teaches a course with a significant writing component (e.g. capstone)	16
Number of different student populations taught (ratio)	12
Participation in writing instruction professional development (yes/no)	5

Membership in a professional teaching organization (yes/no)	13
Professional organization membership (ratio)	13

To begin exploring the antecedents of high efficacy beliefs (Bandura et al., 1996) regarding science writing instruction, Pearson's Chi-Square tests for independence were performed to compare the relation between *high* and *low* modified TSES groups and demographics (gender preference, school context, student population context), writing histories (publications, graduate degree, specific science or technical writing course in college), and teaching experience (years teaching, type of writing reported for science class, participation in professional development). Where contingency tables were 2x2, Yate's continuity correction was used. Independent *t*-tests were also used to compare the relation between *high* and *low* modified TSES groups and writing histories (number of college writing courses) and teaching experiences (number of student populations taught, number of professional organization memberships).

Modified WSPS

The modified WSPS scores for these instructors were used primarily as an interval variable during analysis as some argue that instructors' perceptions of themselves and experiences as writers influence their ability to teach students how to write (Ross et al., 2011). To gain a broad perspective as to how science instructors perceive themselves as writers, I did calculate descriptive statistics for the WSPS scores and ran tests of normality, specifically Shapiro-Wilk, and measures of skewness and kurtosis.

To test whether instructions with low perceptions of themselves as writers also have low efficacy in teaching their students how to write (Ross et al., 2011), independent *t*-tests were performed to compare the relation between *High* and *Low* TSES groups and WSPS scores.

Phase One Results

Modified TSES

According to science instructor modified TSES scores, the majority of participants ranged from being able to do between *very little* and *having some influence* (4.0) to having *a great deal of influence* (8.6) in their classrooms when thinking of science writing instruction (see Figure 1). One instructor however, did feel that they could do *nothing* when thinking of science writing instruction. On average, instructors had a TSES score of 6.3 $\pm$ 1.3. Participant TSES score distribution was slightly skewed towards lower efficacy values (skewness, 0.3) and flattened (kurtosis, 0.6), differing significantly from normal distribution [Shapiro-Wilk(72) = 0.952, p = .008].

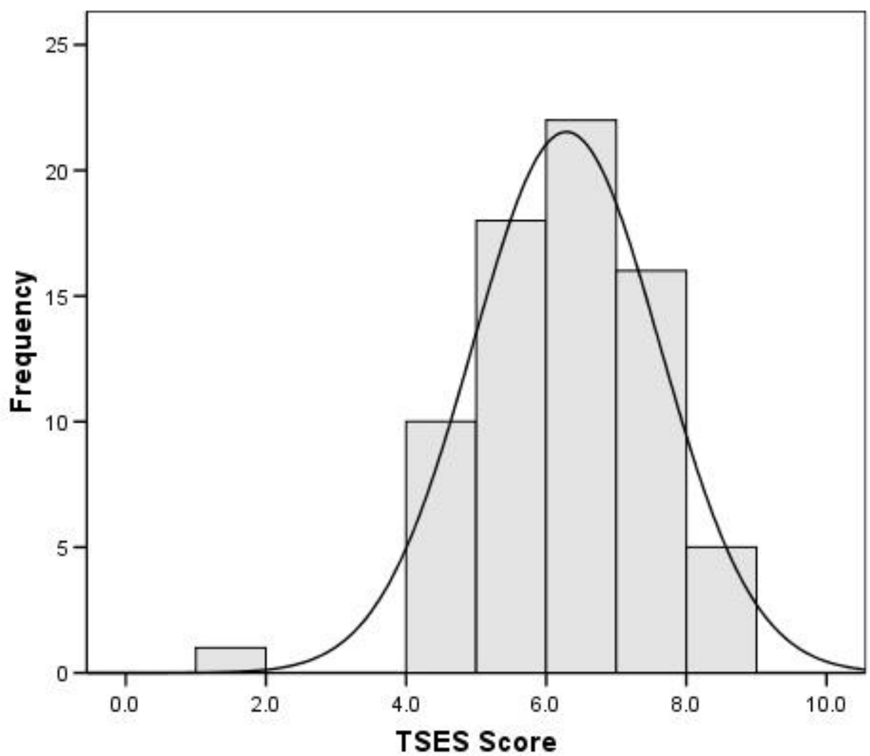

Figure 1. Distribution of TSES scores among participating post-secondary science instructors (*M* = 6.3, *SD* = 1.3).

For the subsequent statistical analyses, modified TSES scores were separated into *High* (n = 37) and *Low* (n = 35). A comparison between the unweighted mean showed differences in the Total TSES score. Results from an independent *t*-test indicated that instructors who were categorized as having high efficacy (*M* = 7.3, *SD* = 0.61) scored significantly higher on the TSES than teachers who were categorized as having low efficacy (*M* = 5.2, *SD* = 1.01), $t(1) = 10.69$, $p < .001$. This difference was seen for all subscales: SE, (*M* = 6.6, *SD* = 1.01), (*M* = 4.8, *SD* = 0.98), $t(1) = 7.80$, $p < .001$; IS, (*M* = 7.7, *SD* = 0.68), (*M* = 5.6, *SD* = 1.20), $t(1) = 8.84$, $p < .001$; CM, (*M* = 7.6, *SD* = 0.75), (*M* = 5.2, *SD* = 1.32), $t(1) = 9.33$, $p < .001$.

Instructor Survey

There was no relationship between demographic and context variables such as gender, institution size, or institution funding source and instructor groups according to *High* and *Low* modified TSES scores. There were also no significant relationships between variables representing instructor writing histories, personal mastery experience, vicarious experience, or verbal persuasion and instructors grouped according to *High* and *Low* modified TSES scores. Categorical variables expected to identify sources of personal mastery experiences included years of teaching experience and type of science writing reported in courses. Participation in professional development about the teaching of science writing included both vicarious experience and verbal persuasion antecedents.

Independent *t*-tests comparing means of interval data according to two efficacy levels indicated no significant differences between groups. Proficiency in additional languages was considered a demographic variable, whereas the number of writing courses taken in college was considered part of an instructor's writing history, number of student populations taught was considered mastery experience. Vicarious experience and verbal persuasion were aspects of membership in professional organizations.

Modified WSPS

Teacher perceptions of themselves as writers ranged from *Low* (102) to *High* (190) with a mean of slightly below *average* (M = 141.7, SD = 20.3) according to WSPS scores (see Figure 2). The WSPS score distribution was skewed toward lower self-perceptions (skewness, 0.128) and peaked (kurtosis, -0.383. However, the distribution did not significantly differ from normal distribution [Shapiro-Wilk(72) = 0.986, $p = 0.594$].

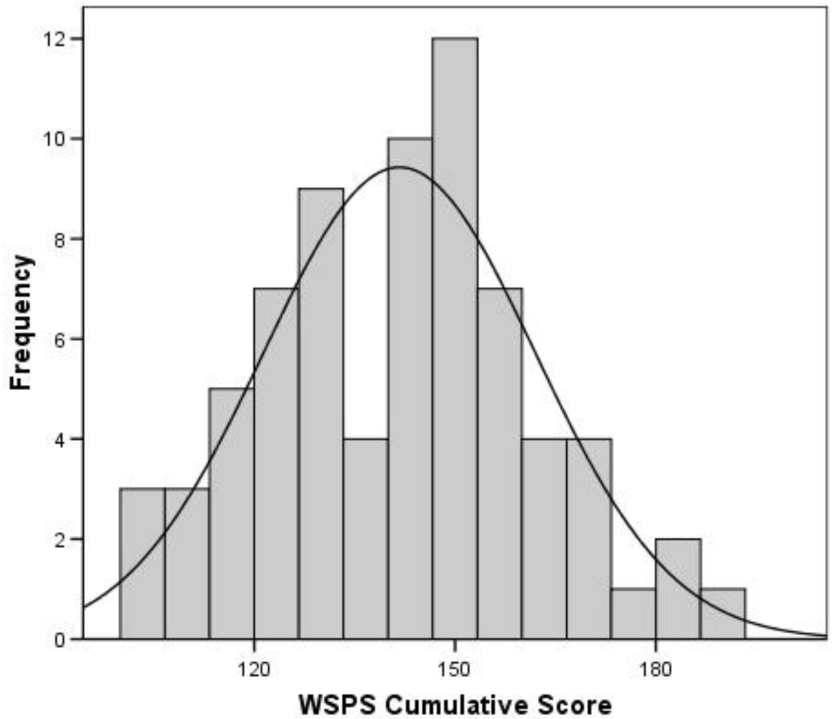

Figure 2. Distribution of WSPS scores among participating post-secondary science instructors ($M = 141.7$, $SD = 20.3$).

Independent *t*-tests comparing means of WSPS and subscale interval data according to two efficacy levels indicated no significant differences between groups. For this analysis, WSPS scores were considered variables representing an instructor's perception of his or her writing history.

Phase One Planning for Phase Two

Using Rogers Diffusion of Innovation Model (Sandholtz, Ringstaff, & Dwyer, 1997; Schrum & Levin, 2012) as a framework, I identified instructors two standard deviations or higher above the group modified TSES mean as *Innovators* (n = 0), instructors less than two standard deviations but greater than one standard deviation above the TSES mean as *Early Adopters* (n = 13), instructors less than one standard deviation but greater than the TSES mean as *Early Majority* (n = 24), instructors less than the mean but greater than one standard deviation below the TSES mean as *Late Majority* (n = 24), and instructors less than or equal to one standard deviation above the TSES mean as *Late Mass* (n = 11). Whereas Rogers Diffusion of Innovation often describes trends in technology adoption and use, in a general sense *Innovators* and *Early Adopters* engage most readily with new ideas and have higher efficacy beliefs (Anderson, Varnhagen, & Campbell, 1998). Thus, I purposefully selected these two groups as potential interview candidates.

Phase Two Interview Questions

In a review of literacy integration into the science classroom, Holliday and colleagues (1994) adapted five questions from Rosaen (1989) to investigate teacher attitudes and interactions with writing in the sciences. Additionally, Sullenger (1990) identified seven perceptions that describe teachers' writing practices in science. Borrowing from both of these sources, I pre-identified eight interview questions (see Figure 3), adding probing questions throughout the interview as appropriate.

How do you define science writing?

How do you currently incorporate science writing into your classroom?

How do you evaluate your students' science writing?

What resources do you have for teaching science writing in your classes?

How have you been prepared to teach science writing in your classes?

What barriers do you face when teaching science writing in your class? How do you overcome those barriers?

What aspects of improving your science writing instruction are most interesting to you?

Figure 3. Pre-identified interview questions for instructors with high science writing instruction efficacy belief scores on the TSES. Probing questions were added as appropriate.

Phase Two Data Collection

Instructor Survey

Qualitative data from the online instructor survey consisted of instructor responses to two sets of two open-ended statements: *I believe I am a good teacher of writing because…* (n = 65), *I doubt I am a good teacher of writing because…* (n = 53), *I can teach science writing because…* (n = 65), and *I cannot teach science writing because…* (n = 48). Almost all instructors (n = 71) responded to at least one of the statements; however, not all instructors responded to every statement.

Interviews

Four interview candidates, two instructors identified as Early Adopters and two instructors identified as Early Majority, were selected using a random number generator. Of the instructors having TSES scores above the group mean, none were classified as Innovators; 10 of 13 Early Adopters and 16 of 24 Early Majority instructors had agreed to further contact and provided contact information. Potential interview candidates were contacted at least twice, either by phone, email, or both. Interview candidates who did not volunteer to participate further in the study were replaced with another randomly selected instructor that fit the initial criteria. Interview candidates were emailed the pre-identified questions in advance of the interview to give them time to consider their answers in preparation for the interview. Interviews were conducted over the phone and all instructors interviewed agreed to have their interview audio recorded and transcribed.

Phase Two Data Analysis

Instructor Survey

Instructor responses to the two sets of two open-ended statements were coded as one data set. All instructors responded to at least one of the open-ended statements, but not necessarily all four statements. These statements included the following: *I believe I am a good teacher of writing because…* (n = 65), *I doubt I am a good teacher of writing because…* (n = 53), *I can teach science writing because…* (n = 65), and *I cannot teach science writing because…* (n = 48). I read over responses to the open-ended statements on the survey several times and took notes on common response categories, developing several codes. Once these codes were well-established, I condensed them in no particular order into seven themes (see Table 4), which were then reviewed by an independent coder. Cohen's kappa was computed for each coder pair and then averaged. Pre-discussion, inter-rater reliability was moderate ($\kappa = 0.49$); after discussing each case and reconciling the differences between instructors as teachers and instructors as writers, coders were able to reach agreement such that inter-rater reliability was excellent ($\kappa = 0.86$).

Table 4

Open-ended Statement Themes

Theme	Description
Value of writing (1)	Writing is part of science Writing is an important skill Instructor understands science writing Instructor mentions or illustrates misunderstanding of science writing
Mastery experience and skill development in teaching science writing (2)	Instructor has experience or practice teaching science writing as evidenced by direct mention of teaching, evaluating, or creation of resources Instructor has experienced professional development in science writing instruction Instructor has not had direct instruction/professional development in science writing instruction
Ethos in science writing (3)	Instructor has prior personal experience with writing or science writing or mentions lack thereof Instructor mentions feelings about writing (enjoys/dislikes) Instructor mentions personal writing proficiency or limitations thereof
Writing part of curriculum (4)	Instructor assigns or uses some kind of writing in his/her class Instructor mentions using writing to learn strategies Instructor feels s/he does not use enough or the right type of writing in class
Writing to Learn (5)	Instructor acknowledges writing as a process Instructor includes opportunities for peer review or revision
Barriers to integrating writing (6)	There is not enough time to teach/assign/evaluate writing as part of the curriculum
Student Response (7)	Students show evidence of progress in writing, or lack thereof Mention of student motivation Students are too distracted to write well (e.g. by technology)

Interviews

With interviewee permission, I audio recorded each interview and then transcribed each recording. Following the data spiral (Creswell, 2007), I listened to and read each interview several times, making notes on each response. As I read each interview, I took notes on each instructor's responses such that I could identify certain categories or codes that were prevalent. After considering these codes, I condensed them into five main themes, again in no particular order (see Table 5).

Table 5

Interview Themes

Theme	Description
Writing in the Discipline	Values science writing Focused on format and content Few opportunities for revision
Writing Instruction	Lecture Examples Offer of pre-deadline review and feedback Office hours available for feedback
Evaluation and Feedback	Provides feedback to students Use of rubrics and grading criteria Does not see instructor as responsible for grammar
Professional Development	Attends workshops Discusses with colleagues
Barriers	Extrinsic Student motivation or preparation Time

Phase Two Results

Instructor Survey

After reading science instructor responses to the four open-ended statements on the online survey, seven themes repeated themselves throughout with both positive and negative aspects, depending upon the question. In this case, positive indicates instructors reporting understanding, comfort, or power to act whereas negative connotes a lack of understanding, comfort, or power to act as reported by instructors, not any judgment upon the instructors themselves. These themes included an inherent value in writing as part of science, experience and development in teaching science writing, personal experience and development as a writer, including writing as part of the science curriculum, exhibiting a writing to learn philosophy, barriers to including writing in the science class, and direct or indirect student responses to writing in science (see Table 4).

Several instructors mentioned *valuing writing* as an important skill for students and as an important part of science. One instructor wrote, “I feel personally that science writing is very important and an integral part of the learning process” (0249). Many also professed being passionate about their discipline and wanting to pass that excitement on to their students. Other instructors did not consider science writing an important part of their course or lacked a clear definition of science writing, reporting “…it takes too much time and is only a minor part of my job description” (0230) and “I focus on teaching the concept of the course material and not so much on the grammatical expression of stated concepts” (0225).

Instructors with *experience in science writing instruction* often reported specific aspects of their teaching experiences, “When given the opportunity, I can convey information to students about improving their writing” (0224) professional development experiences, “Through my support network and reading literature regarding the teaching of writing, I feel that I have worked towards implementing strategies that have been shown to be effective by others” (0249) and access to or development of science writing resources, “I have spent three semesters developing a successful scientific writing technique with students in Introductory Biology for Majors classes” (0229).

Many instructors indicated a lack of specific development in teaching science writing, “I am not an English teacher” (0253) and “I have not had any formal training in the subject” (0229).

With regards to *experience as writers*, instructors overwhelmingly identified as proficient and successful in writing. “I have experience writing research articles and research proposals. My articles are accepted in peer-reviewed journals” (0121) was not an uncommon remark among science instructors. Less frequently, some felt their writing experience was less than other instructors, “I was never a first author” (0247) or “I’m a terrible writer” (0219).

Instructors who *made writing part of their curriculum* reported doing so in a variety of ways ranging from “I teach students to write their final answers in complete sentences using the context of the problem and the correct units” (0215) to “I teach a variety of types of writing: popular articles, questionnaires, scientific papers, song lyrics” (0266).

In some cases, instructors specifically mentioned including *writing to learn* aspects of writing including acknowledging writing as a process and giving students opportunity for feedback and revision. Others sincerely regretted not being able to incorporate this aspect. One instructor mentioned, “I don’t have enough opportunities for feedback and rewrites that would mimic actual manuscript (science) writing” (0236). Many instructors seemed to feel their efforts at including writing were inadequate, explaining “Some of our writing requirements are typical and one-dimensional” (0243), whereas others did not include writing in their courses at all.

Instructors mentioned several *barriers* to integrating writing in their courses, including the need to cover information, “I do not focus on teaching writing because I focus on teaching my science courses” (0203) and time restrictions. Many instructors mentioned issues similar to, “It is hard to find time to do the in-depth feedback students need to become better writers” (0241) or

> I feel like I let my students down because I am not always willing to go the extra mile with opportunities for feedback and practice. I hope to get better in the future, but it is difficult to simultaneously manage with the other priorities of the university. For example, my introductory course is jumping from 80 to 220 students. This doesn’t fit well with a university commitment to writing, especially with no incentives provided for all the extra time it would take to seriously incorporate a strong effective writing component. I can’t do that the way I like and still keep the lights on in the lab. (0249)

Despite these barriers, *student success* was often evidence of personal mastery in science writing instruction as instructors reported believing themselves good instructors of writing because “the quality and efficacy of the writing students do during my writing classes steadily improves” (0271). However, student proficiency in and motivation towards writing were often cited as barriers, frustrating some instructors. Several instructors reported, “I find it comes to me easily and my students are far less well read” (0226) and “I hate grading content that is poorly written” (0270). Another instructor wrote, “I have high expectations and am not as patient/tolerant of students with low motivation as I should be” (0212).

When considering instructor responses to *I believe I am a good instructor of writing…* according to their science writing efficacy score, a general pattern emerged from the 65 instructors who responded (see Table 6). Early Adopters believed themselves to be good instructors of writing because they have experience teaching science writing, are successful writers themselves, use writing with their students, and value writing. One instructor in particular sums up the demeanor of this group, writing “When given the opportunity, I can convey information to students about improving their writing. I set a good example with my own writing. I feel motivated to enhance my current skills and pass on that energy to my students” (0224). Instructors classified as Early Majority are also experienced instructors of science writing, successful writers, and integrate writing into their courses, e.g. “I offer multiple assessment opportunities. These include tests with essay components, but also summaries of primary literature and case studies” (0242). Early majority instructors also report evidence of student success and positive feedback, e.g., “Student course evaluations have consistently reported that they became much better writers as a function of taking my courses. Students I have mentored in writing have successfully published their work in top-tier journals” (0244). Late Majority instructors believed themselves to be good instructors of writing because they have personal experience as writer and as a teacher of science writing, though many were less specific in their comments, e.g. “I am a good writer and have a lot of experience” (0241). Instructors classified as Late Mass responded similarly, emphasizing their experience as writers and teachers of science writing.

Table 6

Instructor Responses to I believe I am a Good Instructor of Writing Because…

Enumerated by Theme.

		Themes						
RDI Classification	*n*	1	2	3	4	5	6	7
Early Adopter	13	4	7	7	7	1	0	3
Early Majority	24	3	14	11	6	5	0	6
Late Majority	20	0	11	13	3	2	0	0
Late Mass	8	0	4	4	1	1	1	1

Note. RDI = Rogers Diffusion of Innovation.

Fewer instructors (53) responded to *I doubt I am a good instructor of writing because…* (see Table 7). Several Early Adopters and Early Majority instructors did not respond to this statement or specifically indicated that they had no doubts. Early Adopter instructors that did respond to this prompt generally discussed barriers to implementing writing in their science courses, specifically time management, the need to cover content, and student motivation. One instructor wrote,

> I struggle to fit the types of feedback and practice for writing into my time management strategies for my overall balance of teaching, so I know I am not providing as many opportunities for feedback and practice as I should (which students then interpret as it's not as important to me, and thus them) (0249).

Instructors classified as Early Majority also indicated student motivation as a barrier. In addition, these instructors found students generally unprepared as writers and themselves needing additional professional development in science writing instruction. Likewise, Late Majority teachers noted their lack of formal professional development in science writing instruction along with significant time and student barriers. Late

Majority teachers also mentioned feeling inadequate as writers or struggled to communicate the process by which they themselves learned how to write scientifically.

> Writing comes fairly naturally for me, and I feel unable to 'teach' the skill. Many of my students have such a poor grasp of written grammar that I find myself focusing on the easy-to-correct copy edits, rather than the much-harder-to-improve organization and understanding. I do not have (or take) the time to send everything through the multiple revisions real improvement requires. (0230).

Instructors classified as Late Mass primarily reported a lack of training in how to teach science writing, some struggling with the same issues of making the tacit explicit as their Late Majority colleagues.

Table 7

Instructor Responses to I Doubt I am a Good Instructor of Writing Because… Enumerated by Theme.

		Themes					
RDI Classification	*n*	2	3	4	5	6	7
Early Adopter	6	0	1	1	1	3	2
Early Majority	18	7	3	2	0	4	5
Late Majority	20	9	5	2	2	5	7
Late Mass	9	5	2	2	0	2	2

Note. RDI = Rogers Diffusion of Innovation.

Sixty-five instructors completed the statement *I can teach science writing because…* (see Table 8). Of these, Early Adopters indicated they could teach science writing because of their experience as science writers and their experience and ability as an instructor of science writing, focusing particularly on paying attention to student needs in writing. These instructors also indicated that they valued writing as a skill and learning tool.

> I care deeply about writing and have spent my entire career working to improve my writing. I have written a great deal in a variety of venues and have studied writing intensively. I have also invested a lot of time listening to the problems students have with scientific writing. I design my course not solely around my own preconceptions of what the students need but take great account of what they say their problems are and of what problems I have observed during almost 40 years of teaching. (0271).

Early Majority instructors also indicated experience as science writers and instructors of science writing, e.g. “I myself write well and I try to be very clear to students regarding my expectations” (0207). Most Late Majority instructors indicated that they can teach science writing because they themselves are experienced science writers or aware of scientific writing conventions and value writing. Late Majority instructors also indicated their experience as science writers and mentioned specific actions they could take as instructors of science writing, e.g. “I recognize good science writing and can help students identify components of good writing” (0205).

Table 8

Instructor Responses to I Can Teach Science Writing Because… Enumerated by Theme.

		Themes						
RDI Classification	*n*	1	2	3	4	5	6	7
Early Adopter	13	4	5	8	1	1	0	2
Early Majority	23	2	7	21	1	2	0	2
Late Majority	21	6	3	15	1	0	1	1
Late Mass	8	1	3	4	1	0	0	0

Note. RDI = Rogers Diffusion of Innovation.

Finally, only 48 instructors completed the statement *I cannot teach science writing because…* (see Table 9). Early Adopters indicated time as the primary barrier to incorporating writing into their science courses. Early Majority and Late Majority instructors agreed, particularly with regards to the time needed to grade student writing. Both groups of instructors also expressed a lack of professional development, notably "I don't know the pedagogy for teaching students how to write. I'm not a writing teacher" (0253). Finally, instructors classified as late mass reported student ability, time, and lack of training as barriers to integrating writing into their science courses. One instructor noted, "It's not my job. I'm quantitative" (0219) and another indicated student response as problematic, "Students downgrade me on evaluations if they do not get their grades back in 24 to 48 hours. Writing cannot be graded that fast" (0270).

Table 9

Instructor Responses to I Cannot Teach Science Writing Because… Enumerated by Theme

		Themes					
RDI Classification	*n*	1	2	3	5	6	7
Early Adopter	6	0	0	1	1	3	0
Early Majority	15	1	5	2	0	4	2
Late Majority	19	4	7	1	2	7	3
Late Mass	8	0	2	0	0	4	3

Note. RDI = Rogers Diffusion of Innovation.

High Efficacy Case Studies

Andy was identified as an Early Adopter as categorized by his TSES score (TSES = 8.6) with a slightly above-average perception of himself as a writer (WSPS =

148). At the time of the interview, Andy had recently earned tenure and was an associate professor in the science department at a small, private faith-based college focused on teaching. Any research Andy essentially conducted was on his own time, and he did have a few research publications as a result. At the time of the interview, Andy had over twenty years of teaching experience and maintained membership in a discipline-specific national teaching organization. His background was primarily in biology and science education, which was the focus of his masters and doctorate degrees. Andy taught several biology courses for his department, primarily for majors. Between the fall and spring semesters, Andy taught history of science, microbiology, anatomy, physiology, capstone, and a biology course for non-majors with class sizes ranging from 5 – 25 students. Andy also had a group of students who work with him on independent research projects over the summer. Not all of his courses included writing, particularly anatomy and physiology, which were focused on providing content for students planning on pursuing degrees in various medical fields. Within his other courses, Andy typically assigned research projects and lab reports, some of which were group rather than individual projects.

Gene was a tenured professor in an earth sciences department at a large, Research I university. According to his TSES score (TSES = 8.5), Gene was classified as an Early Adopter with slightly below average perception of himself as a writer (WSPS = 138), due primarily to low physiological state scores on the WSPS. At the time of the interview, Gene was a full professor and had been teaching over twenty years. He had over twenty publications within his field and even had a few pedagogy publications based on an outreach project using writing to help upper elementary age students learn science. At his university, Gene's time was officially divided into 40% teaching, 40% research, and 20% service and Gene taught four courses each year, two in the fall and two in the spring. Most of Gene's courses were general education credits. He taught a large freshman level introductory, lab-based course for his department with approximately 120 students and a similar junior level course with around 35 students. Gene also taught a science and society upper level/graduate course with 35-40 students and a statistical analysis course of approximately 40 students. His only non-general education course was capstone, which currently has over 35 majors due to a new degree offering within the department. Gene assigned writing in all of his courses (including the large freshman course), which he graded himself. Most of his courses required a term paper, except for his freshman course where he assigned concept sketches. Gene's doctorate was within his field, but once he earned tenure, he began to attend workshops on instructional design and teaching methods pertinent to his courses. He also maintained membership in several national and international professional earth science organizations.

Kathy was also a professor in a biology department at a large Research I university, although she was at the beginning of her career. Kathy had taught for three years and according to her TSES score (TSES = 7.1) was Early Majority with a moderately higher than average perception of herself as a writer (WSPS = 153). Kathy had several research publications and maintained membership in a national professional organization within her field. As an assistant professor, Kathy taught two majors courses for undergraduates, a field-specific developmental genetics course and a cell biology lab course, as well as some graduate-level courses. Her class sizes typically included 15-25 students. Including writing in her courses was important to Kathy because of the strong writing background she gained in her undergraduate honors program. Kathy reported that the writing assignments in her courses are still under development but at the time of the interview she had her genetics students write a mini-research proposal. With her cell biology students, Kathy and her colleague, who team-teaches the course with her, assign mini-results sections throughout the semester and then have students write a research paper as their final exam grade.

Brian was a professor nearing retirement at a medical campus for a large Research I university. According to his TSES score (TSES = 6.9), Brian was identified as Early Majority and had a perception of himself as a writer that was moderately higher than average (WSPS = 159). Brian had taught over twenty years; he had several research publications and a few published books within his field. At the time of the interview, Brian had given up his lab and did not directly advise any graduate students, but continued to enjoy teaching in the medical campus and at a local community college. He also maintained memberships in several national and international professional organizations within his field of science. At the medical school, Brian taught two primary courses, an entry-level content-based course for medical and graduate students and a week-long immersion class following the content course for 10-15 graduate students. At the community college, Brian taught the sole non-laboratory science course that most students used to fulfill their science requirement. For Brian, giving his graduate students an opportunity to practice writing was extremely important. In addition to having them create and present a formal presentation on a specific topic, he also began having his students write a review paper summarizing the literature over their topic. However, he does not include writing in the content course, because of the focus on content and because the program uses exam software to assess the students. For his community college course, Brian had tried to institute writing assignments, but was met with resistance from students and ultimately returned to other forms of assessment.

All four instructors integrated writing into their science courses, although for some, integration was context-specific and related to the goals of the course. For instance, whereas Kathy and Gene included writing in all of their courses, Brian and Andy both noted that the goal of some of their courses was to provide students with content such that they did not assign or include writing projects within the course.

> How important is it to [instructors] that their students can properly write? I'm sure for some, depending on the subjects they're teaching, it may not be nearly as important in other areas… Like my anatomy class… pretty much fact-based, just learning, learning, learning. No formulas to figure things out and not any writing really to speak of other than essay questions on a test. (Andy)

As Andy did include essay questions however, this response potentially points to a potentially narrow definition of science writing, i.e. the lab paper or term report. In Brian's case, he had previously included writing, in the form of discussion questions, as part of his community college course. A lack of student progress and poor evaluations eventually caused him to choose another means of assessment.

> The ones that were interested in science generally were the ones that could do a better job of writing, but the more I thought about it, if you're going to go into computers writing code, I mean, how important is it to learn how to communicate in writing? Or business? …I probably would have continued to do it had I not started to get the comments on the evaluations… it was becoming obvious to me that there were certain students that really did not like the idea that they had to write discussion questions and they were losing points because they weren't writing correctly. … I love the topic, so I decided okay, I want to keep teaching. So, I'll just change the way I'm testing. It's not killing anybody. They're not going to go out there and… be scientists. (Brian)

The primary writing these four instructors asked of their students was based on *Writing in the Discipline* to help their students communicate like scientists. Kathy's writing assignments consisted of the introduction, methods, results, discussion (IMRD) scientific article. Gene also followed the IMRD model in his upper-level courses, particularly the capstone. "So I try to emphasize essentially, again going back to the scientific method..." (Gene). Andy was less focused on IMRD, but still pointed students towards writing like a scientist.

> I wrote a paper on Darwin and Wallace, who should get credit for the theory of natural selection and use that as an example… That's a problem in the history of science, and so [I] pull out some papers, not just mine but others as well that are interesting, to show the format and to show them topics and the like. (Andy)

Finally, for Brian, having his students move from oral presentation to written is an essential part of molding them into professionals.

> But you can be absolutely horrible at writing information and that impacts whether you're able to publish material, whether you're able to get funding – it just cripples you…. Science is complicated. It's a complex subject, it's hard to explain it orally, it's hard to explain it in writing as well. And for someone to be a really good scientist, they have to do both, but it's not easy. (Brian)

In addition to assigning writing, each professor spent time *instructing their students in science writing*. For some, this was explaining science writing in general, and for others it was making sure students understood the requirements of the assignment. When Kathy instructed her students in writing, she spent

> a good half hour or forty-five minutes going through, "Okay, you need an abstract. This is what you need to include in your abstract. This is the introduction, this is what you need to include in the introduction and so forth." So I have them write it like a scientific article and so I think the students were pretty happy with the directions that they got from me. (Kathy)

Brian also points his graduate students toward the literature when teaching them how to write their review paper. He reported

> So I will give them a review article…I say, “Okay, you got your papers, I want you to do the same thing this article has done here now and summarize what you did. What you gave me orally I want you to do now in written form.” (Brian)

For his classes that wrote a research or term paper, Gene also spent a class period discussing how to write a scientific paper. Given his broader audience however, his assignments tended to focus more on writing to learn strategies, which I include here as instruction rather than a writing assignment. The concept sketches he used with his students were short assignments asking students to draw a process and describe their sketch. In his statistics course, Gene assigned writing to help his students connect meaning to their analyses, a technique that he now applies to all of his courses. “It started with that course and I’m thinking ‘Oh gee, I’m teaching these science courses to non-science majors… how do I get them to take scientific information and process it and synthesize it?’” (Gene). In his non-majors biology course, Andy also assigns lab reports for this purpose. “I have them write lab reports because a lot of them have a very poor background in science and so through the course of the semester, as they’re the scientists in laboratory, I have them write lab reports following a specific format that actual scientists would utilize” (Andy).

When *evaluating their students’ writing*, each professor tended to use predetermined criteria. For Kathy and Andy, these criteria were formalized into rubrics. Kathy broke her primary criteria into content and general writing, and Andy similarly focused on paper format, creativity, content, organization, and research methods. Gene pays attention to many of the same criteria, although he considers each paper holistically. As Brian’s course is evaluated on a pass/fail basis, his primary objective is to give his students a chance to practice communicating information in writing and then self-evaluate by listening to a recording of the presentation they gave and comparing it to their paper.

> I go over it and I actually discuss with them, but I let them, rather than me saying this and that, the way it should really be, is I let them come to that conclusion…. I let them listen to what they had to say about the material and then when they read it they say, "Oh, well yeah, I probably should have changed the wording on that." Rather than me saying "No, this is the way you should do it," which is what my mentor did to me. I mean, I'd send it in and he'd send it back and sometimes it was multiple rounds. (Brian)

With the exception of capstone courses, all four instructors provided feedback only after the students handed in the final product, although Kathy, Andy, and Gene mentioned holding extended office hours and giving students the option of turning a draft of their paper in prior to the deadline to receive feedback for revision. Given the lack of response from the majority of her students, Kathy discussed her plans to change the structure of this assignment in the future.

> In the future what I would do is to make them turn in first an outline… and then they have to turn in a rough draft… after they get them back, there will be another two weeks before the final paper is due. At the end [of last semester] I was like "Gosh that was silly, because now they didn't learn anything from doing it. It was busy work." (Kathy)

With their capstone courses, Andy and Gene both broke the students' research projects and papers into smaller steps, provided feedback throughout the process, and met individually with each student once a week or every other week to discuss progress. When giving feedback to students however, one thing none of the instructors generally focused on was grammar. Andy included following grammar and spelling rules as part of his rubric and Gene mentioned that poor grammar throughout a paper would bring a student's grade down. In instances of generally poor writing, both instructors sent their students to their institutions' success or writing center for in-depth assistance. Kathy also referred her students to the university's writing center, as

> to me, the challenging thing is the actual English part of the writing… Maybe [I] don't always give them the feedback about like sentence structure and things like that, that's how they should be outlined, but I'm not an English teacher. I know what sounds good to me, but I think maybe that is most challenging. How to combine the two, that they're not just getting the content presented but also in the way they write it too. (Kathy)

Brian also stressed that writing skills are primarily the purview of the English department. When asked where the graduate students in his course could get help with their writing, he replied,

> That would be their major advisor…. I'm just thinking back to my situation… [My advisor] was the one that provided feedback to me on how to do it correctly, but that was just one person…. I think it would be better if you did it this way. (Brian)

Another commonality among the four instructors was a general openness to *continual development* of themselves as teachers and of their courses. Gene attended several workshops, one on integrating writing into statistics courses and another "about how do you teach science to non-science majors and part of that was on writing" (Gene). Kathy discussed ways to improve student writing with other instructors, "one of my colleagues who's tried doing some peer review exercises with her students… I've played around with some ideas like that as well" (Kathy). Brian also talked about "the possibility of discussing what other people are doing with their immersion… courses for the graduate students" (Brian). Andy also has occasional discussions about writing with instructors teaching the same courses and when I asked about giving students opportunity for revision during the interview, he responded with "That's probably a good idea" (Andy).

Regardless of their current practices and high science writing efficacy beliefs, each instructor faced *barriers* to integrating science writing into their courses. By far, the biggest barrier for each instructor was the writing proficiency and motivation of students. Kathy, Andy, and Gene all typically sent poor writers to their institutions' writing or success centers as a means of overcoming this barrier and for Brian's graduate students, advisors and other graded courses helped resolve many of their writing needs. For his community college students however, Brian did not overcome this barrier, primarily because he stood alone in this requirement.

> I did use essay questions and some of [the students] were actually fairly decent, but most of them were just absolutely horrible. I mean, they had no writing skills at all and were really starting to complain because they weren't able to get the grades without it. "Nobody else was doing this! You're ridiculous." And I realized they were true. I mean I taught [science], I wasn't teaching writing. So I went back to what everybody else was doing. "Just answer the question, alright? A, B, C, or D." No one in math and science said anything about it, I mean their approach has been "you can do whatever you want to do, you're the instructor." But the reality of the situation is that if your class isn't that popular, students spread the word and enrollment drops and, okay – do you really need to continue teaching? (Brian)

In addition to inadequate preparation, many of Gene's students were oriented towards environmental advocacy and a lack of objectivity among students was also a problem. To address this barrier, Gene discussed the issue in class when going over paper requirements and met individually with capstone students. He explained,

> We had one student wanting to… convince local farmers not to use GMOs. I said, "Well, that's not a research project. That's an advocacy project…. You can go interview them… but go in objectively and understand what's going on." In that case it was just three meetings of saying "That's not research, that's advocacy." (Gene)

Finally, for Kathy and Andy time was also a barrier to integrating writing, especially for Kathy as she was still pre-tenure.

> I really don't have time to do much grading of writing and feedback in really detailed ways. That's the thing I struggle with. I want them to write more, but I also, I mean I'm running a lab, I'm teaching, and I've got things going on. I don't have unlimited time also to have them do these pre-drafts of their paper and give them feedback, all of them. So I think that's what's really tricky. (Kathy)

Regardless, Kathy continued to integrate writing into her courses and decided to include a longer writing process. To overcome the issue of time, she instituted the use of a rubric and continues to refine that process as well.

Discussion

The goal of this study was exploration of post-secondary science instructor science writing instruction efficacy beliefs to provide a framework for future professional development, given the need, or requirement, for post-secondary science instructors to use writing and provide writing instruction and feedback within their area of study. Identifying antecedents to high science writing instruction efficacy beliefs will aid in creating effective professional development opportunities. To this end, I asked: What are science instructor science writing instruction efficacy beliefs? and What characterizes individuals with high science writing instruction efficacy beliefs?

Phase One

Modified TSES.

In seeking science instructor science writing instruction efficacy beliefs, I found that the science faculty who responded to the online instructor survey encompassed a range of low- to high-range beliefs. Since the survey was not compulsory, it is possible that most responses came from instructors interested in or already using writing in their science courses. The mean modified TSES and subscale scores for this group of instructors were higher than those found by Fives and Looney (2009) but compared to scores reported for K-12 teachers by Tschannen-Moran and Hoy (2001, 2007) during their construction of the original instrument or subsequent uses of the instrument in their studies, the scores for this group of faculty were lower.

Instructor Survey.

When examining the quantitative data for differences between science instructors with high and low science writing instruction efficacy beliefs, demographic, contextual, personal mastery, vicarious experience, and verbal persuasion variables from the instructor survey were not related to high science writing instruction efficacy beliefs. Fives and Looney (2009) found that female faculty had higher teaching efficacy than male faculty, but professional level and prior experience did not result in differences in teaching efficacy among instructors. Landino and Owen (1988) also found no correlation between faculty teaching efficacy and 12 potential antecedents, including gender, years of experience, number of articles and number of books.

Modified WSPS.

Instructors' mean perception of themselves as writers on the WSPS were slightly lower than what Harbke (2007) found using his Self-Efficacy for Scientific Writing (SESW) scale, though the comparison is very loose given the difference between the SESW and the WSPS.

Regardless, several studies argue that previous writing experience and lack of confidence in writing often blocks K-12 teachers in any discipline from teaching writing to students confidently and efficiently (Lavelle, 2006; Street & Stang, 2008, 2009; Usher & Pajares, 2008). Likewise, Ross and colleagues (2011) found that faculty who supervise graduate students often feel the same, that not being good writers themselves kept them from effectively teaching their graduate students how to write. However, in this study, instructors with high science writing instruction efficacy beliefs did not have significantly higher perceptions of themselves as writers (WSPS) than instructors with low science writing instruction efficacy beliefs. Neither did teachers with high science writing instruction efficacy beliefs have more publication experience, specific science or technical writing courses, or graduate-level experience than teachers with low science writing efficacy beliefs, other potential indicators of writing history from the instructor survey.

Phase One Planning for Phase Two

Given that efficacy beliefs are context-specific (Bandura et al., 1996; Tschannen-Moran & Hoy, 2001), it is not surprising that demographic and contextual variables from the online survey were unable to capture those elements most common to science instructors with high science writing instruction efficacy beliefs. Additionally, it is not the mastery experiences, vicarious experiences, verbal persuasions, and physiological states themselves that influence efficacy beliefs, but an individual's interpretation of those antecedents (Bandura, 1989), underscoring the importance of also collecting qualitative data to provide a richer picture of individual efficacy beliefs. For instance, Brian taught graduate students on a medical campus associated with a large university and undergraduates at a community college. With his graduate students, Brian was able to effectively implement writing as part of the curriculum, but did not persist in using writing with his undergraduates. Thus, the quantitative data were valuable in identifying cases of high science writing efficacy belief that merited in-depth exploration.

Phase Two

Instructor Survey.

As expected (Bandura, 1989; Bandura et al., 1996), instructors with high science writing instruction efficacy beliefs largely reported personal *mastery experiences* with science writing. Early Adopters and Early Majority instructors cited experience as a teacher of science writing and described using writing in their courses. As instructors of all efficacy levels reported their experience as a writer, even as a good writer, this variable is not unique to high science writing instruction efficacy. Rather, as Ross and colleagues (2011) reported, many science faculty learn writing via a slow acculturation into their disciplines and thus have trouble explicitly teaching students how to write for the discipline.

Also through this slow acculturation, faculty are perhaps isolated and remain within a certain cultural framework with little opportunity to gain *vicarious experience* in science writing instruction, something not specifically mentioned in instructor responses to open-ended statements (Fives & Looney, 2009). As Lerner (2009) notes, "the teaching of writing is intertwined with instructors' beliefs about knowledge making or epistemology" (p. 153). Because the nature of the American university is one of partitioned knowledge into separate disciplines (Bazerman, 2005), the predominant curriculum theory is perhaps *Scholar Academic Theory* (Schiro, 2013). Thus, instructors within a discipline have moved along a hierarchy from student to teacher to scholar and may expect to do the same with the students in their classrooms, beginning with teaching them the knowledge and ways of doing within the discipline (Schiro, 2013). Additionally, since the late 1800s, students have generally been perceived as deficient in writing primarily because of increasing standards of writing within higher education (Bazerman, 2005). Thus, within the responses of the instructors to the open-ended statements, vicarious experience presumably occurred through the enculturation of instructors into their disciplines and the Scholar Academic Theory, which shows itself among high-efficacy instructors as the need to cover content and finding students generally unprepared as writers. Enculturation into and separation of disciplines is also why many science instructors respond to writing integration with, *I'm not an English teacher*. Instead of seeing writing norms as specific to their own discipline, many instructors view writing as a general skill learned elsewhere (Carter, 2007).

Early Adopter and Early Majority instructors received *verbal persuasion* primarily through student feedback. This feedback also caused high efficacy instructors to modify their writing instruction and assignments to meet student needs. This is perhaps in contrast to a study that found student feedback had no significant impact on the motivation of social sciences and management faculty to participate in professional development workshops to reflect upon and improve their teaching (Young & Kline, 1996).

Physiological state appeared among instructor responses as an individual's value of and passion for science writing. For most faculty, oral and written communication is one of the top three most important skills undergraduates need to learn (Coil, Wenderoth, Cunningham, & Dirks, 2010). This sentiment is also consistent with Scholar Academic Theory, as to the scholar within discipline, the knowledge of the discipline has the potential to explain the surrounding world and the work of discipline is discovery (Schiro, 2013). Further, within Scholar Academic Theory, the goal for the student is not mere memorization of content, but to participate in the authentic processes that lead to discovery within the discipline. Where even instructors with high science writing instruction beliefs are held back however, is through more subtle evidence of physiological state impacts. Several high-efficacy instructors expressed concern over time barriers to teaching writing within their science courses. Although written for business faculty, deRond and Miller (2005) describe perfectly the journey towards tenure as a "race against time" (p 322) dependent on faculty members' contributions toward research through publication. Additionally, many science labs are funded primarily through large grants, thus as one instructor mentioned, "I can't [seriously incorporate a strong effective writing component] the way I like and still keep the lights on in the lab" (0249).

Interviews.

Gene and Andy described a wealth of *mastery experiences* implementing writing and writing instruction into their classrooms with examples of well-established science writing curriculum. While not formalized as part of a larger university initiative, Gene, Andy, and Kathy outlined expectations similar to those Carter (2007) reported among faculty implementing Writing in the Discipline strategies. As a novice instructor, Kathy was still building her repertoire of mastery experiences, but exhibiting resiliency when she saw areas of her curriculum that needed tweaking. In a K-12 setting, one would expect Kathy's novice status to result in lower efficacy (Soodak & Podell, 1997); however, as demonstrated by the quantitative portion of this study and similar findings (Fives & Looney, 2009; Shavaran et al., 2012), faculty efficacy remains fairly stable, regardless of teaching experience or professional level (e.g. tenured vs. non-tenured).

Most interesting perhaps, and indicative of the contextual nature of efficacy beliefs (Bandura, 1989) was the differing experiences of Brian between his graduate and undergraduate courses. Among the graduate students at the medical school, Brian experienced successful implementation of a writing requirement (mastery experience) and thus persisted and reported an intention to continue persisting in integrating writing into the graduate course. At the community college level however, Brian experienced unsuccessful implementation of a writing requirement and thus ceased to integrate writing into the undergraduate course, with no plans to reinstate the requirement.

Consistent with the findings regarding *vicarious experience* from the open-ended statement responses, the four instructors' inclusion of Writing in the Discipline strategies indicates perhaps a Scholar Academic curriculum theory in which students are given assignments designed to engage them in the processes and skills of the discipline (Schiro, 2013). Kathy likely gained vicarious experience during her undergraduate years as the Honors Biology program seemed to have had a significant impact on her personal teaching philosophy. Gene however, demonstrated a larger breadth of assignment types and purposes, possibly a result of his vicarious experiences gained in attending teaching workshops. Similarly, Weiss and Peich (1980) found that faculty widened their views of writing and writing to learn strategies after a five-day faculty workshop.

Accounts of *verbal persuasion* were largely lacking among these four faculty, except for Kathy, who co-taught one of her courses and had regular conversations with other faculty about improving student writing. As part of his workshop attendance, Gene also likely experienced verbal persuasion, but Brian and Andy remained relatively isolated, without participating in much discussion regarding student writing among their colleagues (Fives & Looney, 2009; Soodak & Podell, 1997). Again, in the context of his undergraduate community college course, Brian received negative feedback from his students and without adequate persuasion from the college or reports of other instructors integrating writing in their courses, Brian did not persist in implementing writing in his course.

Similarly, Brian likely experienced negative *physiological states* regarding his undergraduate course as his decision became a choice between integrating writing into his course and continuing to teach a beloved subject. However, given that writing was a normal part of the graduate program and the pass/fail nature of the course, Brian was able to act as more of a collaborator or guide for students (Chinn & Hilgers, 2000), perhaps a more relaxed state of mind. Similarly, Gene took more of a collaborative position, guiding students in their capstone research projects. Even though Gene regularly evaluated over one hundred assignments from his introductory freshman course, Gene reported that helping activism-oriented students approach research objectively was his largest barrier, which he solved primarily through conversation with students. For Kathy and Andy however, time was a barrier to integrating writing in their science courses, particularly in providing feedback to students. As a pre-tenure instructor, Kathy acknowledged the struggle to balance research, teaching, and life, a source of stress that many instructors have responded to by assigning less writing (Lerner, 2009).

Phase Two Relating to Phase One

Alone, the quantitative results largely indicated only whether or not an instructor had a particular experience, not how experiences were perceived. Thus, many low and high efficacy instructors shared similar experiences. But, as Bandura (1989) pointed out, perception and processing of experiences is what influences efficacy beliefs. The qualitative findings of this study achieved what the quantitative results did not: instructor perceptions of the issues surrounding science writing instruction within their classrooms. As this study depended upon self-reported data, next steps should include methods similar to Chinn and Hilgers (2000) who observed class sessions and analyzed course materials, including syllabi, writing prompts, and rubrics, for a more complete picture of writing instruction practices among faculty.

Conclusions

What are Science Instructor Science Writing Instruction Efficacy Beliefs?

Science writing instruction efficacy beliefs among the science instructors who took part in this survey ranged from low- to high-levels. Thus, the lowest efficacy instructors in this group felt that they could do nothing when teaching science writing and the highest efficacy instructors felt they had a great deal of influence when teaching science writing.

What Characterizes Individuals with High Science Writing Efficacy Beliefs?

Those science instructors with the highest science writing instruction efficacy beliefs valued science writing as integral to science and student learning. They were most characterized by a breadth of experience teaching and integrating writing into their science classes through both writing to learn and writing in the discipline strategies, with evidence of student success and positive feedback. Many instructors with high science writing instruction efficacy faced barriers to integrating science writing in their courses, implementing what they were able rather than eschewing writing altogether.

Many instructors who participated in this study noted a lack of professional development in regards to teaching their students how to write in the sciences. Considering the impact of professional development and the benefit received from discussing student writing with colleagues identified in the high efficacy case studies, it seems that most instructors might benefit from specific professional development opportunities. However, considering the time concerns also reported by a number of instructors, perhaps this professional development should take place within the structure of already existing schedules. Many departments have brown-bag seminars, journal clubs, or similar departmental functions. Inviting a colleague to discuss methods for grading student writing or reading an article on writing to learn, even once per semester would give instructors opportunity to collaborate on research *and* teaching, providing the *vicarious experience* and *verbal persuasion* that post-secondary instructors predominately lack.

References

Anderson, T., Varnhagen, S., & Campbell, K. (1998). Faculty adoption of teaching and learning technologies: Contrasting earlier adopters and mainstream faculty. *The Canadian Journal of Higher Education*, *28*(2,3), 71–98.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191.

Bandura, A. (1989). Regulation of cognitive processes through perceived self-efficacy. *Developmental Psychology*, *25*(5), 729.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In T. Urdan & F. Pajares (Eds.), *Self-Efficacy Beliefs of Adolescents (PB)* (pp. 307–337). Information Age Publishing.

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (1996). Multifaceted impact of self-efficacy beliefs on academic functioning. *Child Development, 67*(3), 1206–1222.

Bazerman, C. (Ed.). (2005). *Reference guide to writing across the curriculum*. West Lafayette, IN: Parlor Press : WAC Clearinghouse.

Bottomley, D. M., Henk, W. A., & Melnick, S. A. (1997). Assessing children's views about themselves as writers using the Writer Self-Perception Scale. *The Reading Teacher, 51*(4), 286–296.

Brammer, C., Amare, N., & Campbell, K. S. (2008). Culture shock: Teaching writing within interdisciplinary contact zones. *Across the Disciplines, 5*.

Bratcher, S., & Stroble, E. J. (1994). Determining the progression from comfort to confidence: A longitudinal evaluation of a National Writing Project site based on multiple data sources. *Research in the Teaching of English*, *28*(1), 66–88.

Bruner, J. S. (1996). *The Culture of Education*. Cambridge, MA: Harvard University Press.

Carter, M. (2007). Ways of knowing, doing, and writing in the disciplines. *College Composition and Communication*, *58*(3), 385–418.

Chinn, P. W., & Hilgers, T. L. (2000). From corrector to collaborator: The range of instructor roles in writing-based natural and applied science classes. *Journal of Research in Science Teaching*, *37*(1), 3–25.

Coil, D., Wenderoth, M. P., Cunningham, M., & Dirks, C. (2010). Teaching the process of science: Faculty perceptions and an effective methodology. *Cell Biology Education*, *9*(4), 524–535.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Los Angeles: Sage.

De Rond, M., & Miller, A. N. (2005). Publish or Perish: Bane or Boon of Academic Life? *Journal of Management Inquiry*, *14*(4), 321–329.

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication*, *28*(2), 122–128.

Fives, H., & Looney, L. (2009). College instructors' sense of teaching and collective efficacy. *International Journal of Teaching and Learning in Higher Education*, *20*(2), 182–191.

Gaskins, I. W., Guthrie, J. T., Satlow, E., Ostertag, J., Six, L., Byrne, J., & Connor, B. (1994). Integrating instruction of science, reading, and writing: Goals, teacher development, and assessment. *Journal of Research in Science Teaching*, *31*(9), 1039–1056.

Goddard, R. D., Hoy, W. K., & Hoy, A. W. (2000). Collective teacher efficacy: Its meaning, measure, and impact on student achievement. *American Educational Research Journal, 37*(2), 479–507.

Harbke, C. R. (2007). *Development and evaluation of the" Self-Efficacy for Scientific Writing" scale*. Washington State University.

Holliday, W. G., Yore, L. D., & Alvermann, D. E. (1994). The reading–science learning–writing connection: Breakthroughs, barriers, and promises. *Journal of Research in Science Teaching, 31*(9), 877–893.

Jerde, C. L., & Taper, M. L. (2004). Preparing undergraduates for professional writing. *Journal of College Science Teaching*, *33*(7), 34–37.

Kroen, W. (2004). Modeling the writing process: Using authentic data to teach students to write scientifically. *Journal of College Science Teaching*, *34*(3), 50–53.

Labianca, D. A., & Reeves, W. J. (1985). Writing across the Curriculum: The science segment: A heretical perspective. *Journal of Chemical Education*, *62*(5), 400.

Landino, R. A., & Owen, S. V. (1988). Self-efficacy in university faculty. *Journal of Vocational Behavior*, *33*, 1–14.

Landon-Hays, M. (2012, October 22). *I would teach it if I knew how: Inquiry, Modeling, Shared Writing, Collaborative Writing, and Independent Writing (IMSCI), a model for increasing secondary teacher self-efficacy in integrating writing instruction in the content areas* (Unpublished doctoral dissertation). Utah State University, Logan, UT.

Lankford, D., & vom Saal, F. (2012). Converting a biology course into a writing-intensive capstone course: Using collaboration between a professor and graduate teaching assistant. *Journal of College Science Teaching*, *41*(4), 14–22.

Lavelle, E. (2006). Teachers' self-efficacy for writing. *Electronic Journal of Research in Educational Psychology*, *4*(1), 73–84.

Lerner, N. (2009). *The idea of a writing laboratory*. Carbondale, IL: Southern Illinois University Press.

McLaren, I. A., Dyche, C. A., Altidor-Brooks, A., & Devonish, H. (2011). Survival or natural death? Issues related to the sustainability of Writing Across the Curriculum programmes. *Journal of Academic Writing*, *1*(1), 254–266.

Moffett, J. (1965). I, You, and It. *College Composition and Communication*, *16*(5), 243–248.

Monroe, J. (2003). Writing and the disciplines. *Peer Review*, (Fall), 4–7.

Moody, C., Obear, K., Gasser, H., Cheah, S., & Fechter, T. (2013). ACPA standards for demographic questions. ACPA Governing Board. Retrieved from http://www.myacpa.org/sites/default/files/Proposal-Demographic-Questions-and-Responses-2.pdf

National Center for Education Statistics. (2007). *Integrated Postsecondary Education Data System 2006-2007*.

Oklahoma State Regents for Higher Education. (2001). *Annual Financial Aid Report 1999-2000*.

Oklahoma State Regents for Higher Education. (2014). *Degrees of Progress: The State of Higher Education in Oklahoma 2013 Annual Report*. Publications Clearinghouse of the Oklahoma Department of Libraries.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an efficacy belief instrument for elementary teachers. *Science Education*, *74*(6), 625–637.

Rosaen, C. L. (1989) Writing in the content areas: Reaching its potential in the learning process. In J. Brophy (Ed.), *Advances in research on teaching, Volume 1. Teaching for Meaningful Understanding and Self-Regulated Learning* (pp. 153-194). Greenwich, CT: JAI Press.

Ross, P. M., Burgin, S., Aitchison, C., & Catterall, J. (2011). Research writing in the sciences: Liminal territory and high emotion. *Journal of Learning Design*, *4*(3), 14–27.

Russell, D. R. (2002). *Writing in the academic disciplines: A curricular history*. Carbondale, IL: Southern Illinois University Press.

Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: creating student-centered classrooms*. New York: Teachers College Press.

Schiro, M. S. (2013). *Curriculum theory : conflicting visions and enduring concerns*. Los Angeles [u.a.]: SAGE.

Schrum, L., & Levin, B. B. (2012). Strategic leadership: Encouraging and assessing technology integration. In L. Schrum (Ed.), *Educational technology for school leaders* (pp. 41–58). Thousand Oaks, CA.: Corwin Press.

Shavaran, S. H. R., Rajaeepour, S., Kazemi, I., & Zamani, B. E. (2012). Development and Validation of Faculty Members' Efficacy Inventory in Higher Education. *International Education Studies*, *5*(2), 175.

Soodak, L. C., & Podell, D. M. (1997). Efficacy and experience: Perceptions of efficacy among preservice and practicing teachers. *Journal of Research and Development in Education*, *30*(4), 214–221.

Soven, M. (1988). Beyond the first workshop: What else can you do to help faculty? *New Directions for Teaching and Learning*, *1988*(36), 13–20.

Stock, P. L. (1986). Writing across the Curriculum. *Theory into Practice*, *25*(2), 97–101.

Street, C., & Stang, K. (2008). Improving the teaching of writing across the curriculum: A model for teaching in-service secondary teachers to write. *Action in Teacher Education*, *30*(1), 37–49.

Street, C., & Stang, K. K. (2009). In what ways do teacher education courses change teachers' self confidence as writers? *Teacher Education Quarterly*, *36*(3), 75–94.

Sullenger, K. S. (1990). *Science teachers' perspectives about writing in science* (Unpublished doctoral dissertation). University of Georgia, Athens, GA.

Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, *17*(7), 783–805.

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, *23*(6), 944–956.

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, *68*(2), 202–248.

Tschannen-Moran, M., & MacFarlane, B. (2011). I know I can! Teacher self-efficacy in the English language arts classroom. In D. Lapp & D. Fisher (Eds.), *Handbook of research on teaching the English language arts* (pp. 218–223). New York: Routledge.

Tsui, L. (1999). Courses and instruction affecting critical thinking. *Research in Higher Education*, *40*(2), 185–200.

U.S. Department of Education, National Center for Education Statistics. (2004). *Common Core of Data (CCD)*. Retrieved from http://nces.ed.gov/ccd/TableDisplay.asp?TablePath=tables/table_01.asp

Usher, E. L., & Pajares, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of Educational Research*, *78*(4), 751–796.

Walvoord, B. E. (1996). The future of WAC. *College English*, *58*(1), 58–79.

Weiss, R., & Peich, M. (1980). Faculty attitude change in a cross-disciplinary writing workshop. *College Composition and Communication*, *31*(1), 33–41.

Yates, S. J., Williams, N., & Dujardin, A. F. (2005). Writing geology: Key communication competencies for geoscience. *Planet*, *15*, 36–41.

Young, K., & Kline, T. J. B. (1996). Perceived self-efficacy, outcome-efficacy and feedback: Their effects on professors' teaching development motivation. *Canadian Journal of Behavioural Science, 28*(1), 43–51.

Appendix A – Manuscript II: Modified TSES (long form)

Teacher Beliefs Directions: This questionnaire is designed to help us gain a better understanding of the things that create difficulties for instructors in their science writing activities. Again, "instructor" is used in this section to indicate any individual teaching a post-secondary course. Please indicate your opinion about each of the statements below. Your answers are confidential.	**How much can you do?** Nothing		Very Little		Some Influence		Quite a Bit		A Great Deal
1. When teaching science writing, how much can you do to get through to the most difficult students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2. When teaching science writing, how much can you do to help your students think critically?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3. When teaching science writing, how much can you do to control disruptive technologies during class?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4. When teaching science writing, how much can you do to motivate students who show low interest in course work?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5. When teaching science writing, to what extent can you make your expectations clear about student use of technology in class?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
6. When teaching science writing, how much can you do to get students to believe they can do well in course work?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
7. When teaching science writing, how well can you respond to difficult questions from your students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8. When teaching science writing, how well can you establish routines to keep activities running smoothly?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9. When teaching science writing, how much can you do to help your students value learning?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10. When teaching science writing, how much can you do to gauge student comprehension of what you have taught?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
11. When teaching science writing, to what extent can you craft good questions for your students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
12. When teaching science writing, how much can you do to foster student creativity?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13. When teaching science writing, how much can you do to get students to follow guidelines for in-class technology use?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
14. When teaching science writing, how much can you do to improve the understanding of a student who is failing?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
15. When teaching science writing, how much can you do to intervene when technologies are disruptive?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
16. When teaching science writing, how well can you establish a flexible approach with each cohort/class/group of students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
17. When teaching science writing, how much can	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

	you do to adjust your lessons to the proper level for individual students?									
18.	When teaching science writing, how much can you use a variety of assessment strategies?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
19.	When teaching science writing, how well can you keep disruptive technologies from impacting the class?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
20.	When teaching science writing, to what extent can you provide an alternative explanation or example when students are confused?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
21.	When teaching science writing, how well can you respond to student users of disruptive technologies?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
22.	When teaching science writing, how well can you assist tutors in helping their students do well in class?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
23.	When teaching science writing, how well can you implement alternative strategies in your classroom?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
24.	When teaching science writing, how well can you provide appropriate challenges for very capable students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

Appendix B – Manuscript II: Instructor Survey

Items:	Response Type:
1. How do you describe your gender identity?	*open*
2. What is your primary (most proficient/fluent) language?	*open*
3. In what other languages are you proficient/fluent?	*open*
4. Name any college level courses you have taken on writing or the teaching of writing(list titles).	*open*
5. Have you ever participated in any workshops/inservice or professional development about the teaching of writing?	Yes, No, Other
6. In my primary science field, I have published approximately ___ research articles.	0, 1 – 5, 6 – 20, Over 20
7. I have published approximately ___ articles on my teaching (in a pedagogy journal, for example).	0, 1 – 5, 6 – 20, Over 20
8. I have published ___ books.	0, 1 – 5, 6 – 10, Over 10
9. Please describe any other experiences you consider significant with regards to the teaching of writing.	*open*
10. How many years of teaching experience do you have?	Less than 1, 1 – 5, 6 – 10, 11 – 20, Over 20
11. If you are currently teaching, which position type best describes you?	Graduate or Teaching Assistant, Adjunct/PT, Lecturer, Instructor (non-tenure track), Assistant Professor, Associate Professor, Professor, Professor Emeritus, Other
12. Which student populations have you taught? Select all that apply.	Majors, Non-majors/General Education, Freshmen, Sophomores, Juniors, Seniors, Graduate Students, Other
13. To what professional organizations do you belong?	*open*
14. Degrees and Concentrations:	B.A., B.S., M.A., M.S., Ed.D., Ph.D., Specialist, Other

Items:	Response Type:
15. At what type of institution do you currently teach? Please choose all that apply.	Public (under 10,000 students), Public (over 10,000 students), Private (under 10,000 students), Private (over 10,000 students), 2-year, 4-year, Online, Other
16. I teach (please select all that apply):	Courses within my discipline that include writing, Have a significant writing component (e.g. Capstone), The writing intensive requirement for my department, The course that teaches writing for the major, All the courses I teach are writing intensive by design, Other

Appendix C – Manuscript II: Modified WSPS

Directions: Listed below are statements about writing. Please read each statement carefully. Then choose the response that shows how much you agree or disagree with the statement. In this section, "instructor" is used to indicate any individual teaching a post-secondary level course.	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1. I write better than other instructors.	SA	A	U	D	SD
2. I like how writing makes me feel inside.	SA	A	U	D	SD
3. Writing is easier for me than it used to be.	SA	A	U	D	SD
4. When I write, my organization is better than other instructors.	SA	A	U	D	SD
5. People in my life think I am a good writer.	SA	A	U	D	SD
6. I am getting better at writing.	SA	A	U	D	SD
7. When I write, I feel calm.	SA	A	U	D	SD
8. My writing is more interesting than other instructors' writing.	SA	A	U	D	SD
9. Those who advise or evaluate me think my writing is fine.	SA	A	U	D	SD
10. Other instructors think I am a good writer.	SA	A	U	D	SD
11. My sentences and paragraphs fit together as well as other instructors' sentences and paragraphs.	SA	A	U	D	SD
12. I need less help to write well than I used to.	SA	A	U	D	SD
13. People in my life think I write pretty well.	SA	A	U	D	SD
14. I write better now than I could before.	SA	A	U	D	SD
15. I think I am a good writer.	SA	A	U	D	SD
16. I put my sentences in order better than other instructors.	SA	A	U	D	SD
17. My writing has improved.	SA	A	U	D	SD
18. My writing is better than before.	SA	A	U	D	SD
19. It's easier to write well now than it used to be.	SA	A	U	D	SD
20. The organization of my writing has really improved.	SA	A	U	D	SD
21. The sentences I use in my writing stick to the topic more than the ones other instructors use.	SA	A	U	D	SD
22. The words I use in my writing are better than the ones I used before.	SA	A	U	D	SD
23. I write more often than other instructors.	SA	A	U	D	SD
24. I am relaxed when I write.	SA	A	U	D	SD
25. My descriptions are more interesting than before.	SA	A	U	D	SD
26. The words I use in my writing are better than the ones other instructors use.	SA	A	U	D	SD
27. I feel comfortable when I write.	SA	A	U	D	SD
28. Those who advise or evaluate me think I am a good writer.	SA	A	U	D	SD
29. My sentences stick to the topic better now.	SA	A	U	D	SD
30. My writing seems to be more clear than other instructors' writing.	SA	A	U	D	SD
31. When I write, the sentences and paragraphs fit together better than they used to.	SA	A	U	D	SD
32. Writing makes me feel good.	SA	A	U	D	SD
33. I can tell that those who advise or evaluate me think my writing is fine.	SA	A	U	D	SD
34. The order of my sentences makes better sense now.	SA	A	U	D	SD
35. I enjoy writing.	SA	A	U	D	SD
36. My writing is more clear than it used to be.	SA	A	U	D	SD
37. Other instructors would say I write well.	SA	A	U	D	SD
38. I choose the words I use in my writing more carefully now.	SA	A	U	D	SD

Dissertation Appendices

Appendix A – Dissertation: Prospectus

Chapter 1: Introduction

At the secondary and post-secondary levels, there is an increasing demand for incorporation of writing in science classes, both as a writing to learn activity and as deliberate instruction in the forms and formats of the disciplinary discourse community (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010; Russell, 2002; Walvoord, 1996). Writing to learn is a central tenet of the Writing Across the Curriculum (WAC) movement, initially a grassroots teaching effort among university faculty (McLaren, Dyche, Altidor-Brooks, & Devonish, 2011; Monroe, 2003; Soven, 1988), which now often manifests as writing intensive (WI) course requirements from university administrations (Walvoord, 1996).

Similarly, the Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects (CCSS-ELA), adopted by 45 states, Washington D.C., 4 territories, and the Department of Defense Education Activity (Common Core State Standards Initiative, 2012) require secondary-level science teachers to incorporate literacy through reading and writing in their science lessons. Compared to other state-level standards, CCSS-ELA represents a considerable change with a moderate shift toward higher-level cognitive activity focused on analysis over performing procedures and placing increased emphasis on English, literature, and reading in history and science (Porter, McMaken, Hwang, & Yang, 2011).

Unfortunately, many science educators at the secondary and post-secondary levels lack confidence integrating writing instruction into their classrooms (Ross et al., 2011; Street & Stang, 2008). Low writing instruction efficacy often blocks educators in any discipline and at any level from teaching writing to students confidently and efficiently (Street & Stang, 2008, 2009). Secondary science teachers especially are often unfamiliar with writing norms within the scientific community and do not feel as well prepared to write (grammatically and mechanically) or teach writing as English teachers (Sullenger, 1990). Thus, many perceive skill in writing as a student responsibility and writing skill development as the purview of the English department (Sullenger, 1990). Similarly, post-secondary science educators resist incorporating writing and writing instruction into their science courses (McLaren et al., 2011) although they are typically proficient, published writers and have higher confidence in their own science writing (Harbke, 2007).

Gaskins and colleagues (1994, p. 1039) acknowledge that "the challenge of integrating the instruction of reading and writing into other subjects is formidable" (p. 1039). Transitioning from traditional methods of instruction to those that include writing to learn is often difficult (Akkus, Gunel, & Hand, 2007; Bratcher & Stroble, 1994) and to be successful and persistent in a new pedagogy, teachers must judge themselves capable of producing favorable outcomes in their classrooms or courses (Bandura, Barbaranelli, Caprara, & Pastorelli, 1996; Tschannen-Moran & Hoy, 2001). Regrettably, the writing instruction efficacy beliefs of science educators are generally low (Ross, Burgin, Aitchison, & Catterall, 2011; Sullenger, 1990), often keeping writing to learn practices out of classrooms and courses (McLaren et al., 2011; Walvoord, 1996).

Problem Statement

Upcoming and existing initiatives like the CCSS-ELA (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010), WAC (Walvoord, 1996), and WI courses (Russell, 2002) require secondary and post-secondary science educators to incorporate science writing instruction into their classrooms and curricula. In-service science teachers and current college-level science faculty are largely unprepared however, to teach science writing skills (Holliday, Yore, & Alvermann, 1994; Labianca & Reeves, 1985), presumably resulting in low science writing instruction efficacy beliefs (Bandura, 1993; Palmer, 2011). Thus, these educators will require appropriate professional development and support to implement writing requirements in their science classes (Akkus et al., 2007; Soven, 1988), especially since teacher efficacy beliefs often impact student performance (Bandura, 1989, 1993; Goddard, Hoy, & Hoy, 2004; Tschannen-Moran & Hoy, 2001). To develop effective writing instruction workshops and forums for educators in Oklahoma, we need to determine baseline science writing instruction efficacy beliefs and identify high efficacy-belief science educators to understand what strategies will be most helpful in developing science educator science writing instruction efficacy belief across the state.

Background and Need

Self-efficacy is the personal belief in one's ability to negotiate a stressful task (Bandura, 1977). Unlike a general sense of self-confidence or self-esteem, self-efficacy depends on context and is affected by perception of personal and vicarious experiences, verbal persuasion, and physiological state (Bandura, 1977). Within the specific context of the classroom, teacher efficacy belief is further defined as "a judgment of his or her capabilities to bring about desired outcomes of student engagement and learning, even among those students who may be difficult or unmotivated" (Tschannen-Moran & Hoy, 2001, p. 783). While teacher efficacy beliefs are so context-specific as to vary across individual classes, these beliefs can be influenced by perception of school climate, relationships with the principal, and a sense of instructional autonomy (Tschannen-Moran, Hoy, & Hoy, 1998).

Among the antecedents to self-efficacy beliefs, mastery experiences are the most powerful (Bandura, 1977). As individuals perceive success within a particular context, self-efficacy increases. Thus, previous negative writing experience often blocks educators from teaching their students to write (Street & Stang, 2008). Whereas establishing writer identity in secondary-level content educators can go a long way in improving self-efficacy in teaching writing to students (Street & Stang, 2008, 2009), post-secondary educators are typically proficient, published writers (Tang & Gan, 2005; Yates, Williams, & Dujardin, 2005). As these same educators may resist incorporating writing and writing instruction into their curricula (McLaren et al., 2011) writing instruction self-efficacy does not reside solely in personal writing skill.

Bandura (1977) indicates that in addition to personal success, vicarious experience and verbal persuasion also improve self-efficacy. Writing identity is often established early through these avenues; teachers in a National Writing Project (NWP) style graduate course remembered teacher feedback and writing for school experiences exclusively, which correlated strongly with self-confidence (Street & Stang, 2009). This often negative form of verbal persuasion and modeling (Ross et al., 2011) impacts later teaching philosophy and practice (Tschannen-Moran et al., 1998). Without adequate development and experience as a practitioner of writing, teachers are less able to engage students in authentic writing to learn activity (The National Commission on Writing in America's Schools and Colleges, 2003). At the post-secondary level, professors exhibiting low writing efficacy often expect students to learn science writing through mimicry and are unable to explain their role in writing beyond feedback and encouragement (Ross et al., 2011).

Encouraging educators comfortable with traditional teaching practices to incorporate student-centered methods like writing to learn can create significant cognitive dissonance (Akkus et al., 2007), which may be a barrier to changing educational paradigms (Fosnot & Perry, 2005). Traditional teachers are often concerned with content and correct answers; implementing student-centered practices requires relinquishing perceived control over student learning (Akkus et al., 2007). Likewise, career teachers are often anxious about assessing student work, unsure of the qualities of successful writing (Bratcher & Stroble, 1994). This integration requires that teachers change their role expectations and view of science (Gaskins et al., 1994). Knowledge of science alone is no longer sufficient; science teachers must also understand reading, writing, and thinking processes (Gaskins et al., 1994). Implementing new instruction is stressful for teachers (Gaskins et al., 1994), perhaps triggering physiological states with negative impacts on science writing instruction efficacy beliefs and locus of control (Bandura, 1977).

Persons with high self-efficacy beliefs however, often already have an internal locus of control, believing themselves capable of controlling themselves and their environment. As such, they are able to engage *threatening* or *risky* tasks, i.e. those with high outcome uncertainty (Bandura, 1989). Student-centered writing to learn programs initiated by educators as part of a grassroots movement (McLaren, 2011) thus point to innovators and early adopters (Sandholtz, Ringstaff, & Dwyer, 1997; Schrum & Levin, 2012) with high writing instruction efficacy beliefs. As teachers are encouraged to exercise an internal locus of control when given formal control of instructional decisions (leading to higher efficacy beliefs) (Goddard et al., 2004; Tschannen-Moran et al., 1998), identifying and understanding the strategies and attitudes of innovators and early adopters will aid administrators in providing appropriate supports for WAC programs, including professional development opportunities and peer mentorships/collaborations that can increase the writing instruction efficacy beliefs of so-called *reluctant converts* (McLaren et al., 2011).

Purpose of the Study

Purpose.

The goal of this sequential transformative mixed methods study (Creswell & Plano Clark, 2011) is to investigate secondary and post-secondary science educator writing instruction efficacy beliefs. I will use *post-hoc* analysis of demographics, writing efficacy beliefs, and science writing instruction efficacy beliefs to look for widespread patterns and correlations in science educator science writing instruction efficacy beliefs. From these surveys, I will identify science writing instruction innovators and early adopters (Sandholtz et al., 1997; Schrum & Levin, 2012) to interview, looking for detailed responses and attitudes toward implementing science writing instruction within a science classroom.

Rationale.

With a majority of U.S. schools (Common Core State Standards Initiative, 2012) implementing the CCSS-ELA (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) and a return of 41,500 hits for a Google search including the phrases *writing intensive courses* and *university*, writing requirements will likely continue to be placed on science education at both the secondary and post-secondary levels. Thus, surveying secondary and post-secondary science educators will provide an indication of writing instruction efficacy in the face of such requirements.

Additionally, secondary level educators with high efficacy beliefs typically indicate a supportive administration and collaborative, collegial environment (Goddard et al., 2004; Hoy & Spero, 2005), professional development (Akkus et al., 2007; Bratcher & Stroble, 1994), positive writing identity (Street & Stang, 2009; Sullenger, 1990), and an internal locus of control (Landon-Hays, 2012). Research on writing instruction efficacy beliefs of post-secondary science educators is limited (Heppner, 1994; Shavaran, Rajaeepour, Kazemi, & Zamani, 2012), and generalizing the antecedents of secondary level educator writing instruction efficacy is counterintuitive. Many post-secondary science educators have high writing efficacy beliefs (Harbke, 2007) which are not reflected in their writing instruction efficacy beliefs (Ross et al., 2011). Thus, interviews with secondary and post-secondary science educators with high writing instruction efficacy beliefs will provide insight for future professional development and instructional development of preservice teachers and future professors.

Description of the study.

This study follows a sequential transformative design, using self-efficacy (Bandura, 1977) as the framework (Creswell & Plano Clark, 2011). I intend to send the Teachers' Sense of Efficacy Scale (TSES), which focuses on teaching efficacy beliefs in three areas: instruction, classroom management, and student engagement (Tschannen-Moran & Hoy, 2001) via online survey links to the 426 Oklahoma school districts for distribution to middle/junior high and high school science teachers and to science departments in the 28 Oklahoma state colleges and universities for distribution to science faculty and graduate teaching assistants. Given the prevalent theory that writing history/identity correlates with writing and writing instruction efficacy beliefs (Landon-Hays, 2012; Street & Stang, 2009), I will also include a revised version of the Writer Self-Perception Scale (WSPS) (Bottomley, Henk, & Melnick, 1997). Minimum sample size is 305 participants divided equally among 5 groups (middle school teachers, high school teachers, graduate teaching assistants, two-year college faculty, and four-year college faculty) for a 95 percent confidence interval and an alpha of 0.05 (Faul, Erdfelder, Buchner, & Lang, 2009). Currently, I intend for the sample to be self-selected, acknowledging that this may result in low efficacy individuals opting out of the survey, especially among college faculty (Shavaran et al., 2012).

From the survey responses, I will interview science educators identified as having high writing instruction efficacy based on Rogers Diffusion of Innovation Model (Sandholtz et al., 1997; Schrum & Levin, 2012). As *innovators* and *early adopters* engage most readily with new ideas, they likely have higher efficacy beliefs (Schrum & Levin, 2012; Tschannen-Moran et al., 1998). Thus, I will choose interview candidates from those with writing instruction efficacy scores at least two standard deviations above the mean (Schrum & Levin, 2012). I will continue with this stratified purposeful approach until I have reached saturation; my initial goal is twelve science educators, six from secondary level institutions and six from post-secondary institutions (Gall, Gall, & Borg, 2007). I will base my interview protocol on Holliday and colleagues' (1994) modified questions from Rosaen to investigate teacher attitudes and interactions with writing in the sciences and Sullenger's (1990) seven perceptions that describe teachers' writing practices in science. During the interview, I will also add probing questions as appropriate.

Expected outcomes.

The data from this study will come from two different methods and will allow for triangulation of two different data types (Gall et al., 2007), lending strength to inferences based on both data sources. Piloting both the survey instrument and the interview protocol and questions ensures a measure of validity and reliability (Creswell, 2009; Gall et al., 2007; van Teijlingen & Hundley, 2001). I also expect independent peer-review of the study to reduce the chance of researcher bias. Given the limited sample sizes for the qualitative aspect of the study, I do not expect the results to be readily generalizable to all contexts (Gall et al., 2007); however this study will serve to create a picture of science educator science writing instruction efficacy beliefs across the state of Oklahoma and inform future professional development in science writing instruction for in-service science teachers and current college science faculty (Fives & Looney, 2009; Holliday et al., 1994; Shavaran et al., 2012; Sullenger, 1990).

Research Questions

The goal of this sequential transformative mixed methods study (Creswell & Plano Clark, 2011) is to investigate secondary and post-secondary science educator writing instruction efficacy beliefs to create a baseline for creation of appropriate professional development in science writing instruction for science educators in Oklahoma. This includes understanding the antecedents to high writing instruction efficacy beliefs among science educators such that these factors can be included in professional development plans. Thus, I ask the following questions:

1. What are science educator science writing instruction efficacy beliefs across secondary and post-secondary contexts?
2. What characterizes individuals with high science writing instruction efficacy beliefs?

Significance of the Study

Much attention is given to improving student writing in the sciences at both secondary and post-secondary levels (e.g., Keys, Hand, Prain, & Collins, 1999; Yates et al., 2005). However, writing intensive course requirements and new Common Core State Standards in English Language Arts (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) indicate that not all science educators implement science writing into their classes effectively, if at all. This lack of science writing instruction may be a result of low science educator science writing instruction efficacy beliefs, although few studies examine science educator efficacy in this specific context (Holliday et al., 1994; Ross et al., 2011; Sullenger, 1990). My study will provide a snapshot of the current level of science educator science writing instruction efficacy beliefs across Oklahoma and offer a unique perspective on the antecedents of high efficacy beliefs in this context.

Survey participants in my study will be offered the opportunity to reflect on their confidence in both writing and writing instruction, considering potential barriers and gateways to implementing writing in their science classrooms. Interview participants will have further opportunity to reflect on and share their thoughts on these topics, providing valuable data that can help shape future professional development opportunities in science writing instruction for both secondary and post-secondary science educators.

Definitions

Writing Across the Curriculum.

Writing Across the Curriculum (WAC) is a learner-centered movement that promotes "writing [as] a unique mode of learning" (Emig, 1977, p. 122) within all disciplines. As an active process, writing requires the learner to engage with material personally, cognitively, and kinesthetically (pen to paper) to carefully organize *inner speech* and create meaning (Emig, 1977).

Self-efficacy.

Self-efficacy is the personal belief in one's ability to negotiate a stressful task (Bandura, 1977). Unlike a general sense of self-confidence or self-esteem, self-efficacy depends on context and is affected by perception of personal and vicarious experiences, verbal persuasion, and physiological state (Bandura, 1977). Whereas early studies on self-efficacy focused entirely on locus of control, self-efficacy is a better predictor of outcome (Goddard, Hoy, & Hoy, 2000). Within a particular context, the magnitude, generality, and strength of efficacy expectations predict engagement, effort, and perseverance towards a task (Bandura, 1977; Bandura et al., 1996).

Limitations

Since I plan to use modified versions of the TSES and WSPS and neither survey instrument is specifically geared for my context of science writing instruction, I need to validate and determine reliability for any modifications. I will likely need to use two forms of the TSES, one for secondary teachers based on the original TSES (Tschannen-Moran & Hoy, 2001) and one for post-secondary instructors similar to the modified TSES (Shavaran et al., 2012). The WSPS was originally designed to measure self-perception of elementary grade writers; thus, the reading level of the survey will need to be increased.

For a 95 percent confidence interval and an alpha of 0.05 (Faul et al., 2009), the minimum sample size is 305 participants divided equally among 5 groups (middle school teachers, high school teachers, graduate teaching assistants, two-year college faculty, and four-year college faculty). According to Gall and colleagues (2007) who indicate a relatively high (66 percent) return for surveys of educators, this sample size should be readily achievable. However, a review of response rates to emailed surveys indicate mean response rates of 19 – 72% (Sheehan, 2001) with a more recent average of approximately 25-30% (Kaplowitz, Hadlock, & Levine, 2004).

Currently, I intend for the sample to be self-selected, although this may result in low efficacy individuals opting out of the survey, especially among college faculty (Shavaran et al., 2012). In addition, self-reported data is often incomplete as individuals can only offer their perspective on events and actions, filtered through their own biases and lenses (Denzin & Lincoln, 2003). Thus, individuals who report high self-efficacy on the survey and describe positive experiences in the interviews may describe an ideal that does not match reality.

Ethical Considerations

To avoid ethical dilemmas regarding participant confidentiality and risk (Esterberg, 2002), I will arrange all observations through the appropriate administrators for each institution. In addition, I will use pseudonyms and make all participants aware that they can withdraw their participation at any time, indicated on approved IRB consent forms.

Chapter 2: Review of the Literature

Introduction

Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects (CCSS-ELA) and writing intensive (WI) courses at the secondary and post-secondary levels, respectively, require science teachers to incorporate writing and writing instruction into their science classrooms (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010; Russell, 2002). However, many science educators exhibit low writing instruction efficacy beliefs (Ross et al., 2011; Street & Stang, 2008), and as such, often regard writing instruction as the responsibility of the English department (Labianca & Reeves, 1985; Sullenger, 1990). As most in-service science educators lack adequate preparation to teach science writing (Holliday et al., 1994; Labianca & Reeves, 1985), these educators require additional professional development (Akkus et al., 2007; Soven, 1988). In preparation however, we first need a baseline understanding of science educator writing instruction efficacy beliefs to provide the most appropriate and targeted professional development opportunities.

The literature review will address six areas related to low science writing instruction efficacy beliefs in the face of science writing requirements at secondary and post-secondary levels. The first section provides a theoretical base and brief history of writing to learn; the second and third sections will address research related to writing in secondary science education and writing in post-secondary science education, respectively. The fourth section will focus on Bandura's theory of self-efficacy, followed by a fifth section on the self-efficacy beliefs of teachers. Finally, the sixth section will discuss research specifically related to science teacher efficacy beliefs regarding writing to learn.

Body of the Review

Theoretical underpinnings of writing to learn.

In a learner-centered curriculum, the aim of education is to meet both individual and societal needs by forming a learning community within the classroom. In this classroom, the role of the teacher is to pose problems that require students to investigate key concepts rather than passively absorb the information from lecture (Marek & Cavallo, 1997). According to Piaget, this type of engagement allows the student to continually evaluate and reform their cognitive structures, the definition of learning according to constructivism (Marek & Cavallo). The basic model of learning proposed by Piaget begins with an individual's cognitive structures at equilibrium. Experiences that fit into these existing cognitive structures are assimilated, i.e. the individual interprets the information according to what they already know. If this information cannot be assimilated, the individual's cognitive structures enter a state of disequilibrium. The individual must adapt to the new information by accommodation. This process is defined by the individual creating new schemes and/or changing the original cognitive structures to account for the new experience. If an individual adjusts their cognitive structures to accommodate this new information, then these cognitive structures are restored to equilibrium. This new cognitive structure is then organized with all other existing cognitive structures (Marek & Cavallo).

Whereas Piaget described learning as originating within the individual and moving outward, Vygotsky viewed learning as originating from the social context and moving inward (Tudge & Winterhoff, 1993). Part of normal development is mastering cultural norms, which are essentially socially acquired methodologies (Vygotsky, 1929). Learning is broken into four stages: primitive, naïve psychology (mimic), external activity, and ingrown/internal (Vygotsky, 1929). The *zone of proximal development* lies between what one can accomplish independently and what one can accomplish with assistance (Vygotsky, 1978). Learning occurs only within the zone of proximal development. Thus, imitation results in learning only if the action being imitated is within the learner's zone of proximal development. Otherwise, the action occurs, but understanding does not. If a learner is not pushed beyond what is already known, cognitive development stagnates (Vygotsky, 1978). Therefore, social interaction serves to initiate learning, which is later internalized through successful mastery. This initial mastery forms a basis upon which the learner is prepared to build more complex understandings. As such, mental development is context dependent (Vygotsky, 1978).

Taking Piaget's theory of learning and combining it with Vygotsky's ideas of cognitive development and semiotic mediation, Bruner (1996) proposes "narrative as a mode of thinking, as a structure for organizing our knowledge, and as a vehicle in the process of education, particularly in science education" (p. 119). For Bruner, narrative is at the heart of the spiral curriculum, in which students move from an intuitive to a fully complex understanding of a concept via subsequent iterations of the topic over an extended period of time. Thus knowledge of reality is not a measurement of reality itself, but rather a construction from narratives, an epistemology based on an ever-changing reality in which knowledge is both personal and socially constructed from experience and interpretation (Davis, 2004).

Whereas Bruner's narratives are largely internal, Moffett (1965) suggests a process of externalizing the narrative through composition, moving from abstraction to concrete ideas through communications with a variety of audiences. The first stage of composition is internal, focused on remembrance of personal experience. The second and third stages include discussion of experience with a friend, first verbally and then through correspondence. The final stage results in abstraction of experience into a general principle that is shared with a public, and thus unknown, audience (Moffett). Whereas Moffett does not make an explicit connection between the four stages of discourse and Piaget's stages of cognitive development, he establishes the idea of writing as *process* over *product* to nurture students' struggles with turning experiences into ideas.

It is Emig (1977) who explicitly connects the ideas of Piaget, Vygotsky, Bruner, and others. Arguing for writing as a unique mode of learning, Emig connects writing to theories of learning by Piaget and Bruner, indicating that writing incorporates enactive, iconic, and representational/symbolic means of learning. Writing is both left- and right-brained, requiring organization and creativity, intense word selection and structuring of inner speech to connect ideas without ambiguity, allowing the learner to connect experiences from past and present, projecting also into the future (Emig). Ultimately, Emig's landmark essay was the impetus for a widespread Writing across the Curriculum (WAC) program and writing quickly became a way for students to make meaning and demonstrate understanding of content in all subjects.

Writing in secondary science education.

In 1975, declines in writing scores from the first National Assessment of Educational Progress report (1969) spurred public outcry (Russell, 2002) as evidenced in the *Newsweek* article "Why Johnny Can't Write" (Sheils, 1975). It was in the midst of the perceived national writing crisis that the National Writing Project (NWP) began to form out of the Bay Area Writing Project (BAWP), an annual writing workshop for teachers at UC Berkley in California that held its first summer institute in 1974 (Gray, 2000). Throughout his career, James Gray had instituted a number of professional development programs and took careful note of what best addressed the needs of teachers in the classroom. While the early focus had included secondary-level teachers alone, eventually NWP came to include elementary and post-secondary educators as well.

> The need to attend to writing crosses all grade levels. Therefore, the work of all writing teachers on the kindergarten through university continuum is equally important to all other writing teachers. … [Teachers] are naturally curious about the learning in other classrooms and at other grade levels, and yet they seldom have the chance to find out what's really going on in any classroom other than their own (Gray, p. 55).

Thus, rather than disseminating information to teachers via writing experts, NWP developed a peer-to-peer professional development system. During a two-week summer writing institute, teachers demonstrate the ways they incorporate writing into their own classrooms and dialogue with one another over teaching philosophies and best practices. Each of these summer institutes also includes former summer institute fellows who engage with the other participants as teacher leaders (Gray). Perhaps one of the most important aspects of the summer institute however, is writing.

> From the beginning, the summer institute has had a writing component, but I didn't realize its central importance until we started getting feedback from the teachers. … Given the chance to spend the summer writing, freed from the heavy load of teaching, free to write about whatever topic they want, and helped and guided by their writing group peers, teachers become writers. They rise to a new level: when they leave the institute they're teachers of writing *who are also writers*. They have experienced writing as a process (Gray, p. 85).

The NWP gained lasting success nationwide. Since 1974 when the program began, 70,000 teacher leaders have taught 1.2 million of their colleagues in nearly 200 NWP summer institutes connected with research universities across America (National Writing Project, 2013). Further, the NWP reports that students of NWP teachers generally show higher writing gains than their peers taught by teachers who have not participated in summer institutes (National Writing Project, 2010). This conclusion is drawn from 16 studies in 7 states in which the comparison group did not score significantly higher than students of NWP teachers (National Writing Project, 2010).

Noting some doubt over the lasting impacts of NWP in some research studies that largely used self-reported data, Bratcher and Stroble (1994) conducted a three-year longitudinal study that also included observational data. Their primary goal was to understand the effectiveness of their program based on the evolution of teachers' concerns and implementation of the writing process following the summer institute. Thus, Bratcher and Stroble followed 69 public school teachers as coaches and researchers, using the Stages of Concern (SoC) questionnaire, a self-developed Innovation Configuration (IC) survey, group and individual interviews, summer institute application essays, and observations of the teachers. During the second year of the study, Bratcher and Stroble focused on six elementary teachers and one high school teacher for interviews and observations. After participation in the summer institute, the development of teacher concerns over writing process instruction moved from a self-focus to an impact-focus according to the SoC. Additionally, teachers increased implementation of writing process in their classrooms over the three-year period of the study. While reflecting on the three-year process, Bratcher and Stroble note that their ultimate goal as summer institute coordinators was to move teachers from a lack of comfort and confidence in writing and teaching writing to increased competence.

> Analysis of teachers' practices in the classroom indicated that their anxieties about assessing and grading seemed to go hand in hand with uncertainties about the qualities of successful writing. Teachers' anxieties and uncertainties blocked their complete implementation of the new paradigm. Where comfort and confidence floundered, competence failed (p. 83).

Thus, Bratcher and Stroble concluded that their summer institute generated enthusiasm, helped teachers understand the writing process, but was not effective in defining successful writing in the classroom. They suggest two avenues that may have affected success in this area: some aspects of writing were discussed but not modeled (e.g. revision) and further, teachers may need to experience a shift in teaching philosophy rather than implement tools and techniques piecemeal. Whereas this study points to interesting patterns that do bridge educational levels (elementary-secondary), it only gives a general overview of these patterns seated in the context of writing in English and Language Arts. There is no mention of patterns across disciplines. One of the elementary teachers makes the comment, "Writing-across-the-curriculum is the hardest to implement because the teacher must know the subject area very well before beginning to branch out into writing" (p. 80). What happens when teachers know the subject level well, but are less familiar with the forms and language associated with writing?

Because NWP is open to teachers of all subjects, it is difficult to tease out impacts on science teachers specifically. Using the NWP model in a graduate-level writing class, Street and Stang (2009) explore the antecedents and affecters of secondary-level teacher writing confidence, also collecting subject area data. This mixed-methods study of 25 in-service teachers (5 who taught in the sciences) included open-ended questionnaires, online discussions, writing history essays, writing samples from the course, and observational data as well as demographic data. Based on the writing histories, two of the science teachers were classified as having positive pre-course self-confidence as writers, two were classified as having neutral self-confidence as writers, and one had negative self-confidence as a writer. Out of the entire class, 48% had negative pre-course self-confidence as writers, whereas only 20% had positive self-confidence (Street and Stang). For 80% of the total participants, teachers and school experiences most influenced their views on writing. Following the course, only 12% of the teachers continued to have negative self-confidence as writers. However, none of the science teachers changed in their self-confidence as writers. Based on the overall success of the course in altering teachers' self-confidence as writers, Street and Stang suggest that professional development should reach teachers where they are, wrap them in *communities of practice*, and support their identities as writers. What is unsatisfactory about this conclusion is that many post-secondary science educators are accomplished writers with many successful publications and yet still exhibit a lack of confidence in their ability to teach writing in their science classrooms. Additionally, it seems that this approach may not have worked as well for the science teachers who participated in Street and Stang's study, although five individuals is an extremely small sample size to make such a generalization. Speaking for myself, I have found the transition from science writing to writing in education difficult. Science writing is generally impersonal and objective whereas writing in education requires the researcher to admit bias and put himself/herself into the manuscript. For someone with a strong science background, this is taboo and can be extremely unnerving. Without knowing the backgrounds of the science teachers in Street and Stang's study, I offer the conjecture that they may not have felt comfortable or part of the community of practice within the class.

Thus, a better approach to understanding the relationship between science teachers and writing is within the context of writing in science. Developed specifically for use in science classrooms, the Science Writing Heuristic (SWH) "is a tool to guide both teachers and students in productive activities for negotiating meaning about laboratory investigations" (Keys et al., 1999, p. 1067). The SWH consists of both a teacher and student template (Figure 1), which can be used as-is or tailored specifically to the laboratory activity. The teacher template (Figure 1, Part I) consists of eight stages that prepare students for the laboratory activity, guide them through the laboratory, and ultimately, make evidence-supported claims from their data (i.e., write an argument). These stages are not a specific list of activities, but rather a guideline to experiences that will give students time to think through their data and develop a complete and well-supported argument (Keys et al.). The student template (Figure 1, Part II) consists of seven steps that guide students through the process of building an argument. To verify the effectiveness of the SWH, Keys and colleagues used the heuristic with two classes of eighth grade students. In each class, the researchers selected two target teams for in-depth, qualitative study. This included students' written reports, video of team discussions, team interviews, and open-ended questionnaires. After analyzing the data, Keys and colleagues developed seven codes: topical (general description), method, observation, inference (general, specific, and hypothesis), observation-inference, metaknowledge, and explication (includes information from print materials). The instructional unit was an eight-week stream study and included curriculum from National Geographic. Throughout the study, students developed in their ability to use the SWH appropriately, thought about their knowledge in comparison to the claims they made, used their own data to make meaning, and expanded upon science ideas (Keys et al.). Students also gained in their understanding of the nature of science, particularly regarding collaboration, argumentation, and evidence. Citing arguments among modernists, postmodernists, and constructivists over how and what students should be taught about science writing, Keys and colleagues indicate that the SWH meets the needs and philosophies of each tradition.

> The SWH suggests fresh formats for reporting on investigations that combine personal and socially constructed meaning with a critical evaluation of evidence backing one's own and others' scientific claims. At the same time, the SWH maintains that which is unique to science as an intellectual enterprise: a respect for the time-honored traditions of gathering data, evaluating data as evidence, and formulating explanations and theories (p. 1082).

Whereas this study established the SWH, the authors themselves indicate the need for further study. In particular, they suggest research on the types of laboratories that work well with the SWH, studies of larger and more diverse populations of students, how the SWH influences student understanding of more abstract concepts, and connections between SWH use and improved scientific reading and writing. What the authors neglect to promote is the impact of SWH on the teacher, or vice versa.

The Science Writing Heuristic, Part I A template for teacher-designed activities to promote laboratory understanding.	The Science Writing Heuristic, Part II A template for students [to guide writing and argument development].
1. Exploration of pre-instruction understanding through individual or group concept mapping.	1. Beginning Ideas – What are my questions?
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.	2. Tests – What did I do?
3. Participation in laboratory activity.	3. Observations – What did I see?
4. Negotiation phase I – writing personal meanings for laboratory activity (For example, writing journals).	4. Claims – What can I claim?
5. Negotiation phase II – sharing and comparing data interpretations in small groups (For example, making a group chart).	5. Evidence – How do I know? Why am I making these claims?
6. Negotiation phase III – comparing science ideas to textbooks or other printed resources (For example, writing group notes in response to focus questions).	6. Reading – How do my ideas compare with other ideas?
7. Negotiation phase IV – individual reflection and writing (For example, creating a presentation such as a poster or report for a larger audience).	7. Reflection – How have my ideas changed?
8. Exploration of post instruction understanding through concept mapping.	

Figure 1. The Science Writing Heuristic (Akkus et al., 2007, p. 1747).

In a later SWH study, Akkus, Gunel, and Hand (2007) compare student outcomes between a traditional teaching approach versus an inquiry-based approach using the SWH, given the emphasis on science inquiry in the *National Science Education Standards* (National Research Council, 1996). Akkus and colleagues indicate that traditional teaching methods do not adequately represent the reality of science, whereas the SWH guides students in thinking and arguing like a scientist. Thus, Akkus and colleagues asked seven teachers to divide their classes into control (traditional teaching approach) or treatment (SWH approach) groups. These classes included 592 students that spanned grades 7-11. All teachers attended a two-day professional development session on using the SWH prior to the study. The study used a mixed methods design, collecting classroom observations of the teachers' teaching styles and pre- and post-test scores from students on one of four different content areas. Each teacher was given an implementation score, having an affinity to either traditional teaching (high traditional, low SWH) or SWH (low traditional, high SWH).

> [The] traditional approach and the SWH approach are viewed as diametrically opposed strategies—the first being teacher centered, teacher controlled, and the second being student centered, teacher controlled …The teachers who were rated as high SWH were consistently focusing on promoting dialogical interaction between students and themselves, and were placing more and more opportunities for students to understand that they controlled the focus of the learning (p. 1753).

Thus, Akkus and colleagues used ANOVA and ANCOVA models to compare post-test scores among groups (traditional or SWH) and levels of teaching (implementation score), eventually separating students by achievement levels (low, medium, high). Baseline studies indicated that there were no significant differences among groups prior to the study. The ANCOVA analysis indicated that students in the SWH group taught by high-SWH implementation teachers scored higher than the students in the other groups and students in the traditional group taught by high-SWH implementation teachers scored higher than students in the same group taught by low-SWH implementation teachers. Likewise, the achievement gap in the SWH group taught by high-SWH implementation teachers was extremely narrow and the lowest achievers in this group significantly outperformed low-achieving students in all other groups. Even when the SWH approach was taught by low-SWH implementation teachers, the achievement gap was narrowed. Thus, Akkus and colleagues indicate "that the quality of the implementation does have an impact on student performance, and that high-quality implementation of the SWH approach has significant advantages in closing the achievement gap within science classrooms" (p. 1762). Even with low-quality implementation of the SWH with little active discussion, the researchers suggest that the stepwise writing component (much like that espoused by Moffett) continues to help the low-achieving students develop content mastery. Whereas Akkus and colleagues describe the trouble some teachers had implementing the student-centered SWH approach, the explanation for this trouble is not well-explored.

> The traditional approaches used by the teachers were reflective of their training and their adopted practices. Using these approaches, teachers were concerned that they were able to manage their classroom and control the flow of the knowledge being addressed, and students were able to provide correct responses to all the questions posed (Akkus et al., p. 1762).

It is this question that remains the focal point of my study. What allows some teachers to be comfortable implementing writing and writing instruction into their science classes?

Currently, implementing writing instruction into the science classroom is at the forefront of secondary science teachers' minds. To date, 45 states have adopted the Common Core State Standards (CCSS), along with Washington D.C., 4 territories, and the Department of Defense Education Activity (Common Core State Standards Initiative, 2012), and have either already implemented these standards or are set to implement in 2014 (Figure 2). These standards are divided into Math and English Language Arts, which is further divided into Reading, Writing, Speaking and Listening, and Language (CCSS). At the secondary level, the ELA standards are separated into two categories: ELA and history/social studies, science, and technical subjects. Given the need for ELA teachers to focus primarily on literature, content area teachers are thus expected to provide instruction and opportunity in reading and writing within their respective discipline. The CCSS are not meant to replace existing content standards however; they are only meant to supplement learning necessary to develop College and Career Ready (CCR) skills.

> To be ready for college, workforce training, and life in a technological society, students need the ability to gather, comprehend, evaluate, synthesize, and report on information and ideas, to conduct original research in order to answer questions or solve problems, and to analyze and create a high volume and extensive range of print and nonprint texts in media forms old and new (CCSS, http://www.corestandards.org/ELA-Literacy/introduction/key-design-consideration).

These standards are based on research evidence, the needs and expectations of colleges and employers, rigorous, and internationally benchmarked (CCSS). The Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12 (WHST) are based primarily on the College and Career Readiness Anchor Standards for Writing (Figure 3). Within WHST, the CCR Anchor Standards are elaborated, particularly for Text Types and Purposes (Figure 3), indicating that arguments should be focused on discipline-specific content and that informative/explanatory texts can include narration of scientific procedures/experiments. In science, WHST standard 3 (narratives) is not a separate requirement, but part of standard 2 in that “students must be able to write precise enough descriptions of the step-by-step procedures they use in their investigation or technical work that others can replicate them and (possibly) reach the same results” (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010, p. 65). Additionally, the WHST standards become more complex from grades 6-8, 9-10, and 11-12 (e.g., Figure 4). As indicated in Akkus and colleagues’ study (2007), some teachers will likely not be comfortable with integrating writing into their science classrooms or using new techniques to do so.

Considering the development of the SWH (Keys et al., 1999), the findings of Akkus and colleagues (2007) regarding use of the SWH, and the development and widespread adoption of the CCSS (Common Core State Standards Initiative, 2012), writing in the sciences is deemed a learning priority but is perhaps currently implemented in a limited fashion. Street and Stang (2009) might suggest that low personal writing self-confidence inhibits many science teachers from assigning or teaching writing in their science classes. From a personal standpoint, this response is unsatisfactory as I have heard the same concerns over integrating writing into science classes from both secondary-level and post-secondary level science educators, the latter of who are often published authors. Thus, my study will establish a baseline of science teacher science writing instruction efficacy beliefs, elaborating on those antecedents that correspond with high-efficacy beliefs to inform future professional development for secondary *and* post-secondary science teachers.

Figure 2. Map of U.S. states, districts, and territories that have adopted Common Core State Standards (Common Core State Standards Initiative, 2012).

Text Types and Purposes

1. Write arguments to support claims in an analysis of substantive topics or texts using valid reasoning and relevant and sufficient evidence.
2. Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.
3. Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details and well-structured event sequences.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
5. Develop and strengthen writing as needed by planning, revising, edition, rewriting, or trying a new approach.
6. Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
8. Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.
9. Draw evidence from literary or informational texts to support analysis, reflection, and research.

Range of Writing

10. Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

Figure 3. College and Career Readiness Anchor Standards for Writing (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010, p. 63).

Grades 6-8 students:	Grades 9-10 students:	Grades 11-12 students:
2d. Use precise language and domain-specific vocabulary to inform about or explain the topic.	2d. Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.	2d. Use precise language and domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.

Figure 4. Example of increasing complexity in the Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6-12 (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010, p. 65).

Writing in post-secondary science education.

Although disciplinary ideas of good writing vary, WAC at the post-secondary level is marked by commonalities, especially when considering the process and purpose of writing (e.g. claims and evidence, logical structure, citation) (Brammer, Amare, & Campbell, 2008). Thus, the initial stages of WAC within a university are often characterized by cross-disciplinary interest in student learning and best approaches to teaching (McLaren et al., 2011). Eventually, many universities developed writing-intensive (WI) courses in an effort to link writing within the general education curriculum (Russell, 2002). Within many WI courses in the sciences, focus shifts to writing like a scientist rather than writing to learn, placing emphasis on rhetorical differences among disciplinary genres, a movement known as writing in the disciplines (WID) (Monroe, 2003). As a simplification then, whereas WAC is *writing to learn*, WID is perhaps *writing to become a professional* (Carter, 2007). The WID focus is specialized rhetoric for a niche audience, after students have completed their general education requirements and become part of a particular discourse community (Stock, 1986). Therefore, writing in post-secondary science can take a myriad of forms, often depending on perceived student needs, course goals, and instructor pedagogy.

Yates and colleagues (2005) point out that “science is fundamentally about communication. Un-communicated science in essence does not exist” (2005, p. 36). Surprised that students did not view writing as part of the scientific process and as such, were limited in their scientific abilities, the group set out to compare student writing in geology with writing produced by published geologists. A panel of writing and science communication experts identified five areas of weakness in student science writing:

appropriate register, iterative writing process, internal structure and appropriate cross-referencing, external references, and argument development without equating observation and interpretation. A subsequent linguistic analysis comparing 49 student writing samples and 49 published geology pieces indicated that experts pack more information into their writing, write more concisely and definitively, and likely make better use of more appropriate terminology (evidenced by a higher frequency of longer words) than students (Yates et al., 2005). Further, during a series of action research seminars, Yates and colleagues found that students lacked understanding of audience, text structure and argument, and did not view writing as an inherent part of the scientific process. Thus, these action research seminars included activities on audience and text analysis, reconstructing arguments from sentences isolated from an existing description, similarly reconstructing an entire report from disembodied sections with headings removed, and demonstrating the nature of writing in science (Yates et al., 2005). What is not included in this study is the impact of these interventions. While the group acknowledges that not all student writing was poor, there is no mention of any improvement in either student writing or attitudes toward writing following participation in the action research seminars.

In other instances of writing interventions (e.g. workshops, seminars, etc.) there seems to be little reported improvement in student science writing skills. Kroen (2004) describes implementing an assignment to help students analyze and interpret authentic data. This practitioner study is based on seven upper-level students who completed a semester-long paper assignment that required them to create graphs from a large data set, interpret the findings, and communicate those findings clearly. Throughout the semester, Kroen offered specific instruction, opportunities for peer review, and assigned journal articles to serve as both content source and writing models. Kroen observed that students continued to have problems with both interpretation and writing skills, specifically in the area of figure legends and incorporating sources. Students also saw the assignment as a requirement for a grade, rather than part of their education as a professional. Like the findings from Yates and colleagues (2005), students are not viewing writing as part of the scientific process and a means to learning. They have not wholly entered into an awareness of science as a discourse community conversing across time and space (Chinn & Hilgers, 2000).

Remembering my own experience as a science undergraduate and graduate student of twelve years I did not enter into this discourse community through coursework, but through relationship with and mentoring from various advisers. As a science writing instructor or working with students as a science writing specialist, it is specific feedback and modeling of the writing process that makes the most difference for student writers. Thus, information and sporadic practice alone may not provide students with the connection to the scientific process that Kroen (2004) and Yates and colleagues (2005) seek. Instead, we should perhaps focus on "how students are acculturated and socialized into the world of scientists" (Chinn & Hilgers, 2000, p. 7) primarily through modeling by professors. To this end, Chinn and Hilgers examined WI course requirements at the University of Hawaii to determine how the professor's approach to writing and writing assignments within science classes would impact student outcomes and how students felt about their own writing skills. Chinn and Hilgers completed the study in two phases. Phase one included reviewing WI course applications, syllabi, written-assignment instructions, and student writing experience evaluations. Phase two focused on a subset of the WI courses that received positive reviews from students. For each of these courses, the authors interviewed instructors, observed classes, conducted student focus group interviews, and interviewed graduating seniors. Across all WI courses, assignments were generally designed either for writing to learn or writing in the discipline. Instructional styles grouped on a continuum from instructor as corrector to instructor as collaborator. Chinn and Hilgers reported that the role of instructor as corrector was predominate in WI courses, meaning that students wrote for the instructor as audience, the assignment represented a product rather than process, and students viewed the writing process as editing. Instructors as journal editors remained aloof from the writing process and assigned anonymous peer reviewers who often responded to their peers' work critically, negatively impacting female and minority students. Instructors as collaborators created a discourse community within the course, providing students with real-world audiences and assignments. Students were often part of research teams for these assignments, using writing to communicate and learn. Students vastly preferred courses taught by collaborative instructors and left with a greater understanding of and preparation for their careers as scientists (Chinn & Hilgers, 2000). The authors identify this approach as treating students as science apprentices and providing

> full-spectrum discipline-specific practices [that] collectively give meaning to learning and support students' transition from viewing their learning as school science (mastery of content measured by grades) to viewing their learning as entry into a professional community (Chinn & Hilgers, 2000, p. 22).

What Chinn and Hilgers do not indicate in their study are the underlying reasons that cause instructors to gravitate toward one end of the spectrum over another.

Preparing instructors to give meaningful feedback on writing assignments is of key importance. In a study tracking self-reported growth in critical thinking skills from 24,837 students at 392 colleges over a four-year period, instructor feedback on papers had the greatest positive effect on students' ability to think critically (Tsui, 1999). Since the study incorporated data from a number of courses, regression analysis also indicated that instructional technique impacted growth in critical thinking more than course type and thus, course content (Tsui, 1999). In a smaller study of 82 biology students, final research paper scores did not correlate with number of college-level writing courses taken, technical writing courses taken, or number of years in college (Jerde & Taper, 2004). Rather, prior experience in science writing and according to student comments, instructor feedback helped students refine their final paper (Jerde & Taper, 2004).

Much of the literature however, especially that encountered in science-specific databases and journals (e.g. Web of Science, *Journal of College Science Teaching*) focuses on specific writing assignments or courses aimed at helping students either engage with content or write like a professional scientist. Killingbeck (2006) shares the success of his *Plant Notes* assignment used to help his botany students identify nearly 300 plants by scientific and common name. While much of his paper is comprised of excerpts from student assignments, Killingbeck notes that incorporating creative writing "engage[s] your students, help[s] them learn, and surreptitiously draw[s] them together into a community of learners" (2006, p. 28). Balgopal and Montplaisir (2011) used a grounded theory approach with reflective essay assignments and interviews to create a model of student meaning making over natural selection and adaptation in an upper-division biology course. The specific purpose of this study was to "inform instructors on how to make their instruction more meaningful to learners… by enabling them to develop writing assignments and assessment tools that recognize how learners make sense of abstract scientific concepts" (Balgopal & Montplaisir, 2011, p. 139). McDermott and Kuhn (2011) describe the success of using different and concrete audiences (papers/presentations were assessed by these audiences) for writing assignments in a non-majors science course. In this case, students in the Science of Water course had to communicate a concept to a fourth-grade classroom and to their academic advisor. In both cases, students received specific feedback from both of these audiences, finding that writing for a third party required a different level of understanding and concept translation than typical college writing assignments (McDermott & Kuhn, 2011). Like Yates (2005), Lankford and vom Saal (2012) walked readers through the creation of a writing-intensive biology capstone course, including examples of assignments, case studies, article critiques, peer evaluation guides, rubrics, and grading schemes. Of note in this case, the GTA collaborating with the course professor "held extensive experience as a former high school biology teacher" (Lankford & vom Saal, 2012, p. 21). Thus, she had likely received extensive professional development in instructional techniques and curriculum design prior to her experience with this particular course. This sample of practitioner articles certainly demonstrates the lasting and widespread existence of instructors as collaborators as defined by Chinn and Hilgers (2000), but the question remains: what aided the development of these individuals as confident (as evidenced by their willingness to publish) science writing instructors?

Self-efficacy theory.

From a behaviorist perspective (e.g., Skinner) learning relies on observable action reinforced by an external agent. Intuitively however, human behavior is more complex; the social cognitivist perspective (e.g., Vygotsky) assumes human agency and extends learning to include observation and modeling (Ormrod, 2011). Bandura (1983) addresses this complexity via triadic reciprocal determinism in which behavior is both effect and affecter and the individual is an active agent that contributes to and changes the environmental, cognitive, and affective forces as well as the social context in which these forces interact. It is against this backdrop of environmental, personal, and behavioral factors that Bandura proposes the concept of self-efficacy.

In the late 1970s, self-efficacy was an emerging theory "that [behavioral] changes achieved by different [treatment] methods derive from a common cognitive mechanism" (Bandura, 1977, p. 191). The development of this theoretical framework centered around "changes achieved in fearful and avoidant behavior" (Bandura, 1977, p. 193). Whereas behaviorist theories rely on outcome expectations (i.e., performance of a certain behavior will produce a given result), self-efficacy introduces a new variable: efficacy expectations. Efficacy expectations are the personal belief in one's ability to negotiate a particular task.

> Outcome and efficacy expectations are differentiated, because individuals can believe that a particular course of action will produce certain outcomes, but if they entertain serious doubts about whether they can perform the necessary activities such information does not influence their behavior (Bandura, 1977, p. 193).

If an individual does undertake a particular behavior, his or her efficacy expectations can affect persistence in the task (Bandura, 1977). Thus, merely expressing the potential for positive outcomes is insufficient to effect sustained behavioral change. Rather, under self-efficacy theory, targeting efficacy expectations will ultimately change behavior.

In treating individuals with various phobias, Bandura (1977) identified four sources of efficacy information: performance accomplishments (mastery experiences), vicarious experience, verbal persuasion, and emotional arousal. Among these antecedents to efficacy beliefs, mastery experiences are the most powerful (Bandura, 1977). Perceived success within a particular context increases self-efficacy, whereas patterns of failure detract. In the absence of personal experience, watching peer models (vicarious experience) allows the observer to visualize personal success, thus changing self-efficacy beliefs (Bandura, 1977). Verbal persuasion (e.g., encouragement or praise) from a respected person to undertake or continue in a task can also increase self-efficacy (Bandura, 1977). Beyond these social factors, an individual's physiological state (emotional arousal) can also influence self-efficacy, depending upon how it is interpreted by the individual. Generally, high emotional states of either excitement or anxiety affect self-efficacy negatively (Bandura, 1977). It is important to note that each of these antecedents is a source of information. None directly affect self-efficacy belief; rather it is the perception and cognitive processing of each that influences efficacy expectations (Bandura, 1977). This processing includes not only mastery experience, vicarious experience, verbal persuasion, and emotional arousal but also "a number of contextual factors, including the social, situational, and temporal circumstances under which events occur" (Bandura, 1977, p. 200). Thus, efficacy beliefs can be generalized to other circumstances, but usually only if the context is similar (Bandura, 1977).

Lasting change in efficacy belief is therefore a result of experience in a variety of contexts over an extended period of time (Bandura, 1977). To accomplish this in a clinical setting, Bandura used "powerful induction procedures initially to develop capabilities, then [removed] external aids to verify personal efficacy, then finally [used] self-directed mastery to strengthen and generalize expectations of personal efficacy" (p. 202). To test this procedure, Bandura had adults with a snake phobia engage in participant modeling (mastery experiences), modeling alone (vicarious experience), or no treatment. Whereas those exposed to modeling alone only observed the therapist engaging with a boa constrictor, those in the participant modeling group performed increasingly risky tasks with the snake themselves. Each person reported their efficacy expectations on 18 tasks for the boa constrictor as well as similar and dissimilar snakes, pre-treatment, post-treatment, and post-behavioral posttest. Thus, efficacy belief was compared to behavior performance with the boa constrictor, similar, and dissimilar snakes. Participant modeling provided the greatest increase in efficacy and performance of risky behavior, generalized to similar and dissimilar tasks (Bandura, 1977). While modeling alone produced less gain in efficacy and behavioral outcomes, efficacy expectations were predictive of behavioral outcome in both treatment groups (Bandura, 1977).

Whereas Bandura established self-efficacy theory using patients with phobias, avoidance behaviors certainly extend to other circumstances. In other studies, Bandura has applied self-efficacy theory to memory functioning (Bandura, 1989), cognitive development and functioning (Bandura, 1993), and academic functioning (Bandura et al., 1996). In regards to this study, I use self-efficacy as the framework for understanding science educator concerns about integrating more writing into their science classrooms, whether at the secondary or post-secondary level. Given well-established evidence that links writing and learning (e.g. Holliday et al. 1994; Akkus et al. 2007), outcome expectations are not the limiting factor. Rather,

> Most courses of action are initially shaped in thought. People's beliefs in their efficacy influence the types of anticipatory scenarios they construct and rehearse. Those who have a high sense of efficacy visualize success scenarios that provide positive guides and supports for performance. Those who doubt their efficacy visualize failure scenarios and dwell on the many things that can go wrong. It is difficult to achieve much while fighting self-doubt (Bandura, 1993, p. 118).

Thus, I expect that science educators will fall along a spectrum of efficacy belief when expected to integrate writing into their classes. What I hope is to find commonalities in the experiences of those with high efficacy belief such that those experiences can be replicated as part of participant modeling to increase the efficacy beliefs of low efficacy belief individuals.

As Bandura continued his work in efficacy beliefs, he moved from phobic patients to more complex contexts, particularly learning and educational systems. Like physical behaviors, mental behaviors are also subject to efficacy beliefs and antecedents (Bandura, 1993).

> Ability is not a fixed attribute residing in one's behavioral repertoire. Rather, it is a generative capability in which cognitive, social, motivational, and behavioral skills must be organized and effectively orchestrated to serve numerous purposes. It also involves skill in managing aversive emotional reactions that can impair the quality of thinking and action. There is a marked difference between possessing knowledge and skills and being able to use them well under taxing conditions. Personal accomplishments require not only skills but self-beliefs of efficacy to use them well. Hence, a person with the same knowledge and skills may perform poorly, adequately, or extraordinarily depending on fluctuations in self-efficacy thinking (p. 118-119).

Bandura goes on to explain that beliefs about ability as static or dynamic, social comparison, social evaluation (feedback), and perceived controllability of the environment all affect efficacy beliefs of both individuals and groups. Efficacy beliefs in turn affect motivation, coping mechanisms, and activity/environment choices that can ultimately shape an individual's life path (Bandura). Choices in education and learning are huge elements of shaping one's life path and so Bandura indicates that

> there are three principal ways in which perceived efficacy operates as an important contributor to academic development: students' beliefs in their efficacy to regulate their own learning and to master different subject matters, individual teachers' beliefs in their efficacy to motivate and promote learning in their students and staffs' collective sense of efficacy that their schools can accomplish significant academic progress (p. 135).

Self-efficacy is such a powerful variable that it can and will affect academic performance (Bandura). Students need help cultivating efficacy beliefs in metacognition, self-regulation, and writing literacy. Promoting these tools help students apply skills and information from one context to another, persevere in learning, and experience mastery in academic settings (Bandura). Hence, students require teachers with a strong sense of self-efficacy, as these teachers are more likely to create environments that support learning. "Those beset by self-doubts construct classroom environments that are likely to undermine students' sense of efficacy and cognitive development" (Bandura, p.140). Since teachers operate as part of an organization rather than individuals, the collective efficacy beliefs of the school can exert strong influences on both teacher and student efficacy beliefs. Thus, when collective efficacy beliefs are high, the level of academic achievement at a school is increased (Bandura). However, when the student body is ill-perceived because of external factors (e.g. low SES) that affect academic performance, collective efficacy is decreased. The reciprocity of efficacy beliefs and achievement throughout all levels of the educational environment places a large burden on teachers, as they are both affecters and effected by both student and collective efficacy beliefs. However, in the context of my study, perhaps if teacher science writing instruction efficacy belief was increased, student writing gains would also increase, creating a positive, rather than a negative, feedback loop.

Teacher efficacy belief.

Clearly, application of self-efficacy theory to an educational setting is not new. Several measures have been created to measure both student and teacher efficacy beliefs in a myriad of contexts. Tschannen-Moran, Hoy, and Hoy (1998) reviewed a nearly 25 year history of teacher efficacy research towards further defining teacher efficacy belief and building a new model to better describe the factors affecting teacher efficacy belief. Ultimately, they combined two modes of thought into this model: Rotter's theory of locus of control and Bandura's theory of self-efficacy with its four primary antecedents. While reviewing the literature, Tschannen-Moran and colleagues found several school-level effects folded into these antecedents. Teacher efficacy increased with principals who provided resources and autonomy while protecting teachers from disruptions. Likewise, teacher efficacy increased in school cultures with abundant opportunities for collaboration, but decreased in school cultures focused on problems rather than problem-solving (Tschannen-Moran et al.). Within their review, Tschannen-Moran and colleagues found the implications of teacher efficacy to be widespread, citing evidence from Berman and colleagues, Guskey, Stein and Wang, Allinder, Ashton and Webb, Gibson and Dembo, Meijer and Foster, and Podell and Soodak, among others.

> Teachers with a strong sense of efficacy are open to new ideas and more willing to experiment with new methods to better meet the needs of their students; they

> also tend to exhibit greater levels of planning and organization… Greater efficacy enables teachers to be less critical of students when they make errors, to work longer with a student who is struggling, and to be less inclined to refer a difficult student to special education (p. 223).

Thus, teacher efficacy belief can impact student achievement within the classroom (Tschannen-Moran et al.). This lends greater credence to pursuing means to increase teacher efficacy belief in science writing instruction, rather than focusing solely on strategies to improve student writing. For instance, recalling Chinn and Hilgers' (2000) findings, one might infer that instructors identified as collaborators would thus have high efficacy belief towards incorporating writing into their science classrooms, whereas correctors may have low efficacy belief. Regardless of where their instructor fell on the corrector-to-collaborator spectrum, students were exposed to significant writing projects. However, the teaching style and perhaps efficacy of their instructor was what made the difference in student learning.

Efficacy beliefs in one context cannot necessarily be generalized to other contexts however (Bandura, 1977; Tschannen-Moran et al., 1998). "Teacher efficacy is context specific. Teachers feel efficacious for teaching particular subjects to certain students in specific settings, and they can be expected to feel more or less efficacious under different circumstances" (Tschannen-Moran et al., p. 227-228). Tschannen-Moran and colleagues explain these situational differences as part of a cyclical model of teacher efficacy (Figure 5). In agreement with Bandura (1977), teacher efficacy begins with consideration and interpretation of sources of efficacy information. However, Tschannen-Moran and colleagues posit that this interpretation alone does not lead to teacher efficacy belief. Rather, they explicitly point out that teachers also analyze the requirements and context of the task at hand. Among other things, this includes student factors, resources, administration relationships, school culture (Tschannen-Moran et al.). Further, Tschannen-Moran and colleagues separate current perception of teaching (an efficacy antecedent) from teaching efficacy, defined as the perception of future functioning. These two factors are what separate Tschannen-Moran and colleagues' model of teacher efficacy from previous applications of self-efficacy to teaching.

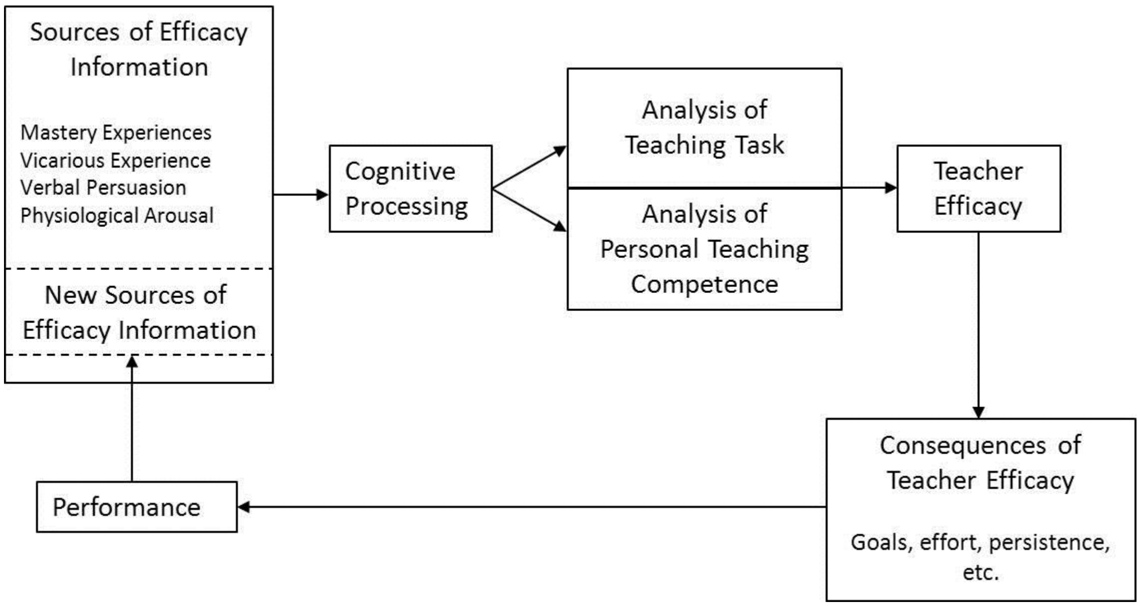

Figure 5. Model of teacher efficacy (Tschannen-Moran et al., 1998, p. 228)

From this model of teacher efficacy (Figure 5) (Tschannen-Moran et al., 1998), Tschannen-Moran and Hoy developed the Teachers' Sense of Efficacy Scale (TSES, originally the Ohio State teacher efficacy scale (OSTES)). The development of teaching efficacy belief measures began with the initial Rand Corporation study (Tschannen-Moran & Hoy, 2001; Tschannen-Moran et al., 1998), to the Teacher Efficacy Scale (Gibson & Dembo, 1984) on which the Science Teaching Efficacy Belief Instrument (STEBI-A) (Riggs & Enochs, 1990) is based. The Teachers' Sense of Efficacy Scale (TSES) is the most recent scale, having both a long and short form (Tschannen-Moran & Hoy, 2001). This scale was developed and refined using three studies. The first study tested the measure with 224 participants, a little over half of which were preservice teachers. In addition to completing the survey, these participants also rated each item as to its importance for effective teaching. At the end of this study, the original 52 items were reduced to 32. The second study included 217 participants, with approximately one-third being preservice teachers. During this study, the scale was reduced to 18 items that fell under three factors: efficacy for student engagement, efficacy for instructional strategies, and efficacy for classroom management with α reliabilities of 0.82, 0.81, and 0.72, respectively. To increase the strength of the scale, Tschannen-Moran and Hoy added new management items, creating both a long (24-item) and short (12-item) scale. From a sample of 410 participants, one-fourth of which were preservice teachers, reliabilities increased to 0.91 for instruction, 0.90 for management, and 0.87 for engagement (Tschannen-Moran & Hoy). Taking the top four items from each scale, Tschannen-Moran and Hoy also created the short-form TSES with reliabilities of 0.86 for instruction, 0.86 for management, and 0.81 for engagement.

Using the TSES, Tschannen-Moran and Hoy (2007) examined teacher efficacy beliefs between novice and experienced teachers. As mastery experiences are the strongest antecedent to efficacy beliefs (Bandura, 1977), Tschannen-Moran and Hoy posit that the efficacy beliefs of novice teachers, who lack mastery experiences, will experience the most change. Experienced teachers however, likely have established firm efficacy beliefs because of their accumulation of mastery experiences. The participant sample consisted of 225 teachers with 1-29 years of teaching experience. Novice teachers were defined as having three years of teaching experience or less. In addition to the efficacy for instructional strategies, efficacy for classroom management, and efficacy for student engagement subscales on the TSES, teachers answered questions on demographics (gender, race, and years of experience), context (school level and setting, resource support), verbal persuasion (interpersonal support of administrator, colleagues, parents, and community), and mastery experiences (satisfaction with performance). Based on TSES results, career teachers generally have a higher sense of efficacy than novice teachers. This result extends to two of the three subscales: instructional strategies and classroom management. Career teachers also reported higher levels of interpersonal support from administrators, resource support, and satisfaction with professional performance. After parallel hierarchical regression analysis, Tschannen-Moran and Hoy found that the self-efficacy of novice teachers was primarily explained by context (specifically resources) and verbal persuasion variables, whereas the self-efficacy of career teachers was explained by context (specifically level taught) and mastery experience variables. Thus, Tschannen-Moran and Hoy conclude that novice teachers rely more on support from others while developing their own mastery experiences. Once developed among career teachers, this dependence on verbal persuasion wanes. Likewise, contextual factors weigh more heavily on novice teachers than career teachers, as they lack the experience required to generalize efficacy beliefs in the face of varying situational factors. The primary limitation of this study is its lack of context specificity. Whereas this study measured a general sense of teaching efficacy across disciplines, it does not consider the introduction of new and unfamiliar teaching tasks into a particular discipline. In the face of new curriculum requirements, particularly writing in the sciences, will novice teachers exhibit lower self-efficacy than career teachers or will novice teachers, still developing efficacy beliefs (Tschannen-

Moran & Hoy, 2007) adapt more quickly to new requirements, better than career teachers who have already formed their efficacy beliefs (Bandura, 1977)? Given the lack of experience held by novice teachers, the changing context brought about by new curriculum requirements may overtax novice teachers' ability to generalize efficacy beliefs. However, if career teachers lack mastery experiences in science writing, novice teachers may have an advantage in their reliance on verbal persuasion.

Given the importance of vicarious experience and verbal persuasion through interpersonal relationships within the school to the self-efficacy of novice teachers (Tschannen-Moran & Hoy, 2007), it is worth mentioning collective teacher efficacy (Bandura, 1993; Goddard et al., 2000), even though it will not be directly measured in this study. Whereas the focus of this study is the efficacy beliefs of individual teachers, each teacher is part of a greater whole: the school as an organization. As defined by Goddard and colleagues, "collective efficacy is an emergent group-level attribute, the product of the interactive dynamics of group members" (p. 482). Like the previously described studies on teacher efficacy belief (Tschannen-Moran & Hoy, 2001, 2007; Tschannen-Moran et al., 1998), Goddard and colleagues developed a model and measure of collective efficacy, which they then test in a series of elementary schools. The model is similar to that of Tschannen-Moran and colleagues (1998), with one distinction. Whereas individuals can separate task analysis and analysis personal teaching competence when judging their own efficacy, the line between these analyses blurs when judging the efficacy of a group (Goddard et al.). After developing an appropriate measure based on this theoretical model, Goddard and colleagues tested the hypothesis that collective teacher efficacy influences student achievement, as does individual teacher efficacy (Bandura, 1993). Administering the collective teacher efficacy scale (reliability 0.92) to 47 urban elementary schools within one district, Goddard and colleagues used multilevel tests to determine that "collective teacher efficacy is a significant predictor of student achievement in both mathematics [explaining 53.27% of between-school variance] and reading achievement [69.64% between-school variance]" (p. 500), greater than that of demographic variables of socioeconomic status, race and ethnicity, or gender. Thus, Goddard and colleagues conclude that collective teacher efficacy is one more piece of individual teacher efficacy and student achievement, according to the theory of triadic reciprocal determinism put forth by Bandura. Again, although collective teacher efficacy will not be a measured variable in this study, it certainly is a contributor towards school culture. Collective teacher efficacy is a general measure, applying to an entire organization that includes teachers of multiple disciplines, not all of whom will necessarily be affected by CCSS or WI courses. Since this study focuses on the specific context of writing instruction in science courses, individual teacher efficacy belief is a more appropriate measure.

The theory of teacher efficacy belief was developed in the K-12 setting and only a handful of studies apply this theory to post-secondary education (Fives & Looney, 2009; Shavaran et al., 2012). Noting that graduate student teaching assistants (GTA) both required and desired more professional development as instructors, Heppner (1994) investigated the teaching efficacy of five psychology GTAs before and after a teaching practicum course. The strongest antecedents to improvements in GTA teaching efficacy were verbal persuasion and mastery experiences (Heppner). Verbal persuasion accounted for 75% of the positive experiences that shaped GTA teaching efficacy, while mastery experience accounted for 25% of the positive experiences and 90% of the negative experiences that shaped GTA teaching efficacy (Heppner). When asked to rate the impact of Bandura's four antecedents according to a 6-point Likert scale, GTAs rated mastery experience as most important (4.5), followed by verbal persuasion (4.2), vicarious experience (3.7), and physiological state (2.7). Thus, Heppner concludes that GTAs benefit from specific professional development when beginning their teaching careers. Although the sample size is extremely small, these findings are reminiscent of Tschannon-Moran and Hoy's (2007) findings on novice vs. career teachers. Like novice K-12 teachers, GTAs (novice instructors) depend heavily on verbal persuasion to bolster their teaching efficacy beliefs, which appear to be malleable at this stage of their career.

In a similar study, Prieto and Meyers (1999) examined the self-efficacy beliefs of psychology GTAs falling into three categories: trained with supervision (40% of participants), trained or supervised (47% of participants), and no training or supervision (13% of participants). The 176 participating GTAs from 116 departments responded to The Self-Efficacy Towards Teaching Inventory-Adapted (SETI-A; reliability 0.93). Factors influencing teaching efficacy included level of teaching duties (teaching vs. nonteaching), previous teaching experience and participant age (mastery experience), and training (primarily vicarious experience). Like Heppner (1994), Prieto and Meyers conclude that GTAs benefit from professional development in teaching. Whereas this sample size was much larger, Prieto and Meyers admit that the definitions of training and supervision was lacking. This underscores the importance of participant interviews to increase the resolution of such a broad snapshot of teacher efficacy beliefs.

Participant interviews will thus be an integral part of my study to more fully understand the antecedents of teaching efficacy beliefs in science writing instruction.

The previous two studies focus only on applying self-efficacy theory to GTAs who are novice teachers. Recognizing that "one would expect that more efficacious professors will strive to challenge their students in a way that stretches their minds and makes them think about the world differently" (Fives & Looney, 2009, p. 182)), Fives and Looney expand self-efficacy theory to faculty and GTAs. Using an online survey based on a modified TSES (Tschannen-Moran & Hoy, 2001) and Collective-efficacy Scale (Goddard et al., 2000), Fives and Looney collected demographic, teacher efficacy, and collective efficacy data from 75 graduate students, 24 non-tenured faculty, and 18 tenured faculty members from a Research I university in the mid-Atlantic region of the United States. Modifications to the TSES included changing *schoolwork* to *coursework, school/classroom rules* to *course policies*, *class* or *classroom* to *course*, and occasionally *students* to *undergraduates* (Fives and Looney). Fives and Looney also deleted six items that explained less than 0.5 of the variance. This modified scale had a reliability of 0.88 overall and subscale reliabilities of 0.82 for student engagement, 0.77 for instructional practice, and 0.61 for classroom management. Fives and Looney report no significant differences in efficacy beliefs based on teaching level, but did find significant difference in efficacy beliefs between individuals from the college of Behavioral and Social Sciences and the college of Education. Additionally, female participants exhibited higher teaching efficacy beliefs than male participants. Based on these results, Fives and Looney posit three initial hypotheses regarding the lack of efficacy differences according to teaching level: low-efficacy individuals self-selected out of participating in the survey, a focus on research and acceptance of adequate teaching at a Research I, and potentially unclear language in the TSES, based on lack of formal pedagogical training. Additionally, comparing their results to research by Soodak and Podell (1997) who found self-efficacy beliefs to be more homogenous among teachers (n = 626) with varying levels of experience at the secondary level than at the elementary level, Fives and Loony suggest that since university environments are similar to high school environments, teaching efficacy of university instructors may develop similarly to high school teachers and that as high schools and universities are both divided into departments, there is a higher level of interpersonal support and teamwork among colleagues. The hypotheses regarding self-selection and out-of-context measure are worrisome, considering my survey method will be similar. However, the other three hypotheses are interesting and lend more support to the comparability of high school teachers and post-secondary instructors.

Seeking to understand faculty efficacy in higher education, Shavaran and colleagues developed the Faculty Members' Efficacy Inventory (FMEI), a 44-item questionnaire with an overall reliability of 0.83. This measure contained four subscales: teaching efficacy (0.83), research efficacy (0.79), social efficacy (0.78), and personal competency (0.81). After establishing the FMEI, Shavaran and colleagues surveyed 261 faculty members from 3 public universities (presumably in Iran) to determine if statistically significant differences in faculty efficacy according to gender and professional level (lecturer, assistant, associated, and full professor). Regarding the teaching efficacy subscale, there was no significant difference between male and female faculty nor was there a significant difference based on professional level. This result is similar to that found by Fives and Looney (2009), but lacks explanation from the authors. Instructors and faculty at Research I universities include individuals from a diversity of cultures. Perhaps teaching efficacy does not necessarily apply across cultures and is thus a hidden variable in both studies. Alternatively, a general measure of teaching efficacy may not be specific enough for reliable use in a university setting. This underscores the importance of using a context-specific measure as teaching efficacy is extremely context dependent (Bandura, 1977; Tschannen-Moran et al., 1998).

Science educator writing instruction efficacy beliefs.

The current context facing many science teachers, both at the secondary and post-secondary levels is required integration of writing into the science curriculum via , CCSS-ELA (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) and WI courses (Russell, 2002), respectively. Tschannen-Moran and colleagues note that

> Rising standards challenge teachers' existing beliefs about the effectiveness of their teaching strategies. However, as teachers develop new strategies to cope with the changes and gain evidence of improved student learning, their personal teaching efficacy increases. (1998, pp. 236–237)

Thus, in the face of new standards, it behooves us to establish a baseline measure of science educator writing instruction efficacy beliefs (WIEB) and identify those strategies used by science educators with existing high WIEB to best plan professional development and support processes for science educators with lower WIEB.

In 1994, Holliday, Yore, and Alvermann reviewed the existing literature on learning science through reading and writing, focusing on then-current breakthroughs, barriers, and promises. Here, I focus on their comments regarding writing and science.

Holliday and colleagues (1994) applaud the spread of WAC through elementary, secondary, and post-secondary institutions, but lament that "little consideration of writing to learn has been given in science teacher education programs, curricula development projects, program evaluations, and teaching/learning research" (p.884). They indicate the largest barrier to using writing as a learning tool in classrooms is a focus on writing as a product and means of knowledge-telling rather than knowledge-transforming. Fortunately, two decades later, the standards set forth in CCSS-ELA (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) correspond with Holliday and colleagues' writing to learn goals of "a) solving communication problems; b) informing or persuading others; and c) constructing understanding, enhancing personal clarity, and producing greater insightfulness" (p.885). Unfortunately is the apparent lack of progress toward that which Holliday and colleagues found promising in 1994.

> Presently, little consensus about writing, explicit instruction, and science learning can be detected. Like science reading research in the 1960s, science writing research appears to be text-driven and fragmented. More interdisciplinary, collaborative explorations are needed (p.887).

At that time, Holliday and colleagues cited three studies regarding science teachers' knowledge and use of science writing. Two decades later, I review one of those studies along with three others.

In what Holliday and colleagues (1994) referred to as a text-driven and fragmented field of research, Sullenger (1990) sought to include the perspectives of teachers on writing in science. Specifically, Sullenger asks six questions about "science teachers' perspectives on (1) their own writing, (2) their students' writing, (3) teaching writing in science, (4) evaluating writing in science, (5) the purpose of writing, and (6) the contribution of writing to learning science" (p.4). Much like my own proposal, these questions were investigated using a two-phased study. Phase I consisted of a questionnaire with both open-ended, semantic differential and Likert-scaled questions completed by 114 secondary-level science teachers. During Phase II, Sullenger interviewed five teachers who had completed the questionnaire, selected for their varied perspectives on science writing. These interviews consisted of four distinct sessions and included three-day observations of each interview participant's classes. The questionnaires indicated consensus among science teachers that writing is an important means of learning science, but disagreement over what aspects of writing should be taught, who should teach and apply writing, and how and when science writing should be evaluated. Ultimately, science writing in classrooms is linked to perceptions of writing to learn science, teaching and evaluating writing in science, differences in disciplinary genres, and what students need to know about science (Sullenger, 1990). From the interview data, science teachers in were unfamiliar with disciplinary genres and did not feel as well prepared to write as English teachers and professional writers, but did feel positive about their own writing. Seeing their students as poor or limited writers, these teachers evaluated student writing based on concepts and some grammar, filling in what the student meant where writing was unclear (Sullenger, 1990). Science teachers perceived skill in science writing as a student responsibility and student writing skill development as the purview of English teachers (Sullenger, 1990). On a personal level, teachers viewed their own writing as a process for transforming knowledge, whereas for their students, writing was instead a product to tell knowledge (Sullenger, 1990). Thus Sullenger notes,

> Science educators who work with preservice teachers need to model the use of writing activities, including evaluation of those writing activities. Preservice teachers need to experience writing as a useful way of learning and as a way of monitoring understanding (p. 220).

In other words, Sullenger proposes that preservice teachers be given opportunities to increase WIEB through verbal persuasion, vicarious and personal mastery experiences as described by Bandura (1993). Aside from the interview data however, much of Sullenger's findings focus on teachers' perceptions of the place of writing in science (i.e., the task itself) rather than their efficacy beliefs of themselves as writing instructors in science.

Indeed, many studies that touch on science teacher writing instruction efficacy beliefs do so only as the concept intersects with the main focus of the study. Recognizing science learning as process-based rather than content based, researchers teamed with middle school teachers to build and assess a new science curriculum (Gaskins et al., 1994). Citing earlier research by Kuhn and Roth, the authors acknowledge that

> The conceptually based, process-oriented approach to science...requires teachers who are knowledgeable not only about science content, particularly the major concepts and principles of science, but also about reading, writing, and thinking processes that undergird learning, understanding, and applying science concepts (p.1041).

Thus, while the body of the study focused on student performance after two units of an integrated science and reading/writing program using a performance-based assessment, the researchers also interviewed the two teachers and their two supervisors at the end of the instruction to understand their experiences during development and implementation of the units. The four participants were each asked the same six questions and their transcribed interviews were then coded into nine themes. These themes included doubt that students would be able to cope with the performance-based assessment and successful student engagement and learning using a collaborative, problem-solving approach. Regarding their views on writing in science, three of the four teachers found that process-based focus in teaching, including reading/writing was most helpful to developing their students into problem-solvers. Keeping a process-based focus was difficult but improved by routine collaboration with colleagues; even so professional development remained a slow and "sometimes painful" (Gaskins et al., p. 1053) process. Considering the upcoming implementation of CCSS-ELA and ongoing WI courses, this study provides an intimate look into the journey of four teachers through significant curriculum change. Gaskins and colleagues note, "Despite the support network of two science teachers and two supervisors, as well as the students' positive responses to the curriculum, teacher found the design and implementation of new instruction to be stressful" (p. 1053). Indirectly, Gaskins and colleagues mention all four of Bandura's (1977) efficacy antecedents: mastery experiences (positive student responses), vicarious experiences (collaboration), verbal persuasion (support network), and emotional arousal (feelings of stress). However, being a single case study, the ability to generalize these results is limited and in truth, these observations are secondary to the assessment of the curriculum itself (Gaskins et al.)

Beyond Sullenger's (1990) otherwise unpublished dissertation research and Gaskins and colleagues' ancillary findings (1994) in the early 1990s, the next study on or related to science teacher science writing instruction efficacy belief is not until over a decade later. To preface, Tschannen-Moran and MacFarlane (2011) published a chapter on teacher self-efficacy in the language arts classroom in which they point out that the self-efficacy beliefs of English language arts teachers can become self-fulfilling prophesies and impact student achievement. Major antecedents to self-efficacy beliefs of these teachers include their own writing performance, observing other teachers, and social persuasion from colleagues (Tschannen-Moran & MacFarlane). Additionally, when faced with curricular changes, teacher self-efficacy often diminishes at the beginning of these changes. The length of time it requires for teachers to recover from this lowered self-efficacy often depends on whether the individual teacher perceives the change as a threat or a challenge (Tschannen-Moran & MacFarlane). While this chapter focuses solely on English language arts teachers, Landon-Hays (2012) published a dissertation examining some of the same beliefs and antecedents among English, social studies, and science teachers.

Given increased emphasis on writing in content areas, Landon-Hays sought to identify teachers' perceptions of writing and themselves as writing instructors. Additionally, Landon-Hays developed and implemented an instructional intervention to help guide teachers in integrating writing into their existing curricula, documenting their development as writing instructors within their respective disciplines. This study is purely quantitative, based on ten focus-group interviews with five high school teachers: two science, one social studies, and two English. During analysis of these taped and transcribed interviews, Landon-Hays focused on how the teachers conceptualize themselves as writing instructors, their guiding philosophy as writing instructors, and how a scaffolded approach to professional development aided these teachers in building self-efficacy as writing instructors. The interviews revealed that teachers with low writing efficacy beliefs associated their ability to implement writing instruction based on external factors and defined writing instruction based on grammar, assessment, and student ability. In contrast, "the teacher with the highest self-efficacy in this study took responsibility for her writing instruction and tended to place less blame on contextual factors" (Landon-Hays, 2012, p. 208). As the teachers progressed through professional development on writing instruction in the content areas, teacher perception of writing instruction efficacy beliefs increased and their definitions of writing instruction became more complex (Landon-Hays, 2012). Additionally, as efficacy belief increased, teachers originally having an external locus of control began to exhibit an inner locus, underscoring the importance of professional development and support networks in the face of curriculum reform (Landon-Hays, 2012). This study sets precedent for my own, which differs in a few critical ways, including a broader sample population (middle school, high school, and post-secondary science educators), a larger sample population through use of mixed methods, and a finer context focus (science educators).

As with studies of general teacher efficacy beliefs, studies on science writing instruction efficacy beliefs are few. One such study focuses on the relationship between major advisors and their graduate students (Ross et al., 2011). Recognizing that learning how to *write like a scientist* is a transformation and that many students find themselves becoming stuck in various stages of this transformation, Ross and colleagues sought to discover what tasks students and their advisors find difficult and what strategies within the sciences can aid in moving students through their transformation into becoming a member of their disciplinary discourse community. The authors used a mixed method approach, beginning with surveys for students (36 respondents) and advisors (29 respondents) followed by interviews with focus groups and interviews of students and supervisors. Students and supervisors came from a variety of disciplines, including health sciences, sciences, engineering, and math and computing. However, the majority of responses came from the sciences (Ross et al.). Students and advisors agreed thesis and manuscript publication/preparation are both the most important and most difficult activities, though advisors placed a higher emphasis on these qualities than students. From the surveys, students indicated that their advisor was the main source of support for doctoral writing and that this support was either insufficient or nonexistent. A number of professors agreed (Ross et al.). Some professors exhibit low writing efficacy themselves, considering themselves poor writers (Ross et al.). These professors often expect students to learn science writing through mimicry and are unable to explain their role in writing beyond feedback (often negative) and encouragement (Ross et al.). This lack of ability and unwillingness to teach writing results in professors who

> …do not necessarily know "how to teach writing skills." Perhaps this is because they do not perceive this as their role and/or the slow acculturation into the disciplines that they experienced restricts their ability to articulate the tacit (Ross et al., p. 14).

This sentiment is in agreement with Holliday and colleagues' observation that

> Frequently, literate people forget that words, syntax, and linguistic rules lack meaning to people who have not established the link between words as concept labels and experience with the related events and habits of the mind associated with specific types of communications and patterns of argumentation (1994, p. 878).

Ross and colleagues ultimately indicate a need to create a culture of mindfulness within the sciences. Given the results of their study, the writing experiences of graduate students are extremely stressful and often traumatic, perhaps leading to low writing efficacy beliefs as professors. Since low writing efficacy belief influences writing instruction efficacy belief (Landon-Hays, 2012; Tschannen-Moran & MacFarlane, 2011), this creates a potential negative feedback loop that continues to hinder post-secondary science instructors from incorporating writing into their science courses.

While much attention is given to improving student writing and learning in the sciences (Keys et al., 1999; Yates et al., 2005), it seems that both secondary and post-secondary level science educators remain largely unprepared to teach science writing skills and effectively incorporate writing into their science classes. I propose that this lack of implementation is due to low science educator science writing instruction efficacy beliefs. While several implementation barriers and efficacy belief antecedents are suggested for both groups (Holliday et al., 1994; Ross et al., 2011; Street & Stang, 2009), little has been resolved. For professional development in science writing instruction to be effective, we need to have a solid understanding of current levels and antecedents of science educator science writing instruction efficacy beliefs. Given the paucity of research in this particular area for both the secondary and post-secondary levels, my study will provide a snapshot of statewide science educator science writing instruction efficacy beliefs as well as a unique perspective into characteristics of individuals holding high efficacy beliefs in science writing instruction.

Chapter Summary

Writing is not only integral to disciplinary discourse in the sciences, it is also a way for students to process and make sense of new concepts and experiences encountered within a science class (Bruner, 1996; Emig, 1977; Moffett, 1965). However, many students (Yates et al., 2005) and teachers (Landon-Hays, 2012) have difficulty recognizing writing as part of *doing science*. Thus, secondary and post-secondary science teachers alike become correctors rather than collaborators, turning writing into a grammar exercise rather than a process of discourse (Akkus et al., 2007; Bratcher & Stroble, 1994; Chinn & Hilgers, 2000). This fallback to traditional and familiar structures may indicate low self-efficacy in the teacher's own ability to implement a new approach to learning (Akkus et al., 2007; Bratcher & Stroble, 1994; Tschannen-Moran et al., 1998). As teacher efficacy beliefs can affect student performance (Bandura, 1989; Tschannen-Moran et al., 1998), providing opportunities for teachers to increase their efficacy beliefs is essential. Since self-efficacy is highly contextual (Bandura, 1977), general measures of teacher efficacy beliefs are inadequate in the face of new requirements affecting specific disciplines. Currently, both secondary and post-secondary science educators face reforms that will force them to integrate writing into their classrooms (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). Whereas the links between self-efficacy and writing instruction within disciplines has been recognized previously, there are few studies providing information on the antecedents of science teachers' science WIEB (Gaskins et al., 1994; Holliday et al., 1994; Landon-Hays, 2012; Ross et al., 2011; Sullenger, 1990). Out of these, many include data on science teachers' science WIEB as an aside, rather than a direct goal of the study (Gaskins et al., 1994; Landon-Hays, 2012). Thus, my study will fit into the current gap in the literature to provide data on the antecedents of science teacher science writing instruction efficacy beliefs in both secondary and post-secondary settings. This information will be useful to provide effective professional development for secondary teachers facing Common Core State Standards requirements and post-secondary educators integrating writing intensive requirements into their courses.

Chapter 3: Methods

Introduction

Writing is an integral part of science as the primary mode of conversation within the scientific discourse community (Chinn & Hilgers, 2000; Syh-Jong, 2007; Tang & Gan, 2006; Yates et al., 2005). Writing also improves learning in both secondary and post-secondary classrooms (Bangert-Drowns, Hurley, & Wilkinson, 2004; Gunel, Hand, & McDermott, 2009; Hyers, 2001; Walker, 2006) and allows students to link new concepts with personal experience (Fulwiler, 1982) to develop personal narratives that incorporate new perspectives from a diverse community of learners (Bruner, 1996; Russell, 2002). With a majority of U.S. schools (Common Core State Standards Initiative, 2012) implementing the Common Core State Standards for English Language Arts (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) and a return of 41,500 hits for a Google search including the phrases *writing intensive courses* and *university*, writing will likely continue to be integrated with science education at both the secondary and post-secondary levels. However, transitioning from traditional methods of instruction to those that include writing to learn is often difficult (Akkus et al., 2007; Bratcher & Stroble, 1994). To be successful and persist in a new pedagogy, teachers must judge themselves capable of producing favorable outcomes in their classrooms or courses, even when faced with difficult and unmotivated students (Bandura et al., 1996; Tschannen-Moran & Hoy, 2001). These efficacy beliefs are powerful, predicting both teaching practices and student achievement (Bandura, 1977; Bandura et al., 1996; Goddard et al., 2000; Tschannen-Moran et al., 1998). Unfortunately, the writing instruction beliefs of science educators is generally low (Ross et al., 2011; Sullenger, 1990), often keeping writing to learn practices out of classrooms and courses (McLaren et al., 2011; Walvoord, 1996).

Thus, the goal of this sequential transformative mixed methods study (Creswell & Plano Clark, 2011) is to investigate secondary and post-secondary science educator writing instruction efficacy beliefs. This includes understanding the antecedents to high WIEB among science educators. To do so, I ask the following questions:

1. What are science educator science writing instruction efficacy beliefs across secondary and post-secondary contexts?
2. What characterizes individuals with high science WIEB?

This study follows a sequential transformative design (Figure 6), using self-efficacy (Bandura, 1977) as the framework (Creswell & Plano Clark, 2011). Electronic surveys will be sent to secondary and post-secondary schools in Oklahoma via email, resulting in a final dataset of self-selected participants. From these survey data, I will select twelve high efficacy belief individuals, six from secondary and six from post-secondary, to interview. This interview data will provide a richer picture of the antecedents to high science teacher science WIEB.

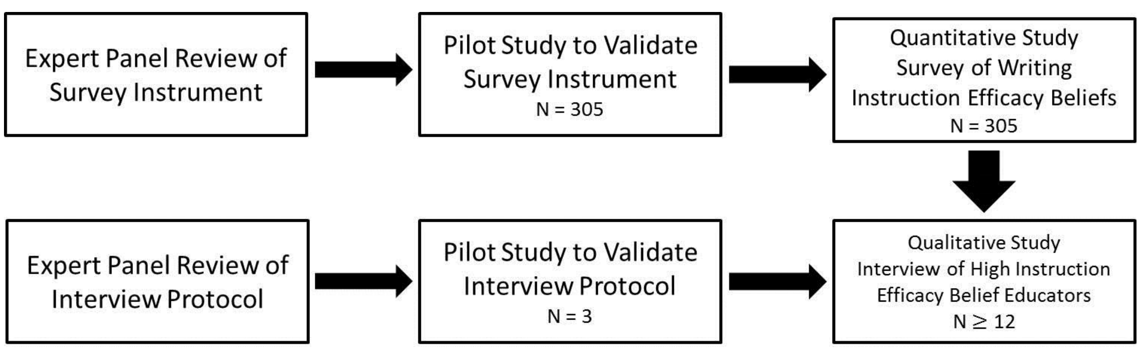

Figure 6. Research design for this sequential transformative mixed-methods study (Creswell & Plano Clark, 2011), including development and validation of survey instrument and interview protocol.

Sample/Participants

I intend to send online survey links to the 426 Oklahoma school districts for distribution to middle/junior high and high school science teachers and to science departments in the 28 Oklahoma state colleges and universities for distribution to science faculty and graduate teaching assistants. Minimum sample size is 305 participants divided equally among 5 groups (middle school teachers, high school teachers, graduate teaching assistants, two-year college faculty, and four-year college faculty) for a 95 percent confidence interval and an alpha of 0.05 (Faul et al., 2009). This sample size should be readily achievable, as Gall and colleagues (2007) indicate a relatively high (66 percent) return for surveys of educators. Currently, I intend for the sample to be self-selected, although this may result in low efficacy individuals opting out of the survey, especially among college faculty (Shavaran et al., 2012).

Prior to beginning my study, all survey instruments, emails, and procedures will be submitted to IRB for approval. I have also already completed the *Professional Ethics Training and Responsible Conduct of Research* course required by the University of Oklahoma and will soon renew my CITI certificate. Once approval is obtained, I will continue to follow the procedures set forth by IRB and ethical research practices. Access to secondary level emails will hopefully be obtained through contacts at the Oklahoma State Department of Education or the Oklahoma Science Teachers Association (OSTA) listserv. Barring these avenues, I will use the school websites posted to the Oklahoma State Department of Education website to contact each district superintendent, requesting that they pass the survey link on to the science teachers in their districts. Access to post-secondary level emails will be through each institution’s webpage, since there are much fewer colleges and universities than school districts.

Prior to sending these emails however, I will check with IRB to determine what permissions are required from each district and institution to approach their faculty for research purposes. I plan to use the Jeannine Rainbolt College of Education Qualtrics account to develop the electronic survey. Prior to encountering the survey questions, participants will be asked to give their electronic consent to participate. This consent form will follow the format established by the IRB. Participants may withdraw their consent at any time and will not be forced to answer any question. To protect participant identity, survey data will be aggregated and no single data point will be identified in such a way that would inevitably reveal the identity of a particular teacher (e.g., district or university name or specific geographical location). Once downloaded from Qualtrics, all data will be downloaded and stored on a portable hard drive that can be kept in a secure cabinet. The online data can then be deleted. Each survey response will be assigned a unique identification number and contact information will be stored in a separate data file. Participants can choose to give their contact information for interview purposes; they are not required to provide this information. Once survey participants have been selected and interviewed, participant names and contact information will be destroyed.

From the survey responses, I will interview science educators identified as having high writing instruction efficacy based on Rogers Diffusion of Innovation Model (Sandholtz et al., 1997; Schrum & Levin, 2012). As innovators and early adopters are those that engage most readily with new ideas, they likely have higher efficacy beliefs (Schrum & Levin, 2012; Tschannen-Moran et al., 1998). Thus, I will choose interview candidates from those with writing instruction efficacy scores at least two standard deviations above the mean (Schrum & Levin, 2012). I will continue with this stratified purposeful approach until I have reached saturation; my initial goal is twelve science educators, six from secondary level institutions and six from post-secondary institutions (Gall et al., 2007). To protect interview participant identities, each will be assigned a pseudonym and descriptive information that could still identify them (e.g., district, institution, underrepresented gender or ethnicity) will not be included.

Measurement Instruments

Demographics and open-ended questions.

The survey will include measures relating to demographics, specifically, gender, ethnicity, professional teaching category, highest degree earned and in what discipline, approximate number of students taught in one year, and publication/professional writing history. Additionally, I will include two open-ended prompts: *I can integrate writing into my science class because…* and *I cannot integrate writing into my science class because…*. These open-ended prompts will provide an avenue to explore possible barriers to science writing implementation and antecedents to science writing instruction efficacy beliefs across the larger population of participants, which compared with interview data, may provide triangulation and generalizability of the findings. I am limiting the number of open-ended prompts as they can be time-consuming to answer, resulting in fewer completed surveys (Gall et al., 2007).

Modified Teacher's Sense of Efficacy Scale.

The development of teaching efficacy belief measures began with the initial Rand Corporation study (Tschannen-Moran & Hoy, 2001; Tschannen-Moran et al., 1998), to the Teacher Efficacy Scale (Gibson & Dembo, 1984) on which the Science

Teaching Efficacy Belief Instrument (STEBI-A) (Riggs & Enochs, 1990) is based. Most recently, Tschannen-Moran and Hoy developed the Teachers' Sense of Efficacy Scale (TSES) with both a long and short form (Tschannen-Moran & Hoy, 2001).

The TSES (Figure 7) focuses on teaching efficacy beliefs in three areas: instruction, classroom management, and student engagement (Tschannen-Moran & Hoy, 2001). To score this measure, a response of *nothing* is assigned a value of 1, and *a great deal* is assigned a value of 9. Thus, unweighted means of the items are calculated for each factor. In a sample size of 410 inservice and preservice teachers, the unmodified TSES had reliability measures of 0.91 for instruction, 0.90 for classroom management, and 0.87 for student engagement (Tschannen-Moran & Hoy, 2001). Together these variables explain 58.47 percent of the variance using the long form (24 questions) and 69.10 percent using the short form (12 questions) (Tschannen-Moran & Hoy, 2001). A 19-item modified version used with 117 college instructors had an overall reliability of 0.88 (Shavaran et al., 2012).

Format:	**Sample Items:**
24 items (long form) or 12 items (short form), 9-point scale anchored at 1—nothing, 3—very little, 5—some influence, 7—quite a bit, and 9—a great deal.	How much can you do to control disruptive behavior in the classroom? (classroom management) How much can you do to motivate students who show low interest in school work? (student engagement) To what extent can you craft good questions for your students? (instruction)

Figure 7. Teachers' Source of Efficacy Scale (Tschannen-Moran & Hoy, 2001). Classroom management, student engagement, and instruction are the three factors considered relevant to teaching efficacy beliefs.

Additionally, the TSES uses language recommended by Bandura (2006) when constructing items. "The items should be phrased in terms of *can do* rather than *will do*.

Can is a judgment of capability; *will* is a statement of intention" (Bandura, 2006, p. 308). Since the TSES is robust and has enough reliability and validity to reasonably survive contextual changes, I plan to use modified versions of this measure. The survey instrument is not specifically geared for my context of science writing instruction, thus I need to validate and determine reliability for any modifications. I will also likely need to use two forms of the measure, one for secondary teachers based on the original TSES (Tschannen-Moran & Hoy, 2001) and one for post-secondary instructors similar to the modified TSES (Shavaran et al., 2012). However, the short form of the TSES is worded such that it may apply to both secondary and post-secondary settings.

The Writer Self-Perception Scale.

Given the prevalent theory that writing history/identity correlates with writing and WIEB (Landon-Hays, 2012; Street & Stang, 2009), I will also include a measure of science writing efficacy as part of the survey instrument. Modified from the Reader Self-Perception Scale (RSPS) the Writer Self-Perception Scale (WSPS) includes measures of performance (general and specific), observational comparison, social feedback, and physiological states (Figure **8**).

Format:	**Sample Items:**
38 items, 5-point scale from strongly agree to strongly disagree.	Writing is easier for me than it used to be. (GPR) The words I use in my writing are better than the ones I used before. (SPR) I write better than other kids in my class. (OC) Other kids think I am a good writer. (SF) When I write, I feel calm. (PS) I think I am a good writer. (GEN)

Figure 8**. The Writer Self-Perception Scale (Bottomley et al., 1997). General Progress (GPR), Specific Progress (SPR), Observational Comparison (OC), Social Feedback (SF), and Physiological States (PS) are the five scales included in the WSPS as well as one general question.**

To score the WSPS, strongly agree answers are assigned the highest value of 5 and strongly disagree answers are assigned the lowest value of 1. Since each subscale is associated with a different number of questions, the highest possible score for each is as follows: general progress, 40; specific progress, 35; observational comparison, 45; social feedback, 35; and physiological state, 30. Average values for each are 35, 29, 30, 27, and 22, respectively. Low values are 30, 24, 23, 22, and 16, respectively. The unmodified WSPS was designed for children and had reliability measures of 0.90 for general progress, 0.89 for specific progress, 0.90 for observational comparison, 0.87 for social feedback and 0.91 for physiological states from a sample size of 964 students in grades four, five, and six (Bottomley et al., 1997; Henk, Bottomley, & Melnick, 1996). Factor loadings for each item was 0.40 or greater and correlations among the scales ranged from 0.51 to 0.76 (Bottomley et al., 1997).

Interview questions.

In a review of literacy integration into the science classroom, Holliday, Yore, and Alvermann (1994) adapt five questions from Rosaen to investigate teacher attitudes and interactions with writing in the sciences.

1. What is their current knowledge level of the writing process in general and of [science] writing in particular?
2. What is their current skill level at using their knowledge to develop effective writing-to-learn [science] strategies?
3. To what extent are the teachers in “metacognitive control”… of the complexities associated with implementing change in their [writing-to-learn] instruction?

4. What are their attitudes about [science] writing, and dispositions to develop and promote its use in the classroom?
5. Which aspects of improving their [science] writing instruction are most interesting and challenging to them? (Holliday et al., 1994, p. 887).

Additionally, Sullenger (1990) identified seven perceptions that describe teachers' writing practices in science. These factors include

- the contribution of writing to learning science
- their own writing
- their students' writing
- teaching writing in science
- evaluating writing in science
- the difference between writing in science and English classes
- what is important for students to know about science (Sullenger, 1990, p. 192).

Thus, I will base my interview protocol on Holliday and colleagues' (1994) modified questions and Sullenger's (1990) findings. During the interview, I will also add probing questions as appropriate.

Data Collection/Procedures

Survey.

Since the writing instruction efficacy belief measure is a compilation of several previously existing measures with some modifications, I will perform an initial pilot study with teachers and professors to validate and calculate reliability for this specific measure (Gall et al., 2007). After discussing the instrument with a team of experts, I will distribute a final measure to a sample population based on the characterization of groups within the population, inviting them to add criticisms and recommendations for each question (Gall et al., 2007; van Teijlingen & Hundley, 2001). Five groups (e.g., middle school teachers, high school teachers, graduate teaching assistants, two-year college faculty, and four-year college faculty) requires 305 participants for a 95 percent confidence interval and an alpha of 0.05, whereas two groups (e.g. secondary and post-secondary educators) requires 210 participants (Faul et al., 2009). As Gall and colleagues (2007) note however, pilot studies often require less respondents than the final study. In the event of appropriate results, the pilot study can act as an internal pilot study where these results are included with those of the final study, although this approach is not always recommended (van Teijlingen & Hundley, 2001).

Following validation and appropriate revision of the writing instruction efficacy belief instrument, I will proceed with the quantitative, self-reported survey study to observe the range of WIEB among secondary and post-secondary science educators. The nature of this survey is cross-sectional, as this survey will represent a one-time measure of writing instruction efficacy (Creswell, 2009).

Interview.

Prior to conducting interviews with teachers and professors identified as having high WIEB, I will discuss the interview questions with a panel of experts and pilot test the protocol with at least three individuals not selected as part of the study (Gall et al., 2007). This will alert me to any communication issues, bias in my interview technique, and unclear or sensitive questions (Gall et al., 2007).

The introduction to the interview will include an explanation of my research purpose and general interview protocol (Esterberg, 2002; Gall et al., 2007). This includes assurance of confidentiality and the option to pass on any particular question (Esterberg, 2002; Gall et al., 2007). To avoid ethical dilemmas regarding participant confidentiality and risk (Esterberg, 2002), I will arrange all observations through the appropriate administrators for each institution. In addition, I will use pseudonyms and make all participants aware that they can withdraw their participation at any time, indicated on approved IRB consent forms.

Data Analysis

Survey.

During analysis, I will report descriptive statistics for the sample population, reporting survey return rates and any response bias (Creswell, 2009). As Tschannen-Moran and Hoy (2001) recommend using factor analysis and unweighted means to determine how participants respond to the questions, I expect to do the same using appropriate statistical software. Without *a priori* assumptions, I plan to use ANOVAs and t-tests to compare means among demographic categories as well as correlation to analyze WSPS scores with WIEB-TSES scores.

To analyze responses to the open-ended questions, I will follow Creswell's (2007) data analysis spiral (Figure 9), using an inductive approach. I will begin by organizing the data into a single file and reading each response, noting similar words, phrases, and ideas. From these notations, I will develop categories of common responses. Throughout this process, I will make sure to write copious notes explaining my thinking and decision-making so as to increase transparency. Once I have completed my initial analysis, I will request that one or two colleagues read and categorize a sample of these responses to provide peer review. After discussion with these colleagues, I will develop specific codes representing the final categories. After assigning each response the appropriate code, I will interpret the codes into themes, again requesting peer review as a check against my own biases.

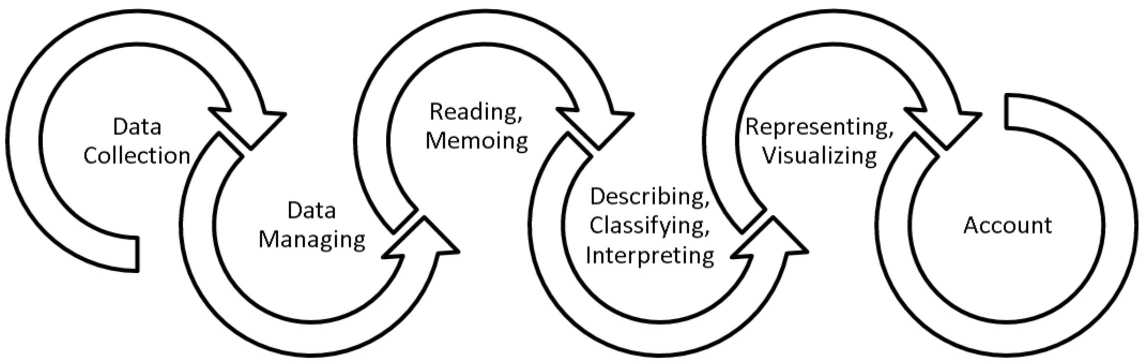

Figure 9. Data Analysis Spiral for analyzing quantitative data (Creswell, 2007).

Interview.

Like the open-ended data, I will follow an inductive approach (Creswell, 2007), using the data analysis spiral (Figure 9). After transcribing each recording and reading the transcriptions several times, I will compile and organize this data as suggested by LeCompte (2000) to recognize where gaps exist in my data. To maintain transparency, I will take notes on my thought processes and decision-making as I note common thoughts and ideas in each interview, making sure to also consult my interview notes and observations. After separating sections of the interviews into categories, I will ask one or two colleagues to analyze a subsample of the interview transcripts. After discussing and comparing categories, I will develop a coding system to apply to each transcript. Following coding, I will interpret the themes that become apparent. After transcribing, I will describe the data, including my own preliminary analysis concurrent with the interview or observation. Once I develop themes that become apparent in my mind, I will again request peer review from colleagues to avoid interpreting the data through a biased lens.

References

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry-based approach known as the Science Writing Heuristic to traditional science teaching practices: Are there differences? *International Journal of Science Education*, *29*(14), 1745–1765.

Balgopal, M. M., & Montplaisir, L. M. (2011). Meaning making: What reflective essays reveal about biology students' conceptions about natural selection. *Instructional Science*, *39*(2), 137–169.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191.

Bandura, A. (1983). Temporal dynamics and decomposition of reciprocal determinism: A reply to Phillips and Orton. *Psychological Review*, *90*(2), 166–170.

Bandura, A. (1989). Regulation of cognitive processes through perceived self-efficacy. *Developmental Psychology*, *25*(5), 729.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, *28*(2), 117–148.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In T. Urdan & F. Pajares (Eds.), *Self-Efficacy Beliefs of Adolescents (PB)* (pp. 307–337). Information Age Publishing.

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (1996). Multifaceted impact of self-efficacy beliefs on academic functioning. *Child Development*, *67*(3), 1206–1222.

Bangert-Drowns, R. L., Hurley, M. M., & Wilkinson, B. (2004). The effects of school-based writing-to-learn interventions on academic achievement: A meta-analysis. *Review of Educational Research*, *74*(1), 29–58.

Bottomley, D. M., Henk, W. A., & Melnick, S. A. (1997). Assessing children's views about themselves as writers using the Writer Self-Perception Scale. *The Reading Teacher*, *51*(4), 286–296.

Brammer, C., Amare, N., & Campbell, K. S. (2008). Culture shock: Teaching writing within interdisciplinary contact zones. *Across the Disciplines*, *5*.

Bratcher, S., & Stroble, E. J. (1994). Determining the progression from comfort to confidence: A longitudinal evaluation of a National Writing Project site based on multiple data sources. *Research in the Teaching of English*, *28*(1), 66–88.

Bruner, J. S. (1996). *The culture of education*. Harvard University Press.

Carter, M. (2007). Ways of knowing, doing, and writing in the disciplines. *College Composition and Communication*, *58*(3), 385–418.

Chinn, P. W., & Hilgers, T. L. (2000). From corrector to collaborator: The range of instructor roles in writing-based natural and applied science classes. *Journal of Research in Science Teaching*, *37*(1), 3–25.

Common Core State Standards Initiative. (2012). In the states. *Common Core State Standards Initiative*. Retrieved March 12, 2013, from http://www.corestandards.org/in-the-states

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks: Sage.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed method approaches*. Thousand Oaks, Calif.: Sage.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Los Angeles: Sage.

Davis, B. (2004). *Inventions of teaching: A genealogy*. Mahwah, N.J.: L. Erlbaum Associates.

Denzin, N. K., & Lincoln, Y. S. (2003). *The landscape of qualitative research: Theories and issues*. Thousand Oaks, Calif.: Sage.

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication*, *28*(2), 122–128.

Esterberg, K. G. (2002). *Qualitative methods in social research*. McGraw-Hill Boston.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior research methods*, *41*(4), 1149–1160.

Fives, H., & Looney, L. (2009). College instructors' sense of teaching and collective efficacy. *International Journal of Teaching and Learning in Higher education*, *20*(2), 182–191.

Fosnot, C. T., & Perry, R. S. (2005). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice* (Second ed., pp. 8–38). New York: Teachers College Press, Columbia University.

Fulwiler, T. (1982). The personal connection: Journal writing across the curriculum. *Language connections: Writing and reading across the curriculum*, 15–31.

Gall, M. D., Gall, J. P., & Borg, W. R. (2007). *Educational research: An introduction*. Boston: Pearson/Allyn & Bacon.

Gaskins, I. W., Guthrie, J. T., Satlow, E., Ostertag, J., Six, L., Byrne, J., & Connor, B. (1994). Integrating instruction of science, reading, and writing: Goals, teacher development, and assessment. *Journal of Research in Science Teaching*, *31*(9), 1039–1056.

Gibson, S., & Dembo, M. H. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology*, *76*(4), 569–582.

Goddard, R. D., Hoy, W. K., & Hoy, A. W. (2000). Collective teacher efficacy: Its meaning, measure, and impact on student achievement. *American Educational Research Journal*, *37*(2), 479–507.

Goddard, R. D., Hoy, W. K., & Hoy, A. W. (2004). Collective efficacy beliefs: Theoretical developments, empirical evidence, and future directions. *Educational Researcher*, *33*(3), 3–13.

Gray, J. (2000). *Teachers at the center: a memoir of the early years of the National Writing Project*. Berkeley, Calif: National Writing Project.

Gunel, M., Hand, B., & McDermott, M. A. (2009). Writing for different audiences: Effects on high-school students' conceptual understanding of biology. *Learning and Instruction*, *19*(4), 354–367.

Harbke, C. R. (2007). *Development and evaluation of the" Self-Efficacy for Scientific Writing" scale*. Washington State University.

Henk, W. A., Bottomley, D. M., & Melnick, S. A. (1996). Preliminary validation of the Writer Self-Perception Scale. In E. Sturtevant & W. Linek (Eds.), *Growing* *literacy*, 18th yearbook of the College Reading Association (pp. 188–199). Harrisonburg, VA: College Reading Association.

Heppner, M. J. (1994). An empirical investigation of the effects of a teaching practicum on prospective faculty. *Journal of Counseling & Development*, *72*(5), 500–507.

Holliday, W. G., Yore, L. D., & Alvermann, D. E. (1994). The reading–science learning–writing connection: Breakthroughs, barriers, and promises. *Journal of Research in Science Teaching, 31*(9), 877–893.

Hoy, A. W., & Spero, R. B. (2005). Changes in teacher efficacy during the early years of teaching: A comparison of four measures. *Teaching and Teacher Education*, *21*(4), 343–356.

Hyers, A. D. (2001). Predictable achievement patterns for student journals in introductory earth science courses. *Journal of Geography in Higher Education*, *25*(1), 53–66.

Jerde, C. L., & Taper, M. L. (2004). Preparing undergraduates for professional writing. *Journal of College Science Teaching*, *33*(7), 34–37.

Kaplowitz, M. D., Hadlock, T. D., & Levine, R. (2004). A comparison of web and mail survey response rates. *Public Opinion Quarterly, 68*(1), 94–101.

Keys, C. W., Hand, B., Prain, V., & Collins, S. (1999). Using the Science Writing Heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching*, *36*(10), 1065–1084.

Killingbeck, K. (2006). Field botany and creative writing: Where the science of writing meets the writing of science. *Journal of College Science Teaching*, *35*(7), 26–28.

Kroen, W. (2004). Modeling the writing process: Using authentic data to teach students to write scientifically. *Journal of College Science Teaching*, *34*(3), 50–53.

Labianca, D. A., & Reeves, W. J. (1985). Writing across the Curriculum: The science segment: A heretical perspective. *Journal of Chemical Education*, *62*(5), 400.

Landon-Hays, M. (2012, October 22). *I would teach it if I knew how: Inquiry, Modeling, Shared Writing, Collaborative Writing, and Independent Writing (IMSCI), a model for increasing secondary teacher self-efficacy in integrating writing instruction in the content areas* (Ph.D.). Utah State University.

Lankford, D., & vom Saal, F. (2012). Converting a biology course into a writing-intensive capstone course: Using collaboration between a professor and graduate teaching assistant. *Journal of College Science Teaching*, *41*(4), 14–22.

LeCompte, M. D. (2000). Analyzing qualitative data. *Theory into practice*, *39*(3), 146–154.

Marek, E., & Cavallo, A. M. (1997). *The learning cycle: Elementary school science and beyond* (Rev Ed.). Portsmouth, NH: Heinemann.

McDermott, M., & Kuhn, M. (2011). Using writing for alternative audiences in a college integrated science course. *Journal of College Science Teaching*, *41*(1), 40–45.

McLaren, I. A., Dyche, C. A., Altidor-Brooks, A., & Devonish, H. (2011). Survival or natural death? Issues related to the sustainability of Writing across the Curriculum programmes. *Journal of Academic Writing*, *1*(1), 254–266.

Moffett, J. (1965). I, you, and it. *College Composition and Communication*, *16*(5), 243–248.

Monroe, J. (2003). Writing and the disciplines. *Peer Review*, (Fall), 4–7.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards (English Language Arts)*. Washington D.C.: National Governors Association Center for Best Practices, Council of Chief State School Officers. Retrieved from http://www.corestandards.org/ELA-Literacy

National Research Council. (1996). *National Science Education Standards*. Washington, D.C.: The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=4962

National Writing Project. (2010). *Writing Project professional development continues to yield gains in student writing achievement* (No. 2). Research Brief (pp. 1–8). Berkeley, CA: University of California.

National Writing Project. (2013). About NWP. *National Writing Project*. Retrieved March 12, 2013, from http://www.nwp.org/

Ormrod, J. E. (2011). *Human Learning* (6th ed.). Upper Saddle River, N.J.: Pearson.

Palmer, D. (2011). Sources of efficacy information in an inservice program for elementary teachers. *Science Education, 95*(4), 577–600.

Porter, A., McMaken, J., Hwang, J., & Yang, R. (2011). Common Core Standards: The new US intended curriculum. *Educational Researcher*, *40*(3), 103–116.

Prieto, L. R., & Meyers, S. A. (1999). Effects of training and supervision on the self-efficacy of psychology graduate teaching assistants. *Teaching of Psychology, 26*(4), 264.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an efficacy belief instrument for elementary teachers. *Science Education*, *74*(6), 625–637.

Ross, P. M., Burgin, S., Aitchison, C., & Catterall, J. (2011). Research writing in the sciences: Liminal territory and high emotion. *Journal of Learning Design*, *4*(3), 14–27.

Russell, D. R. (2002). *Writing in the academic disciplines: A curricular history*. Carbondale, IL: Southern Illinois University Press.

Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: creating student-centered classrooms*. New York: Teachers College Press.

Schrum, L., & Levin, B. B. (2012). Strategic leadership: Encouraging and assessing technology integration. In L. Schrum (Ed.), *Educational technology for school leaders* (pp. 41–58). Thousand Oaks, Calif.: Corwin Press.

Shavaran, S. H. R., Rajaeepour, S., Kazemi, I., & Zamani, B. E. (2012). Development and validation of faculty members' efficacy inventory in higher education. *International Education Studies*, *5*(2), p175.

Sheehan, K. B. (2001). E-mail survey response rates: A review. *Journal of Computer-Mediated Communication*, *6*(2), 0–0.

Sheils, M. (1975, December 8). Why Johnny can't write. *Newsweek*, p. 58.

Soodak, L. C., & Podell, D. M. (1997). Efficacy and experience: Perceptions of efficacy among preservice and practicing teachers. *Journal of Research and Development in Education*, *30*(4), 214–221.

Soven, M. (1988). Beyond the first workshop: What else can you do to help faculty? *New Directions for Teaching and Learning*, *1988*(36), 13–20.

Stock, P. L. (1986). Writing across the Curriculum. *Theory into Practice*, *25*(2), 97–101.

Street, C., & Stang, K. (2008). Improving the teaching of writing across the curriculum: A model for teaching in-service secondary teachers to write. *Action in Teacher Education*, *30*(1), 37–49.

Street, C., & Stang, K. K. (2009). In what ways do teacher education courses change teachers' self confidence as writers? *Teacher Education Quarterly*, *36*(3), 75–94.

Sullenger, K. S. (1990). *Science teachers' perspectives about writing in science* (Ph.D.). University of Georgia, United States -- Georgia.

Syh-Jong, J. (2007). A study of students' construction of science knowledge: talk and writing in a collaborative group. *Educational Research*, *49*(1), 65–81.

Tang, B. L., & Gan, Y. H. (2005). Preparing the senior or graduating student for graduate research. *Biochemistry and Molecular Biology Education*, *33*(4), 277–280.

The National Commission on Writing in America's Schools and Colleges. (2003). *The neglected "R": The need for a writing revolution* (p. 40). College Entrance Examination Board.

Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, *17*(7), 783–805.

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, *23*(6), 944–956.

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, *68*(2), 202–248.

Tschannen-Moran, M., & MacFarlane, B. (2011). I know I can! Teacher self-efficacy in the English langauge arts classroom. In D. Lapp & D. Fisher (Eds.), *Handbook of research on teaching the English language arts* (pp. 218–223). New York: Routledge.

Tsui, L. (1999). Courses and instruction affecting critical thinking. *Research in Higher Education*, *40*(2), 185–200.

Tudge, J. R., & Winterhoff, P. A. (1993). Vygotsky, Piaget, and Bandura: Perspectives on the relations between the social world and cognitive development. *Human Development*, *36*, 61–61.

van Teijlingen, E., & Hundley, V. (2001). The importance of pilot studies. *Social research update*, (35), 1–4.

Vygotsky, L. S. (1929). The problem of the cultural development of the child. *Journal of Genetic Psychology*, *36*(3), 414–434.

Vygotsky, L. S. (1978). Interaction between learning and development. *Readings on the Development of Children*, 34–41.

Walker, S. E. (2006). Journal writing as a teaching technique to promote reflection. *Journal of Athletic Training*, *41*(2), 216–221.

Walvoord, B. E. (1996). The future of WAC. *College English*, *58*(1), 58–79.

Yates, S. J., Williams, N., & Dujardin, A. F. (2005). Writing geology: Key communication competencies for geoscience. *Planet*, *15*, 36–41.

Appendix A – Prospectus: Modified TSES (long form)

Teacher Beliefs Directions: This questionnaire is designed to help us gain a better understanding of the things that create difficulties for teachers/professors in their science writing activities. Please indicate your opinion about each of the statements below. Your answers are confidential.	**How much can you do?** Nothing		Very Little		Some Influence		Quite a Bit		A Great Deal
1. When teaching science writing, how much can you do to get through to the most difficult students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2. When teaching science writing, how much can you do to help your students think critically?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3. When teaching science writing, how much can you do to control disruptive behavior in the classroom?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4. When teaching science writing, how much can you do to motivate students who show low interest in school/course work?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5. When teaching science writing, to what extent can you make your expectations clear about student behavior?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
6. When teaching science writing, how much can you do to get students to believe they can do well in school/course work?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
7. When teaching science writing, how well can you respond to difficult questions from your students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8. When teaching science writing, how well can you establish routines to keep activities running smoothly?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9. When teaching science writing, how much can you do to help your students value learning?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10. When teaching science writing, how much can you do to gauge student comprehension of what you have taught?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
11. When teaching science writing, to what extent can you craft good questions for your students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
12. When teaching science writing, how much can you do to foster student creativity?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13. When teaching science writing, how much can you do to get students to follow classroom rules?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
14. When teaching science writing, how much can you do to improve the understanding of a student who is failing?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
15. When teaching science writing, how much can you do to calm a student who is disruptive or noisy?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
16. When teaching science writing, how well can you establish a classroom management system with each group of students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
17. When teaching science writing, how much can you do to adjust your lessons to the proper level for individual students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
18. When teaching science writing, how much can you use a variety of assessment strategies?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
19. When teaching science writing, how well can you keep a few problem students from ruining an entire lesson?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
20. When teaching science writing, to what extent can you provide an alternative explanation or example when students are confused?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
21. When teaching science writing, how well can you respond to defiant students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
22. When teaching science writing, how well can you assist families/tutors in helping their students do well in class?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
23. When teaching science writing, how well can you implement alternative strategies in your classroom?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
24. When teaching science writing, how well can you provide appropriate challenges for very capable students?	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

Appendix B – Prospectus: Modified WSPS

Directions: Listed below are statements about writing. Please read each statement carefully. Then circle the letter that shows how much you agree or disagree with the statement.	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1. I write better than other teachers/scientists.	SA	A	U	D	SD
2. I like how writing makes me feel inside.	SA	A	U	D	SD
3. Writing is easier for me than it used to be.	SA	A	U	D	SD
4. When I write, my organization is better than other teachers/scientists.	SA	A	U	D	SD
5. People in my family think I am a good writer.	SA	A	U	D	SD
6. I am getting better at writing.	SA	A	U	D	SD
7. When I write, I feel calm.	SA	A	U	D	SD
8. My writing is more interesting than other teachers'/scientists' writing.	SA	A	U	D	SD
9. My principal/department chair thinks my writing is fine.	SA	A	U	D	SD
10. Other teachers/scientists think I am a good writer.	SA	A	U	D	SD
11. My sentences and paragraphs fit together as well as other teachers'/scientists' sentences and paragraphs.	SA	A	U	D	SD
12. I need less help to write well than I used to.	SA	A	U	D	SD
13. People in my family think I write pretty well.	SA	A	U	D	SD
14. I write better now than I could before.	SA	A	U	D	SD
15. I think I am a good writer.	SA	A	U	D	SD
16. I put my sentences in order better than other teachers/scientists.	SA	A	U	D	SD
17. My writing has improved.	SA	A	U	D	SD
18. My writing is better than before.	SA	A	U	D	SD
19. It's easier to write well now than it used to be.	SA	A	U	D	SD
20. The organization of my writing has really improved.	SA	A	U	D	SD
21. The sentences I use in my writing stick to the topic more than the ones other teachers/scientists use.	SA	A	U	D	SD
22. The words I use in my writing are better than the ones I used before.	SA	A	U	D	SD
23. I write more often than other teachers/scientists.	SA	A	U	D	SD
24. I am relaxed when I write.	SA	A	U	D	SD
25. My descriptions are more interesting than before.	SA	A	U	D	SD
26. The words I use in my writing are better than the ones other teachers/scientists use.	SA	A	U	D	SD
27. I feel comfortable when I write.	SA	A	U	D	SD
28. My principal/department chair thinks I am a good writer.	SA	A	U	D	SD
29. My sentences stick to the topic better now.	SA	A	U	D	SD
30. My writing seems to be more clear than other teachers'/scientists' writing.	SA	A	U	D	SD
31. When I write, the sentences and paragraphs fit together better than they used to.	SA	A	U	D	SD
32. Writing makes me feel good.	SA	A	U	D	SD
33. I can tell that my principal/department chair thinks my writing is fine.	SA	A	U	D	SD
34. The order of my sentences makes better sense now.	SA	A	U	D	SD
35. I enjoy writing.	SA	A	U	D	SD
36. My writing is more clear than it used to be.	SA	A	U	D	SD
37. Other teachers/scientists would say I write well.	SA	A	U	D	SD
38. I choose the words I use in my writing more carefully now.	SA	A	U	D	SD

Appendix B – Dissertation: Institutional Review Board Information Sheet

University of Oklahoma
Institutional Review Board
Information Sheet to Participate in a Research Study

Project Title: Science Writing Instruction Efficacy Beliefs of Secondary and Post-Secondary Science Instructors

Principal Investigator: Carrie J. Miller-DeBoer

Department: Instructional Leadership and Academic Curriculum

You are being asked to volunteer for this research study. This study is being conducted at the University of Oklahoma. You were selected as a possible participant because you teach science at the secondary or post-secondary level in Oklahoma. In this study, the word "science" includes any of the STEM areas (e.g. math, physics, engineering, etc.).
Please read this information sheet and contact me to ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study

The purpose of this study is to learn more from secondary and post-secondary science teachers and instructors about their experience with writing and teaching science writing.

Number of Participants

About 500 people will take part in this study. Approximately 100 people (33 middle school teachers, 33 high school teachers, and 34 college or university instructors) will take part in a pilot study to test the survey. Approximately 400 people teaching in Oklahoma (133 middle school teachers, 133 high school teachers, and 134 college or university instructors) will take part in the final survey, and 18 (6 middle school teachers, 6 high school teachers, and 6 college or university instructors) who participated in the survey will also participate in an interview.

Procedures

If you agree to be in this study, you will be asked to complete an online survey about your experiences with writing and the teaching of writing in your science classes. First, you will be asked questions about basic demographic data. You will then be given a series of statements about yourself as a writer and asked to rate your agreement or disagreement with each statement. Finally, you will be asked a series of questions about teaching science writing and asked to rate your ability from not being able to do anything about the situation to being able to do a great deal about the situation. Later, you will be asked if you would also like to participate in a potential interview. You may choose to only complete the survey and not participate in a subsequent interview.

Length of Participation

Completing this survey should take approximately 20-30 minutes.

Risks and Benefits

There are no foreseeable risks or discomforts to you for taking part in this study. There are no direct benefits to you from participating in this study. However, your responses will give you an opportunity to reflect on your experiences with writing. Your responses will also potentially help improve science writing pedagogy and workshops at institutions beyond your own.

Confidentiality

In published reports, there will be no information included that will make it possible to identify you. Research records will be stored securely and only approved researchers will have access to the records.
Your part in this study will be handled in a confidential manner. However, because of the nature of web-based surveys, it is possible that respondents could be identified by the IP address or other electronic record associated with the response. Neither the researcher nor anyone involved with this survey will be capturing those data. After taking the survey, you will be asked if you would like to further participate in an interview associated with this project. In this case, you will be identified only to the researcher; this information will not be reported or kept with your survey responses. Any reports or publications based on this research will use only group data and will not identify you or any individual as being affiliated with this project.

There are organizations that may inspect and/or copy your research records for quality assurance and data analysis. These organizations include the OU Institutional Review Board.

Voluntary Nature of the Study

Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

Future Communications

The researcher would like to contact you again to recruit you into this study or to gather additional information. At the end of the survey, you will have the option to select one of the following responses:

- I give my permission for the researcher to contact me in the future.
- I do not wish to be contacted by the researcher again.

Contacts and Questions

If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at (405) 325-1498 or cmiller4462@ou.edu. Timothy Laubach is the faculty advisor and can be contacted at (405) 325-1979 or laubach@ou.edu.

Contact the researcher(s) if you have questions or if you have experienced a research-related injury.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

This study has been approved by the University of Oklahoma, Norman Campus IRB.

IRB Number: 4587 **Approval date:** *9/2/14*

Appendix C – Dissertation: Interview Consent Script

Thank you for your time and willingness to participate in an interview. As you know, I am interested in learn about the experiences of secondary and post-secondary science educators in writing and teaching science writing.

I want you to know that the decision to participate in this research project is voluntary. If the questions are general and abstract, you may volunteer any detail you wish. Based on your answers, I may add probing questions. You also have the option of declining to answer – passing on – any of the questions and may stop the interview at any time.

There are no foreseeable risks or discomforts to you for taking part in this study, nor are there direct benefits to you from participating in this study. Your part in this study will be handled in a confidential manner. Neither your name nor identifying details from our conversation will be reported in any reports or publications based on this research. With your permission, I would like to record our interview. This recording will be transcribed and the audio file deleted afterwards. Do I have your permission to record the interview? To provide further confidentiality, would you like to use a pseudonym during our interview? Is there a particular pseudonym you would like to use?

Do you have any questions before we start?

1. How do you define science writing?

2. How do you currently incorporate science writing into your classroom/courses?

3. How do you evaluate your students' science writing?

4. What resources do you have for teaching science writing in your classes?

5. How have you been prepared to teach science writing in your classes?

6. What barriers do you face when teaching science writing in your class? How do you overcome those barriers?

7. What aspects of improving your science writing instruction are most interesting to you?

8. What aspects of improving your science writing instruction are most challenging to you?

9. Tell me what you think I need to know but didn't ask regarding these things we talked about in this interview.

Now that we are finished, do you have any questions you would like to ask me about this research project? If you want to contact me later, you can reach me at cmiller4462@ou.edu, (405) 325-8879 or my advisor, Tim Laubach at laubach@ou.edu, (405) 325-1979. Also, I may need to contact you later for additional questions or clarification. May I contact you again at a later date?