A Mixed-Method Evaluation of Anxiety Antecedents Related to Biology Content Among K-16 Educators

by

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"Happiness can be found, even in the darkest of times, if only one remembers to turn on the light." – Albus Dumbledore

This dissertation is dedicated to the 2 lights in my life that have made all of this possible -

My amazing and supportive wife, KristyAnn

And my curious and rambunctious bubba, Greyson.

~Always~

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ABSTRACT

This dissertation is comprised of three studies that define and subsequently evaluate different antecedents to STEM (science, technology, engineering, mathematics) anxiety in elementary, secondary, and tertiary faculty. The literature review developed a framework of antecedents to anxiety in STEM classrooms or contexts. This was accomplished through a review of anxiety literature in each of the STEM domains, also incorporating statistics. The STEM anxiety framework was then used to develop research questions for the quantitative and qualitative study. Both studies used a cross-sectional survey design, and data for both studies was collected simultaneously, but separated prior to analysis. The quantitative study used a Likert-style survey to gather teacher efficacy data for a list of biology concepts developed by biology content experts with both secondary and tertiary education experience. The comparison of self-efficacy scores across different demographics found that both the teaching context (elementary, secondary, or tertiary) and the approximate number of undergraduate biology courses had significant impacts on self-efficacy scores. Both those teaching in elementary contexts and those who reported <5 undergraduate biology courses exhibited significantly lower self-efficacy scores, followed by tertiary and secondary educators respectively. The qualitative study utilized a personification writing prompt asking the participants to personify their own relationship with biology. This study found that, in terms of code diversity, those in tertiary education had the highest diversity of relationship codes, followed by secondary and elementary educators respectively. This could be seen as indicative of the amount of training leading to more developed relationships. The findings of these studies, together, indicate that there is a need to revisit the curricula of

elementary teacher training programs. Elementary educators are responsible introducing students to formal education, and as shown in the pair of empirical studies herein, those that exhibit lower self-efficacy can unintentionally inhibit their students' progress throughout the entirety of their education.

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CHAPTER I: STUDY RATIONALE AND BACKGROUND

Introduction

There are numerous barriers to effective teaching and learning in formal classroom contexts (Stichler et al, 2011; Wallace, 2011). Some of these barriers include language and cultural differences between teachers and students (Henderson & Wellington, 1998; Parker et al., 2005), students' socioeconomic status and the subsequent availability of resources and supports (SES; Jury et al., 2017), and teacher or student anxiety in the classroom (Levine, 2008). In particular, anxiety can be caused by any number of factors within the classroom space. For instance, anxiety levels can be related to the content being taught for both the teacher attempting to teach the materials and the students negotiating it (Rodger et al., 2007). In addition, anxiety can be content-independent and related to the social norms and learning structures within the environment (England et al., 2017) or other practices that are engrained in academic settings, such as testing (Cassady & Johnson, 2002). The studies described in the following chapters focused on anxiety, particularly as pertaining to teachers and the discipline of biology.

To elaborate, content anxiety refers to those anxieties that have been identified and studied within particular disciplinary areas such as mathematics or science (e.g., Mallow, 1986; Tobias & Weissbroad, 1980). Both of the following studies focused specifically on the disciplinary anxiety related to the life sciences. There are numerous aspects related to increases in disciplinary anxiety, in both teachers and students, that are reported in their respective research literatures, such as student SES, teaching self-efficacy, and gender. This is not meant to be an exhaustive list, and more will be discussed in Chapter 2 of this dissertation, but what these findings indicate is that teacher content anxiety is not merely a product of the content itself and can result from a multitude of personal and contextual factors.

In addition to those factors related to anxiety listed above, there is also the potential for teacher training in the disciplinary subject matter, or lack thereof, to lead to an increase in teacher disciplinary anxiety in the classroom. In particular, it has been reported that those who have less background in science content are more likely to avoid teaching it (Ramey-Gassert & Shroyer, 1992). Additionally, there is the potential that the avoidance behavior described by Ramey-Gassert and Shroyer (1992) could manifest in the decision to teach at the elementary level in order to avoid particular content areas. Broadly speaking, elementary teacher training programs have more courses for pedagogical training than they do content training. In contrast, secondary teacher training is often done through the disciplinary department with the pre-service teacher obtaining a content major with a minor in education. Therefore, secondary education teachers often have deeper background knowledge as it relates to the content that they will be teaching when compared to elementary teachers. There has been some research in the discipline of mathematics to support the claim of content training in elementary teachers as related to their reported levels of mathematics anxiety (e.g., Beilock et al, 2010).

Instructional training in higher education contexts is even more skewed toward disciplinary training, with a subsequent reduction in pedagogical training. For example, those graduate students within content disciplines that ultimately become graduate teaching assistants (GTAs) often have an undergraduate degree in the content they are teaching but have little to no pedagogical training (Hendrix, 1995). This lack of pedagogical training is often not remedied throughout their time as a GTA (Gardner & Jones, 2011). Similarly, a majority of faculty positions require disciplinary research experience with less emphasis on teaching experience. Theoretically, this could lead to instructional responsibilities in higher education being filled with individuals with the least amount of pedagogical training but more disciplinary content training.

This differential approach towards content and pedagogical training provides an interesting lens for the evaluation of different classroom factors related to teachers' disciplinary anxieties. Extending upon results from studies in both mathematics and science, more science content courses could lead to an increase in teaching self-efficacy (Velthuis et al. 2014) and consequently could serve as an early remediation step towards preventing the social transmission of an instructors' disciplinary anxiety to their students (Beilock et al. 2010). This particular phenomenon has not been studied in a specific disciplinary context, such as biology, across the teaching spectrum from primary to tertiary educational contexts.

Study Purpose and Overview of the Organization of the Dissertation

The purpose of this dissertation is two-fold. First, this dissertation aimed to explore and develop a model of integrated science, technology, engineering, and mathematics (STEM) content anxiety. The proposed model includes multiple antecedents and sources of these feelings of anxiety within the individual. In the context of this dissertation the individual in question is the teacher. However, the model may be applicable to students or other individuals in the classroom space. Construction of this model was accomplished through the critical literature review in Chapter 2 that explored how multiple independent STEM fields have conceptualized and studied content anxiety within disciplinary contexts. Research through multiple disciplines (e.g., science and mathematics) has identified numerous variables, such as self-efficacy and attitudes, that can increase anxiety and that have the potential to serve as barriers to an individual's success and retention within STEM fields (Allen-Ramdial & Campbell, 2014; Grossman & Porche, 2013; Kuley et al., 2017; Pia, 2015).

Chapter 2 provides an overview of the field of anxiety, including the psychological basis of the construct, as well as a synthesized model for STEM anxiety developed throughout the literature review. The chapter goes on to explore content anxiety as an important, and potentially emergent, barrier to student success under the numerous calls for STEM reform and curricular integration. The literature review has been structured to answer the following research questions.

1. How has anxiety been conceptualized in education research within the individual STEM disciplines (Science, Technology, Engineering, Mathematics)?
2. How has disciplinary anxiety been measured in education research? How valid and reliable are these measurement instruments?
3. What moderating antecedents have been shown to relate to disciplinary anxiety in education research studies?

Following the critical synthesis presented in Chapter 2, two empirical studies are also presented, each centering on one of two STEM content anxiety antecedents that were identified in the model presented in Chapter 2. Both of these studies were carried out within the context of biology, as Endler & Hunt (1966) point out that anxiety scales should be developed for specific contexts in order to be more accurate.

These studies, while later presented independently, were conducted in parallel using a concurrent nested mixed methods design. The goal of study one (Chapter 3) was to measure K-16 educators' self-efficacy as it relates to biology content. The study was guided by the research questions below:

1. How does teacher efficacy for teaching biology differ across demographic and instructor-related groups?
2. How does teacher efficacy for teaching biology differ across biology topics within demographics and instructor-related groups?

This quantitative study specifically evaluated the self-efficacy of K-16 educators within biology content, as many researchers have also expanded models of pedagogical content knowledge (PCK; Shulman, 1985) to encompass the effect of the teaching context (Abell, 2007; Gess-Newsome, 2015). Additionally, Pajares and Schunk (2001) posited that the self-efficacy of teachers, specifically, must be measured within a disciplinary context because the teachers' self-efficacy beliefs can be different when comparing multiple content areas.

The second study (Chapter 4) utilized a qualitative methodology and analysis in order to evaluate educator attitudes toward biology. Both positive and negative attitudes are often rooted in emotional responses and experiences that elicited those emotions. These types of reactions and data surrounding them have previously been successfully elicited via personification (Zazkis, 2015). These attitudes can also impact how these topics are approached in the classroom. The research question proposed to guide the qualitative study was:

1. What does a personification of biology prompt reveal about K-16 educators' attitudes towards biology?

Definition of Terms

This section will outline some of the important definitions that have been deemed instrumental for this dissertation.

Anxiety. First and foremost, this dissertation examined the conceptions of disciplinary anxieties presented in the STEM disciplines' respective research literatures. In particular, this dissertation uses the state anxiety and trait anxiety constructs as defined by Spielberger and Rickman (1990). From the aforementioned study, state anxiety is defined as the contextually-grounded emotional response to any anxiety-inducing situation; while trait anxiety is defined as the stable emotional responses that an individual develops in reference to particular anxiety-inducing situations. Additionally, this dissertation also uses the different psychological threats described by Lazarus and Averill (1972) that can lead to an anxiety response in an individual. Namely, these are symbolic, anticipatory, and uncertain threats. Symbolic threats are more often perceived when presented information directly conflicts with an individual's established mental framework, functioning much like cognitive dissonance. Anticipatory threats are environmental perceptions that act upon the biological and physiological need for safety and preservation of life and therefore could trigger the fight-or-flight response. Finally, uncertain threats are those that stem from assumptions that are made by the individual relating to the outcome of the situation at hand. These definitions and constructs will be presented again, and with more detail, in Chapter 2.

Attitudes. It was noted by Osborne et al. (2003) that the term attitudes was not well understood because it is comprised of numerous sub-constructs. For this study, I will be defining attitudes as those reactions, either positive or negative, towards science content and the original emotions that supported the development of these reactions. This content will, again, be biology content. Studies have shown that attitudes are inversely related to anxiety (Akin & Kurbanoglu, 2011). For instance, someone with a negative attitude towards biology is more theoretically likely to have higher biology anxiety.

Self-Efficacy. This study will, in part, use the definition of self-efficacy proposed by Bandura (1997), which says that self-efficacy is an individual's self-appraisal of their own ability. In the studies described here, these will be examined in relation to self-efficacy for teaching biology topics, which is an expanded definition encompassing teaching self-efficacy proposed by Tschannen-Moran & Hoy (2001). Studies have modeled the relationship between self-efficacy and anxiety and found that they are proportionally related (Akin & Kurbanoglu, 2011). For example, someone that has a positive self-efficacy related to content is more likely to exhibit low levels of content anxiety.

CHAPTER II: THE RESEARCH LANDSCAPE OF ANXIETY CONCEPTIONS ACROSS SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) CONTEXTS

Introduction to Chapter

This chapter will provide the theoretical underpinnings of this dissertation as a whole. This is being prepared in anticipation of submission to *Studies in Science Education*.

Overview of Chapter

Within Science, Technology, Engineering, and Mathematics (STEM) education, there have been numerous calls for instructional realignment to desired student outcomes such as disciplinary learning, STEM literacy, interest, and persistence in their chosen STEM field (Honey et al., 2014; Moore et al., 2020). Instructional alignment with these outcomes is a goal that seeks to advance STEM literacy at all educational levels (K-16) to ultimately meet the growing need for informed citizens and a more STEM-oriented workforce. This can be achieved by anchoring instruction to more real-world applications and situations, which by nature are more interdisciplinary (Bybee, 2010; Moore et al., 2020; Talanquer, 2014). There have been numerous conceptualizations for what is meant by an integrated STEM discipline that might anchor more real-world instruction in K-16 classrooms (Moore et al., 2020). However, some scholars argue that integrated STEM is simply the integration of two disciplines, while others argue that the integration of STEM is only achieved if there are conceptual and theoretical underpinnings of each of the disciplines (Brown & Bogiages, 2019).

As the focus of instructional policy and practice shifts from the individual disciplines of science, technology, engineering, and mathematics to integrated STEM, as a single content field, there is the potential for emergent difficulties facing both instruction and student learning. One of these potential barriers to instructional implementation of integrated STEM curricula is STEM content anxieties of both teachers and their students. The idea of content anxieties is not a novel one and is evidenced by decades of anxiety research in individual STEM content areas, such as mathematics anxiety (Tobias & Weissbrod, 1980). However, these disciplinary research agendas have been conducted in isolation from other content areas with very little consideration of how anxiety might manifest itself in cross-curricular or integrated STEM settings. With the proposition of a more integrated curricular model of STEM, there is the potential for novel STEM anxiety to arise as an emergent property of these reform efforts. In order to attempt to understand the impact of STEM anxiety on both students and teachers, there first needs to be a model for assisting in unpacking what theoretically STEM anxiety is.

This literature review aims to explore the similarities and the differences in anxiety at the level of the STEM content disciplines. To this end, the author aimed to review the literature pertaining to anxiety in each of the individual STEM disciplines independently and discuss the overlap between anxiety antecedents as part of an integrated discussion. To begin, the author will provide a historical perspective on the development of psychological anxiety concept. The remainder of the literature review was guided by a series of research questions:

1. How has anxiety been conceptualized in education research within the individual STEM disciplines (Science, Technology, Engineering, Mathematics)?

2. How has disciplinary anxiety been measured in education research? How valid and reliable are these measurement instruments?
3. What moderating antecedents have been shown to relate to disciplinary anxiety in education research studies?

Historical Development of the Anxiety Concept in Psychology

Before this paper utilizes the STEM literature to answer the above presented research questions, a brief review of the history of anxiety research is necessary to orient oneself to the anxiety constructs in the STEM disciplines. General anxiety was originally defined by Freud as a heightened emotional state, that cycled between feelings of anger or agitation and feelings of depression, coupled with stress. Lazarus and Averill (1972) expanded upon this original definition and delineated three domains of anxiety-causing threats: symbolic, anticipatory, and uncertain. Symbolic threats are not unlike the psychological tension, described by Festinger (1957) as cognitive dissonance, when one's beliefs are perceived as being inconsistent with the information presented. Symbolic threats produce an anxiety response when presented information is in direct conflict with an individual's established mental models. Anticipatory threats are related to perceived environmental threats to the individual, such as things that would activate the physiological fight-or-flight response. Finally, uncertain threats stem from assumed outcomes. This refers to heightened emotional responses over exactly what will happen, whether it will happen, when it will happen, and what can be done about it.

Lazarus and Averill (1972) posited an updated definition of anxiety as emotion-based upon perceptions of symbolic, anticipatory, and uncertain threats, as defined above. They also discuss that anxiety is more likely when an individual's cognitive systems, or others may know it as schema in education, no longer enable a person to relate meaningfully to the individual realized world that they have constructed within themselves. Again, this mirrors the construct referred to as cognitive dissonance.

Following Lazarus and Averill's (1972) research into the determinants of anxiety, Spielberger and Rickman (1990) expanded upon the general anxiety model by explaining the evolution of two types of anxiety that are contextually specific: state anxiety and trait anxiety. State anxiety is a transitory emotional experience stemming from apprehension, nervousness, and worry, specifically as it relates to a given context. Following the production of state anxiety, trait anxiety is defined as the stable differences in individual responses to state anxiety. The additional elements of state and trait anxiety extended the context of Lazarus and Averill's work (1972) by identifying specific anxiety responses to the threats they described. This model subsequently redefined anxiety as an unpleasant emotional reaction resulting from an appraisal of a situation in which the individual feels that the demands of the environment exceed their own abilities (Schwarzer et al., 1985).

Psychological Anxiety in Educational Contexts

Educational settings, such as classrooms, can be anxiety-inducing in both students and teachers. The nature of formal education is the acquisition of new knowledge, which may or may not easily assimilate into a student's existing schema. Learning in a classroom context can be an example of a symbolic threat to a student, as well as a potentially uncertain threat. The symbolic threat is the perceived difficulty connecting new information to old information. The potential uncertain threat is assumptions that the student would make about how they will be perceived by others for having difficulty in the learning process.

Response to an anticipatory threat is more physiological than psychological in that it has the potential to trigger an individual's biological fight-or-flight response. There are a number of examples in classrooms. For example, if there are students in a racial or socioeconomic (SES) minority, then they could be subject to anticipatory threats depending upon their background and experiences both inside and outside of the classroom. Low SES students could have negative experiences in, for example, science or math classrooms which could then serve as a priming event when they enter any science or math classrooms as opposed to literature classrooms.

Another example of an anticipatory threat could be students who are being bullied. The students' emotions or feelings that are triggered as part of their responses to these threats are their state anxiety or anxiety related to emotion. The trait anxiety is in how the students actually respond to their state anxiety. It is important to understand both the basis and trajectory of psychological anxiety research in order to evaluate research on anxiety in other disciplines. Using the ideas described above as initial conceptualizations, this literature review aims to draw parallels between psychological conceptions of anxiety and the individual STEM disciplines.

Literature Search Procedure

This literature search was conducted using both Google Scholar and the university library database. For each of these databases, the author searched with seven basic search terms *Psychological Anxiety*, *Science Anxiety*, *Technology Anxiety*, *Engineering Anxiety*, *Statistics Anxiety*, and *Mathematics Anxiety*. There were no date limitations placed on the articles, as one goal of this review was a historical perspective of the anxiety construct in each of the respective disciplines. The respective initial sample sizes throughout the filtering process for the anxiety definitions can be found in Figure 1.

Inclusion Criteria

The following list defines the inclusion criteria for studies found as part of the literature search.

1. Studies needed to be empirically-based, peer-reviewed, in a STEM education context, and had to have explicitly defined anxiety within the article.
    a. Articles were categorized based upon the rigor of their anxiety definitions. These categories were: 1) the study used the term anxiety without an explicit definition. Studies that were categorized here were eventually excluded; 2) the study provided a definition of anxiety through the use of references to other studies, or 3) the study provided a novel conceptualization for anxiety.
2. Studies were found in one of the aforementioned databases or were cited by studies found through this search protocol.
3. Primary studies from peer-reviewed journal articles, dissertations/theses were included, as well as Chapters from edited volumes or professional reports.

Exclusion Criteria

The following list defines the exclusion criteria for studies found as part of the literature search.

1. Studies that referred to anxiety in a classroom context but were not in STEM fields (e.g., literacy or reading anxiety) were excluded from this review.

2. Studies that were in the STEM disciplines fields but were in non-educational (e.g., business or laboratory management) contexts were excluded.

Selection Process

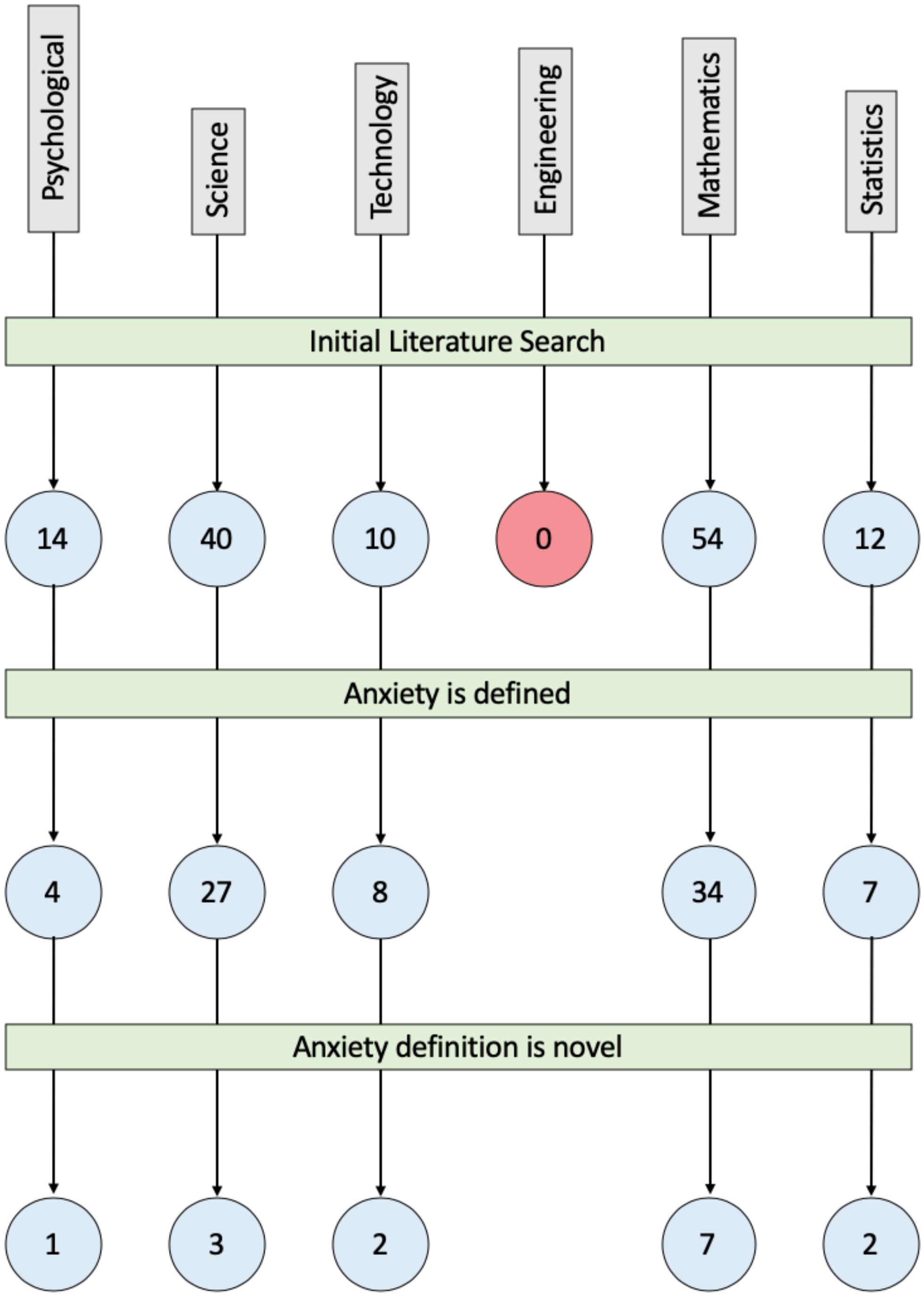
The literature search was conducted with Google Scholar and the university library database, for studies related to content anxieties in STEM disciplines. Information from those studies that met the inclusion criteria was collected. This included article title, publication year, and publication name. Once these data had been collected, the papers were mined for methodological information, such as sample size and description, research questions, research design, and validation steps in the context of the measurement instrument, if applicable.

To develop the individual conceptions of anxiety, an original sample size of n =130 studies was collected utilizing this method. Figure 1 shows the workflow for selecting articles for this portion of the review and reducing the sample. First, all articles were categorized by their respective disciplines either Science, Technology, Engineering, or Mathematics/Statistics. There is a literature base for Statistics Anxiety as well that the author felt would provide an important perspective on the development of this framework so this category was included in addition to the traditional STEM fields.

Using the original pool of n =130 studies, the author further divided the pool into studies that had defined anxiety (n =80), and of those which ones provided novel definitions for anxiety (n =15; see inclusion criteria 1a above), leading to a total n =95.

Figure 1.

The literature search workflow for selection of articles to define anxiety. Circles indicate the number of articles at each of the filters (green).



A Critical Review of the Anxiety Literature in STEM

The results from the literature search are presented below as STEM sub-disciplinary anxiety (e.g., science anxiety, technology anxiety). Within each of the subsections below, the results are further organized by the research questions, restated here:

1. How has anxiety been conceptualized in education research within the individual STEM disciplines (Science, Technology, Engineering, Mathematics)?
2. How has disciplinary anxiety been measured in education research? How valid and reliable are these measurement instruments?
3. What moderating variables have been shown to relate to disciplinary anxiety in education research studies?

Science Anxiety

How is it conceptualized?

The original concept of science anxiety was defined as the fear that students exhibit in response to learning science and stemming from negative self-appraisals of ability (Greenburg & Mallow, 1983). In 1986, Mallow published a seminal work on science anxiety detailing different hypothesized causes of science anxiety, potential ways to treat science anxiety, and how to develop and maintain a science anxiety clinic. Despite the evolution of research into science anxiety, to this day the definitions cited in many studies remain largely unchanged from Mallow's original work. The definition proposed by Greenburg and Mallow (1983) highlights the importance of the context, science learning environments, and the negative self-views of individual teachers' individual development of science anxiety.

The components of this original, and long-standing, definition correlate to some of the concepts described in the psychological literature. Specifically, by recognizing the importance of negative self-appraisals, it draws on the state anxiety condition wherein students are processing nervousness and worry related to science during their learning experiences. Additionally, by highlighting the importance of the context and learning environment, specifically science classrooms, this definition describes the anticipatory threats perceived by the individual within the classroom space, remembering that anticipatory threats are related to the specific environment where the anxiety is triggered.

How has it been measured?

The Science Anxiety Questionnaire (Alvaro, 1979) has been used in both empirical studies and anxiety clinics as a way to measure science anxiety (Mallow 1986, 1994; Udo et al., 2001). Recently, some groups have developed additional discipline-specific anxiety or self-efficacy rating scales for use in the classroom, specifically in physics (Sahin et al., 2015), in addition to other more general science anxiety scales (Bursal, 2008; Güzeller, & Doğru, 2012, Mehar & Singh, 2018). The following paragraphs track and critique these developments over time. It is important to note that science self-efficacy scales are discussed because they have been conceptualized as measuring the inverse of anxiety.

The initial Science Anxiety Questionnaire was used in the Loyola University Science Anxiety Clinic, a center established to assist university students in the remediation of their science anxiety and was adapted from Alvaro (1979) and published by Mallow (1986). This was a 44 item, Likert-style survey where students were asked to rate "how much [the student is] FRIGHTENED BY IT NOWADAYS" (Mallow, 1986, pg. 62). The Likert scale ranged from "not at all frightened" to "very much frightened" and included statements that aimed to delineate anxieties toward everyday tasks from science-specific tasks, anxiety related to STEM and non-STEM courses, anxiety related to STEM tasks and arts tasks, anxiety related to standard exams and midterm or final exams in STEM or non-STEM courses, and anxieties related to instruction by teaching assistants and professors.

For example, one of the item statements reads "studying for a final exam in Chemistry, Physics, or Biology" and could be compared to the anxiety that results from "studying for a midterm exam in a History course." These example statements are evaluating both the effect of the course content and the effect of exams on student anxiety levels. There was no published addendum or edited version of this questionnaire found as a product of the literature search. While these items are certainly useful ways to delineate potential variables of interest related to science anxiety, there are anecdotal concerns with psychologically priming the recipient with the use of the term "frightened" in the instructions at the beginning of the survey. Additionally, the instructions for the questionnaire were done in part with entirely capitalized words, which could also prime students with the implicit meaning of capitalization in today's culture, which is that things written entirely in capital letters are seen and read as shouting at the participant and may prime a sense of anger directed at the participant.

This Science Anxiety Questionnaire was *a priori* divided into nine psychometric factors for analysis: lab anxiety, science test anxiety, quantitative conversion, observer anxiety, nonscience test anxiety, memory anxiety, performance and precision anxiety, photography anxiety, and practical precision anxiety. These construct individually referred to:

- Lab anxiety items were those that alluded to fear directed toward the use of lab equipment, such as microscopes, or lab techniques, such as titration, that may be encountered in laboratory sections of a science course.
- Science test anxiety items were statements that ask about the fear of studying for either a midterm or final exam in a particular science course.
- Quantitative conversions are statements that instructed the participants to convert between standard and metric measures, or currency conversions.
- Observer anxiety items differed in the identity of the observer, either instructor, teaching assistant, or lab supervisor in an attempt to identify differential fears based upon different authority figures.
- Nonscience test anxiety items were very similar to those assessing science test anxiety, the main difference being that these made reference to exams in the liberal arts, such as history.
- Memory anxiety items referred to fearing memorization tasks required for class, both science and nonscience.
- Performance and precision anxiety items were subcategorized as being fear of either performance or precision-based activities. Performance activities were those that required students to perform a task such as appraising art quality (as an example of a non-science task). Precision

tasks were things that require precision in their execution, such as guitar tuning or mixing home remedies for common ailments.

- Photography anxiety were items that indicated a fear of situations that require manipulation or use of some kind of photographic equipment, such as cameras or movie projectors.
- Finally, practical precision anxiety items are very similar to precision anxiety, however, the situations described are more common, everyday examples, and less situationally specialized. One of these examples would be using cold water to cool down a bath, as opposed to the mixing of home remedies for bee stings.

As described above, this instrument measures scientific ideas and methods more generally without necessarily measuring anxiety specific to a particular scientific discipline, such as biology or physics.

Following the initial instrument designed by Alvaro, three groups have developed general science anxiety scales for different age groups due to validity concerns related to the original instrument. The original scale developed by Alvaro was done in the context of university students who had years of science background and experiences. Güzellar and Doğru (2012) developed a scale specifically for elementary-aged students. This was an important development because elementary-aged students are early in their education and have little to no formalized science experiences that could lead to the development of science anxiety. Many of the items were written from the perspective of a student as opposed to a more general audience, as seen in Alvaro's scale.

This scale also uses items related to the individual anxiety as well as items that evaluate how the environment might lead to anxiety, such as the classroom or study space being used. For this scale, the researchers carried out both exploratory and confirmatory factor analyses (EFA and CFA respectively) to test instrument reliability and validity. EFA was used on clauses (items) that met factor loads of at least 0.40, which led to the exclusion of 13 clauses, and the identification of 2 subscales termed *personal* and *environmental*. The CFA was used to test model fit and was found to be significant ($\chi^2 = 1114.22, p < .001, \text{RFI} = 0.96, \text{RMSEA} = 0.071$). Reliability for the scale was between $\lambda = 0.25$ and $\lambda = 0.81$. Discriminant validity between the two sub-scales was determined using lower tolerance (Fornell & Larcker, 1981) wherein the comparison between constructs is between squared correlation values and the amount of respective variance.

Bursal (2008) developed an instrument that was given to pre-service elementary teachers in a science methods course, another important development in the science anxiety literature. This is the first study that recognized, though implicitly, the importance of teacher education in science anxiety and the role of the teacher in the development or remediation of science anxiety in their students. The scale used a science anxiety (SANX) instrument designed by the author, as well as the Science Teaching Efficacy Belief Instrument (STEBI-B; Riggs & Enochs, 1990). The Cronbach's alpha for the pre- and post-assessments of the SANX was .91. Other reliability and validity evidence was given through factor analysis. Bursal (2008) reports that the cutoff point used for items aligned with the significant factors was .3 and that all items in the pre- and post-SANX loaded onto factors with values between .329 and .428 respectively.

Finally, Mehar & Singh (2018) developed a science anxiety scale that was for students in the middle and secondary grades, therefore bringing science anxiety scales that could be validly utilized at all levels K-16, however no published version of the scale could be found during this search. The reported evidence for reliability was a reliability coefficient = 0.90 calculated using the test-retest method. Validity evidence presented was content validity that came as a result of consultation with experts in the field regarding each of the included items.

The instruments described above were developed, and provide excellent evidence for validity and reliability, to ascertain anxiety as related to general science methods or practices for teaching science while not referencing any specific science content, such as ecological relationships or kinetic energy. This use of disciplinary concepts is the next logical step to identifying potential content-anxiety.

What are the antecedents?

The instruments described above, through their development, begin to describe antecedents to the development of science anxiety. Many studies have been conducted into the potential causes of science anxiety and found that there are both intrinsic and extrinsic factors that contribute to increases or decreases in science anxiety.

The extrinsic factors that may contribute to anxiety are as follows. Mallow (1986) hypothesized that teachers can contribute to the development of science anxiety in their students due to the teachers feeling unprepared to teach the curriculum, which also implicates curriculum as a potential source of anxiety. This is echoed by Beisel (1991).

Further, Mallow (1986) discusses the effect of the influence of teachers, both explicit and implicit, on the perceived difficulty and likelihood of success in science towards women and minority students (p. 3). Some teachers could be reacting to the curriculum or their own science anxiety in the classroom (p. 45), potentially even unintentionally misrepresenting the science taught in class (p. 57).

Gender was additionally studied by Udo et al. (2004) and found that women exhibited higher levels of science anxiety as compared to men. The effect of curriculum or content was also anecdotally reported by Beisel (1991) and Gottlieb (1983). Mallow (1986) also describes the representation of science and scientists in the media, including television and comics being “the root of science anxiety” (p. 1). One of the more amorphous contributors to science anxiety that Mallow (1986) describes is that of societal norms. He describes the scenario of failing a course, elaborating that social and societal expectations make it unacceptable to receive a failing grade in a liberal arts course, such as history or literature. However, students who fail chemistry or physics see the failing grade as a “badge of honor” (p. 32).

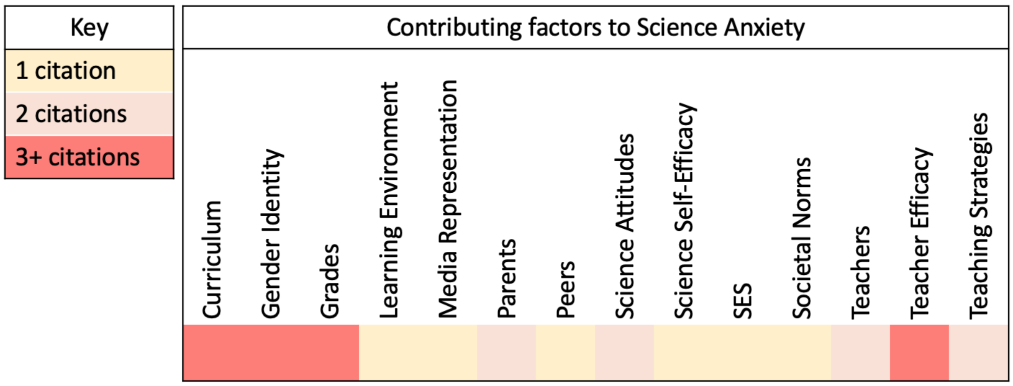
In addition to these, Mallow (1986) also hypothesized the influence of both peers and parents on development of science anxiety. Though no literature was found that discussed the influence of peers further, Meissner (1988) studied the influence of parents, finding that they can contribute to the science anxiety of their children, though the effect was small ($R^2 = .0263$). Mallow (1986) also initially hypothesized the effect of the intrinsic factor, science attitudes and the factor of self-efficacy as strong cognitive/affective contributors to science anxiety (Greenberg & Mallow, 1983). To support these claims, Cox and Carpenter (1989) discussed a course designed to improve science attitudes in elementary in-service teachers as a way to mediate science anxiety.

Aside from the contributions of Mallow (1986), there are other studies that have postulated novel mediators of science anxiety. Multiple studies have examined the potential for the contribution by teaching strategies on anxiety (Oludipe & Awokoy, 2010; Ural, 2016). Both of these studies examined the effect of different teaching strategies, specifically cooperative learning and guided-inquiry respectively, as ways to alleviate students' anxieties related to science laboratory courses. There is also a contribution of grades to the development of science anxiety. Kaya and Yildirim (2014) report that there is an inverse relationship among grades and science anxiety, saying that students with higher grades seem to have lower levels of science anxiety. The final piece of science anxiety for the general population was reported in the survey designed by Güzellar & Doğru (2012), which elaborated on the effect of the learning or studying environment where the science learning is taking place. There were no studies found on this specific topic aside from the item in the aforementioned survey.

There is a final component that may influence science anxiety that has been studied in a very specific population. Anxiety for teaching science has been studied in teachers in terms of alleviation measures (Cox & Carpenter, 1989), and more generally to define and refine the construct (Westerback, 1982, 1984).

Figure 2.

Contributing factors to science anxiety synthesized from the literature review.



Though excellent work has been done in order to initially determine the different antecedents described above, there were no studies found during the course of this literature search that documented potential interactions. For instance, logically, teacher efficacy could have an effect on the teaching strategies being used or the learning environment itself. More research is needed in order to evaluate potential interactions effects of the antecedents to science anxiety. In general, the most common moderators of science anxiety were the curriculum, the gender identity of the participant, course grades and instructor self-efficacy in the discipline (Figure 2).

Technology Anxiety

How is it conceptualized?

The author recognizes that the definition of "technology" within STEM education scholarship can be variable and contentious (Koehler & Mishra, 2009; Pea, 1985; Quinn et al., 2020). Therefore for the purposes of this review technology is conceptualized similarly to Dosi and Grazzi (2010) wherein technology is defined as a tool that is designed and subsequently used to reach a certain goal. In education, this goal can be to amplify either individual thinking or classroom experiences as a result of instruction. The primary instructional technology that could be considered ubiquitous across educational contexts, as well as a tool described in educational technology literature, is the computer.

In this sense, technology anxiety will be discussed, throughout this review, using the term computer anxiety. The author recognizes that using the term *computer anxiety* is a limit in itself, however this is the most researched focal anxiety that both falls under the term technology and also does not seem to be implicitly cross-disciplinary, as in the case of calculators and their technological application to mathematics (Idris, 2006; Waxman, 1994; Wilson, 1997). Additionally, those studies that use technology anxiety as a construct as a result of this literature search were all discussing technology anxiety defined as anxiety caused by continued and increasing interfacing with computer technology in situations fitting under Exclusion criteria 2 (Johnson et al., 2012; Meuter et al., 2003; Yang & Forney, 2013).

Computer anxiety was first conceptualized by Raub (1981) as a series of complex emotional reactions stemming from individual appraisals of computers as threatening to the individual. This description is an instance of state anxiety via anticipatory threat as defined by the psychology literature.

Following these studies, Russell and Bradley (1997) evaluated the impact of computer anxiety in teachers for the purpose of designing professional development. Russell and Bradley (1997) found that many teachers had negative feelings towards computers and, consequently, were avoiding their use in classroom instruction. Worthington and Zhao (1999) proposed that the advancement of computer technology necessitated a reframing of the initial definition put forth by Raub (1981). This study concluded that much of the research on computer anxiety needed to be revisited. One of the justifications that was used was that the initial definition was vague in both its conception and use of the term *computer*. This study was also the first to recognize that computer anxiety was more of a societal construct than a psychological one due to the rapid integration of technology into society in the preceding decades.

Many of the studies that also provided novel definitions of computer anxiety were published prior to 2000. It is unclear why the definitions do not seem to have progressed, though the research has continued, in light of computer technology becoming so ubiquitous. Though this finding does seem to echo Worthington and Zhou's (1999) sentiment that there is something more to be found, though it is unclear as to what that is. While again recognizing that using the term *computer anxiety* as a synonym for *technology anxiety* in the current review, this is also a clear direction for the research community.

How has it been measured?

The Computer Anxiety Scale (CAS; Marcoulides et al, 1985) was developed as a method to assess computer-related anxiety specific to certain contexts, therefore using the psychological construct of state anxiety. The CAS is a Likert-style survey where the individual items are summed to evaluate the participants' computer anxiety. The original scale could not be found, however Arigbabu (2009) examined the psychometric properties of the original scale. The analysis favored a two-factor solution with internal consistency of .88 and .70 for factors one and two, respectively; as well as an internal reliability of .89. The factors that were identified using this method were general computer anxiety and an equipment factor, respectively. General computer anxiety was defined as anxiety that emerged as a result of experience with computer technology use, while the equipment component is related to the procedures involved in anxiety surrounding equipment operation.

Research on computer anxiety also showed correlations between computer anxiety and computer achievement. Marcoulides (1988) evaluated the effect of computer anxiety on student achievement related to computer skills by using both the CAS and the Computer Aptitude Literacy and Interest Profile (CALIP; Poplin et al, 1984). This study found that computer skills was a significant predictor of computer anxiety, more of a predictor than previous experience with computers, a finding that was replicated by Cohen and Waugh (1989). For this study, the CAS was evaluated with a test-retest with a reliability coefficient of .71. Additionally, the internal reliability was calculated at .97. This study was the first of the two-factor model as described by Arigbabu (2009). They also used the CALIP instrument with calculated a test-retest reliability coefficient at .70 and internal consistencies calculated at .90. The Mathematics Anxiety Rating Scale (MARS) was also used for this study, though no additional psychometrics were reported.

The different scales that have been described above are well designed in order to identify potential antecedents to an individual's computer anxiety, while also being broad enough to determine potential differential factors, such as experience or ownership (Powell, 2013). However, as the author has stated, it is possible that using this narrow concept of computer anxiety as an analog for technology anxiety could skew the results of this search. Therefore, more research is needed to evaluate if there is a technology anxiety that has yet to be studied, which could then be used to potentially reevaluate portions of the model being proposed throughout this review.

The instruments described here seem to be able to evaluate the construct described herein as computer anxiety. This is evident as they have been used for decades, though it does not seem that there have been revised scales as computer technology has evolved. This seems like the next logical step in this field.

What are the antecedents?

Maurer (1994) reviewed the correlates of computer anxiety. Previous experience with computers is a hypothesized predictor of computer anxiety, but the studies Maurer reports are inconclusive as to the role of computer experience. Other studies have found that prior experience seems to mediate computer anxiety (Arigbabu, 2009; Cambre & Cook, 1985; Fariña et al., 1981; Raub, 1981).

Another predictor of computer anxiety was specific to college students. It was found that students in education and other non-computer science or technology majors, that did not have a large computer component, had higher computer anxiety than those in computer science, technology, or computer-integrated majors, such as business (Cambre & Cook, 1985; Maurer, 1994; Raub, 1981; Rosen et al, 1987).

Marcoulides (1988) also studied the effect of both computer attitudes and computer self-efficacy on computer anxiety. Computer attitudes refers to the feelings that someone has towards computer technology and has been found to be a predictor of computer anxiety (Marcoulides, 1988; Poplin et al., 1984; Powell, 2013); similarly, computer self-efficacy is a set of feelings related to someone's perceived ability to successfully interact with computer technology (Marcoulides, 1988).

Another predictor that has been studied is what Marcoulides (1988) termed the equipment factor. This is defined as the knowledge of procedures that are necessary to successfully use computer technology. Having a low procedural knowledge here correlates to a higher chance of computer anxiety (Arigbabu, 2009; Cohen & Waugh, 1989; Marcoulides, 1988).

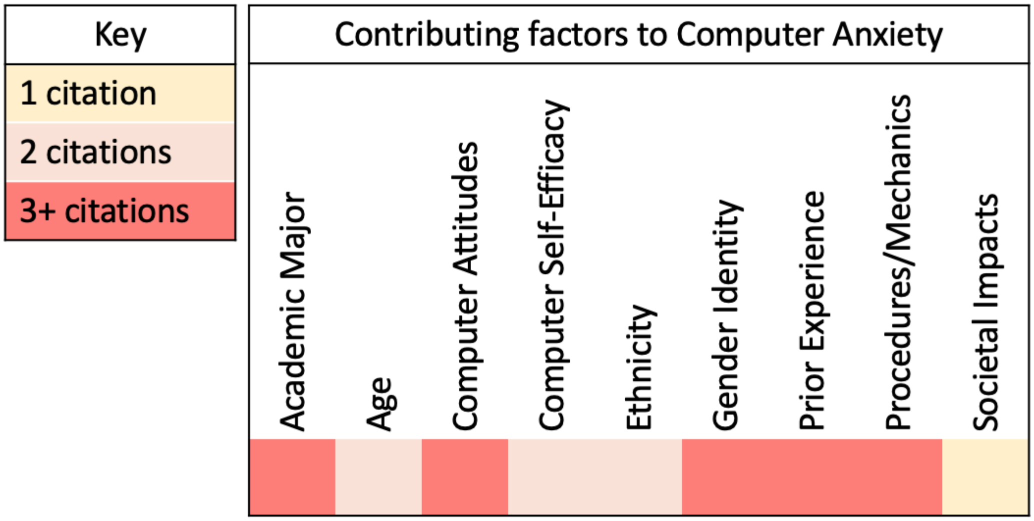
Fariña et al (1991) also evaluates the perceived societal impacts of computers and technology as a potential factor to produce computer anxiety. They theorize that computers have such a wide-ranging potential for influence across disciplines and industries, then people's perceptions of these impacts could lead to them developing computer anxiety. They found that those that viewed computers as a tool that could improve or streamline their life or work were less likely to develop computer anxiety.

Also included in studies of computer anxiety are the relationship of ethnicity and age to computer anxiety, however in the studies that examined these variables, the results were not statistically significant (Cambre & Cook, 1985; Gilroy & Desai, 1986; Maurer, 1994; Rosen et al., 1987). The definition of the gender variable was expanded in other studies to evaluate the role of self-selected gender identity. One such study (Rosen et al, 1987) found that students that identified as feminine were more anxious regardless of sex.

Powell (2013) subsequently reviewed all of the antecedents described above and developed a categorization scheme. This categorized the antecedents as either personal or interactive. As stated earlier, this concept of computer anxiety as it pertains to computer as tools is a very useful construct. However, in the educational setting technology as a subject is becoming more prevalent, and there needs to be research moving towards the development of a concept of technology anxiety equivalent to science or mathematics that have been evaluated for individual disciplinary anxieties.

Figure 3.

Contributing factors to computer anxiety synthesized from the literature review.



As previously stated, the research into computer anxiety has been well done thus far. In terms of value to educational research, this could be a conception of technology anxiety, which requires more consensus on the definition of technology as a discipline. Similar to science anxiety, gender seems to play a role in mediating computer anxiety. Other important antecedents that moderate computer anxiety are academic major, attitudes towards computers, prior experience with computers, and the procedures involved in working with computer technology.

Engineering Anxiety

As part of this literature review, an attempt was made to evaluate engineering anxiety research. The search produced no empirical studies, editorials, or essays, though numerous search terms and databases were used. In particular, multiple iterations and combinations of [“engineering anxiety”, “anxiety in engineering”, and “STEM anxiety engineering”] for example, were searched and there were no studies found. This is an area that is in need of further research, especially since there is no discernable background.

Mathematics Anxiety

How is it conceptualized?

Mathematics anxiety was first postulated by Feierabend (1960), a formalized definition, however, was not published until Richardson and Suinn (1972). This definition of mathematics anxiety was feelings of tension that interfere with mathematical practices, such as numerical manipulation and problem solving. Again, since these definitions highlight the importance of both the context and the negative emotions that precede the anxiety, this would be an example of a situational, or state, anxiety as defined in psychology.

Tobias and Weissbrod (1980) further defined mathematics anxiety as panic and helplessness that can lead to mental disorganization and paralysis when people are faced with the prospect of solving mathematical problems. Originally, mathematics anxiety was also theorized as a subset of mathematical attitudes (Schoenfeld, 1985), though McLeod (1992) argued that the term *attitudes* was not descriptive enough for what studies were finding in relation to mathematics anxiety. Brady and Bowd (2005) expanded the model of mathematics anxiety, saying that mathematics anxiety is based upon unpleasant past experiences with mathematics that can impede future learning. Other studies done in mathematics classrooms has shown that, unlike other psychologically based phenomena, mathematics anxiety is potentially socially transmissible to students from either teachers or parents (Beilock et al., 2010; Maloney et al., 2015). This is not indicative of a mathematics specific phenomenon, but rather an area for further research in other disciplines.

The preceding conceptions of mathematics anxiety are very thorough and have been steadily developed through the course of this research base. Decades of research have developed thorough conceptions that include potential antecedents, and these conceptions have been revised through the course of this research. This thorough conceptualization gives a strong foundation to the framework being developed throughout this literature review.

How has it been measured?

There have been numerous instruments developed to study mathematics anxiety, however this review will focus on those that are derived from the original mathematics anxiety instrument. Richardson and Suinn (1979) reported the psychometrics analysis from the development of the mathematics anxiety rating scale (MARS). Reliability was calculated using a test-retest method, the Pearson coefficient between the test and retest was calculated to be .85, and internal reliability was calculated at .97. There were separate validity studies used to generate validity evidence. Construct validity was obtained in three different studies that saw a decrease in students' MARS scores following behavioral interventions.

Plake and Parker (1982) amended the initial MARS instrument to produce the MARS-short. Plake and Parker (1982) report that the motivation behind producing the MARS-short was to use items from the MARS that may be usable to identify math-type anxiety among students in a statistics course. This reduced the 98-item MARS to the 24-item MARS-short. Internal consistency for MARS-short was calculated at .97.

Suinn and Edwards (1982) developed a MARS-A that was recalibrated for use with adolescents. Construct validity for the MARS-A was generated by aligning MARS-A scores with scores in mathematics classes where low mathematics performance was correlated with high MARS-A scores. Additional construct validity was found through the use of factor analysis. The factor analysis was indicative of a two-factor solution, with 89 items exhibiting >.30 loading on a single factor, termed numerical anxiety. Nine items showed loading to a second factor, mathematics test anxiety. Reliability was calculated using the Spearman-Brown split-half coefficient (.90) and the Guttman split-half method (.89), in addition to the internal reliability coefficient (.96).

There have been numerous alterations to the original MARS instrument, many of them to adapt to a new population. There are a few described above, though there are others where either the psychometrics or the study reporting the psychometrics was unavailable to the author of this review. Those that are described above rarely make large-scale alterations to the content of the items in the MARS, which implies a robust instrument.

What are the antecedents?

Rubinstein and Tannock (2010) grouped the contributors to mathematics anxiety into three broader categories: cognitive, personal, and environmental factors. Cognitive factors are learner-intrinsic, including things like innate appraisals of ability. Personal factors are things like low self-esteem and a lack of confidence. Environmental factors are things, like previous experiences with mathematics learning or specific teachers or classes. Though these are discussed in isolation, each of the factors described by Rubinstein and Tannock (2010) can mediate each of the other factors in the production of mathematics anxiety. Similarly, Hadfield & McNeil (1994) group contributors into three categories: personality, intellectual, and environmental. These categories seem to parallel those described by Rubinstein and Tannock (2010), where cognitive and intellectual, personal and personality, and environmental and environmental are respectively equivalent. Another study (Chang & Beilock, 2016) further refined these categories to personal and environmental factors, where cognitive and intellectual, and personal and personality were all included as personal contributors.

The contributors in the literature will be described using the Chang and Beilock (2016) categories previously described namely personal and environmental factors. These have been put into these groups by the author, though the author recognizes that these are not independent groups and there is the potential for significant interactions between and across these categories. Also, of note, though there are studies that evaluate the effect of test anxiety as a contributor to math anxiety, Aly (2018) distinguishes these as entirely distinct constructs due to the specificity of the math anxiety construct, and the necessary generality of the test anxiety construct.

The personal contributors to mathematics anxiety include mathematics self-efficacy, gender, age, mathematics attitudes, SES, and prior experience. Numerous studies have described the impact of mathematics self-efficacy. This is an individual’s perceptions of their own mathematical ability, some studies referring to this as internal appraisals of ability (e.g., Rubinstein & Tannock, 2010). The studies that have reported on this variable have shown that students that exhibit higher levels of mathematics anxiety are more likely to have lower mathematics self-efficacy. Gender has been often studied in the context of mathematics anxiety, though many of the results seem to be contradictory or context-specific. Some studies report that females tend to be more math anxious than males (ex. Reilly, 1992). Others report that males exhibit higher math anxiety than females (ex. Bernstein, 1992). Finally, there are some studies that report that there is not a significant difference in males and females in terms of math anxiety (ex. Lussier, 1996). It is also important to note that these findings may be skewed in terms of students' self-efficacy based upon assumptions that males or females are naturally better at mathematics (Beilock et al., 2010; Furner & Berman, 2003). Only one study was found that described the effect of age. Bernstein (1992) reported that mathematics anxiety was more common in males until age 14, when females become more math anxious. Finally, prior experience has been studied by multiple groups (Betz, 1978; Brady & Bowd, 2005; Rubenstein & Tannock, 2010) which all say that negative prior experiences with mathematics, which could ultimately be attributed to other factors, predispose students toward the development of mathematics anxiety. These negative prior experiences can also lead students to have poor math attitudes, which is also indicative of higher potential for math anxiety (Akin & Kurbanoglu, 2011; Çathoğlu et al., 2014).

SES was not a topic that seemed to be explicitly discussed in any of the studies cited, however there were instances of inference that lower SES correlated with high mathematics anxiety due to parental involvement and the learning environment, highlighting the inherent nature of these contributors to bleed across the categories being used to organize them (Betz, 1978; Rubenstein & Tannock, 2010).

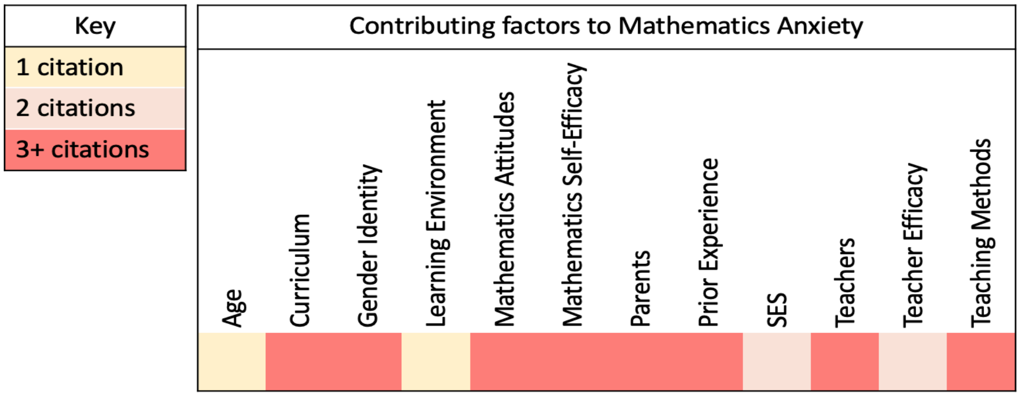
Environmental contributors include teachers, teaching methods, teacher efficacy, parents, the learning environment, and curriculum. Teachers and parents have both been studied as sources for mathematics anxiety in their students/children, particularly in the cases where the teachers or parents themselves identify as math anxious (Beilock et al, 2010; Fiore, 1999; Furner & Berman, 2003; Heydari et al., 2013; Kutner, 1992; Rubinstein & Tannock, 2010; Sepehrianazar & Babaee 2014). Additionally, teacher-mediated contributors, such as teacher efficacy and teaching methods have been shown to effect students' math anxiety. Teachers that exhibit low efficacy have students that have higher probabilities of being math anxious (Gresham, 2009; Jaggernauth, 2010), while teaching methods that emphasize procedural understanding over conceptual understanding tend to produce math anxious students (Akhter et al, 2016; Greenwood, 1984; Hughes, 2016; Kidd, 2003).

Curriculum was also found to predispose students to mathematics anxiety. In particular, many studies cite that mathematics anxiety is more likely in upper middle and secondary grades (Harper & Daane, 1998; Ma & Kishor, 1997; Zientek et al., 2010), which at the time these studies were done, is also when mathematics differentiated curriculum in the upper grades (e.g., Algebra I, Geometry, Algebra II), whereas mathematics in the secondary grades is now taught more as integrated subjects. The learning environment has also been discussed as a contributor to math anxious students in the sense that the learning environment can influence students' mathematics attitude (Vandecandelaere et al., 2012).

Mathematics anxiety is the oldest of the anxiety research bases described as part of this review, and as such the antecedents have more thorough and numerous empirical findings. As stated previously, this provides a very strong foundation for the model being developed at the conclusion of this review.

Figure 4.

Contributing factors to mathematics anxiety synthesized from the literature review.



Statistics Anxiety

How is it conceptualized?

Though, as a discipline, statistics is not explicitly included in STEM, the author feels that it is a discipline that permeates most, if not all, of the other STEM disciplines and that the research done in this field will serve to improve the conceptions being developed throughout this review, and ultimately the proposed model.

One of the first conceptions of statistics anxiety was published by Onwuegbuzie et al. (1997). The authors of the cited study said that statistics anxiety is an apprehension that occurs when someone is presented with statistics in any form, at any educational level. This study also frames it as a subset of state anxiety due to contextual specificity. Much of the research in statistics anxiety uses this definition with very little variation. Earp (2007) analyzed decades of statistics anxiety research in terms of definitions, instruments, and relation to statistics attitudes. Through this analysis, six broad domains were found to influence statistics anxiety: anxiety, fearful behavior, attitude, expectation, history, and performance. These domains will be explained in more detail below.

Through reviewing the literature on statistics anxiety, the author notes that there are many that seem to equate mathematics anxiety and statistics anxiety, though there are also publications that describe the differences (Baloglu, 2004; Paetcher et al., 2017).

How has it been measured?

The original instrument designed to measure statistics anxiety was the Statistics Attitude Survey (SAS; Roberts & Bilderback, 1980), which is a 34-item Likert-style survey that has a reliability coefficient ranging from .93-.95 over the course of three samples. There was no validity evidence reported. A later scale was published by Wise, called the Attitudes Towards Statistics (ATS; 1985). This scale was published as Wise thought the original SAS instrument was invalid based upon item content. The ATS scale was not found as a result of searches, so psychometrics are unavailable. The Statistics Anxiety Rating Scale (STARS; Cruise et al, 1985) identified six dimensions related to statistics anxiety: worth of statistics, interpretation anxiety, test and class anxiety, computational self-concept, fear of asking for help, and fear of statistics teachers. The original publication could not be found to evaluate the methods that produced these dimensions, but the dimensions are cited in other studies (Earp, 2007; Onwuegbuzie, 2004; Onwuegbuzie & Wilson, 2003; Williams, 2010). After the publication of the STARS, Zeidner (1991) published the Statistics Anxiety Inventory (SAI) saying that the statistics anxiety construct was comprised of two dimensions: statistics content anxiety and statistics test anxiety, though the distinction is made that statistical test anxiety is different than general test anxiety. Most recently, Earp (2007) developed the Statistics Anxiety Measure (SAM). The full construction and validation data are reported as a part of the cited dissertation (Earp, 2007).

The measures discussed above all report some level of reliability and validity evidence, however Earp (2007) noted that some of these instruments were developed as alternatives to each other due either to lack of evidence or evidence that was questioned. There were no additional instruments published after Earp (2007) that were found through the process of this literature search.

What are the antecedents?

This portion of the review will draw upon the work done by Earp (2007), who produced a statistics anxiety model comprised of six domains that were all taken from the historical statistics anxiety literature. Again, these six domains are: anxiety, fearful behavior, attitude, expectation, history, and performance. Earp (2007) recognized that the domains overlap and therefore I will elaborate on how these will be grouped in turn throughout the following discussion.

The anxiety domain is comprised of statistics content anxiety, statistics test anxiety, class anxiety, interpretation anxiety, test anxiety, math anxiety, math test anxiety, numerical anxiety, and lack of mathematical foundations. For the purposes of this review, due to the contextual nature of these constructs, statistics content anxiety, statistics test anxiety, and interpretation anxiety are being pooled into curriculum; math anxiety and math test anxiety are being pooled into math anxiety. Numerical anxiety is also being pooled into math anxiety because numerical anxiety, as a construct, is evaluated as part of the MARS. Math anxiety is recognized as a contributor, but as a construct it has already been discussed. Therefore, the components being discussed below are curriculum, class anxiety (termed learning environment), and lack of mathematical foundation (termed background knowledge). Background knowledge, particularly in mathematics, was found to be correlated to statistics anxiety (e.g., Burton & Russell, 1979), though there were no studies found during this literature search that evaluated the effect of statistical foundational knowledge. This same logic could also be extended to curriculum by discussing the amount and frequency of statistics content in the curriculum (e.g., Fishbein & Ajzen, 1975). The connection to the learning environment (Earp, 2007) is a similar link as in science anxiety wherein the classroom ecology, including peers, the teacher, and norms, can lead to the development of statistics anxiety.

The fearful behavior domain is made of fear of asking for help, fear of statistics teachers, extensive worry, intrusive thoughts, mental disorganization, tension, and behavioral responses. For this portion, extensive worry, intrusive thoughts, mental disorganization, tension, and behavioral responses are being pooled into a category termed trait anxiety, as this is the psychological term for these mental and physical responses to anxiety and stress. The contributors being discussed for this section are fear of asking for help (termed self-efficacy), fear of statistics teachers (termed teachers), and trait anxiety. As in the other disciplines, self-efficacy seems to be inversely proportional to anxiety (e.g., Cruise & Wilken, 1980). The influence of the teacher can mediate the feelings of anxiety, again as discussed in the other disciplines where this has been found to be a factor (Earp, 2007). Finally trait anxiety, which is defined in psychology as the ways one responds emotionally to different situations, can potentially initiate anxiety in cases where the response is negative (e.g., Breckler & Wiggins, 1989).

The attitude domain encompasses math attitudes, perceived worth of statistics, affect, and psychological arousal. Math attitudes were discussed prior, though it will be recognized as a contributor to statistics anxiety. Affect and psychological arousal refer to the emotional response and will be discussed with trait anxiety. Perceived worth of statistics as described by Cruise and Wilken (1980), will be discussed under statistics attitudes. The contributors being discussed for this segment are statistics attitudes, and trait anxiety. As discussed in other disciplines, attitudes are often seen as correlational to anxiety, meaning that those with negative statistics attitudes would more likely exhibit statistics anxiety (e.g., Chew & Dillon, 2015).

The expectation domain is made of subjective norms, motivation to continue learning, steps in information processing, cognition, social expectations, parental or peer pressures, pressure to succeed in mathematical solving situations, past experiences, and low levels of mathematical reasoning ability. Subjective norms will be discussed as curriculum. Motivation for learning, information processing, and cognition will be pooled as cognitive demand. Social expectations and pressure to succeed in mathematical solving situations will be pooled under societal norms. Low level of math reasoning will be discussed under background knowledge. The contributors for this domain are curriculum, which was discussed in a prior section, cognitive demand, societal norms, prior experience, and background knowledge. Cognitive demand refers to those situations that are mentally grounded, such as mental computation or information processing, (e.g., Eagly & Chaikin, 1992), and although motivation for learning is included in this term, the author recognizes that there are often extrinsic motivators as well. The societal norms are those extrinsic factors that are either intrinsic or extrinsic that often dictate interactions (Earp, 2007). Finally, although prior experiences and background knowledge seem nearly identical, the author is delineating them as previous lived experiences and previous academic learning, respectively. Negative prior experiences can predispose individuals towards the development of statistics anxiety (e.g., Benson & Bandalos, 1989). Background knowledge was described in the context of a previous domain.

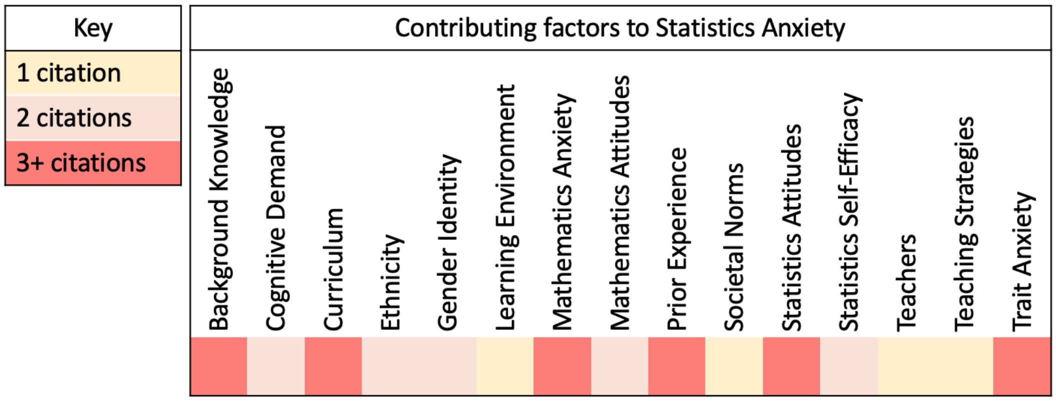
The history domain contains low mathematics self-esteem, prior mathematics class experiences, self-concept, motivation to learn, and instructional situations. Low mathematics self-esteem will be grouped under math attitudes. Prior math class experiences will be grouped with prior experience. Motivation to learn, like the previous section, will be grouped under cognitive demand. The contributors attributed to this domain are prior experience, cognitive demand, learning environment (such as instructional situations) and self-efficacy (self-concept), all of which have been discussed within previous sections.

Finally, the performance domain is solely the self-appraisal of statistics ability, which will be discussed as self-efficacy. From the numerous identified contributors described as falling under the domains, the pooled contributors to be discussed are curriculum, learning environment, background knowledge, self-efficacy, teachers, trait anxiety, statistics attitudes, cognitive demand, societal norms, and prior experience. Additional contributors from other sources are declared major (Onwuegbozie & Wilson, 2003), gender (Benson, 1987; Benson & Bendalos, 1989), and ethnicity (Onwuegbozie, 1999).

Earp (2007) does an excellent job of reviewing the literature on the antecedents of statistics anxiety. Although, it should be noted that statistics anxiety is the only of the disciplinary anxieties that includes another discipline, specifically mathematics anxiety, as an antecedent. Figure 5, below, shows a summary of the antecedents discussed through statistics anxiety.

Figure 5.

Contributing factors to statistics anxiety.



STEM Anxiety Framework

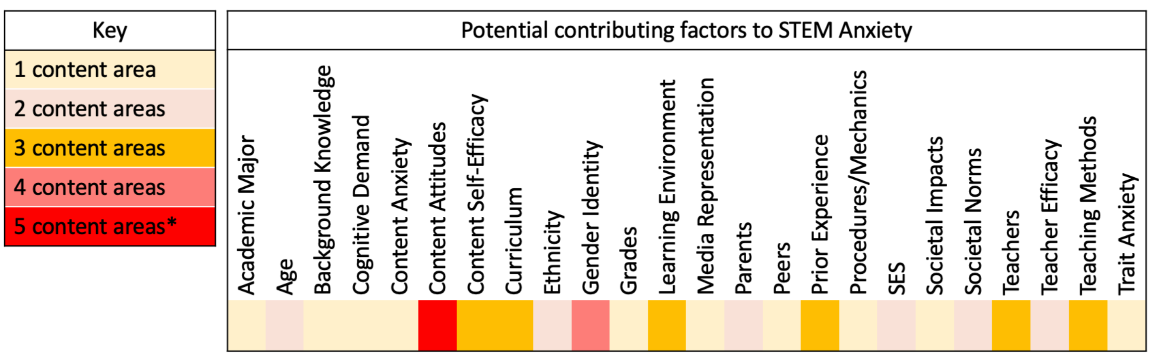
There have been recent studies that have proposed integrated STEM frameworks for the purpose of furthering research on STEM integration. Ortiz-Revilla et al. (2020) proposed a model that focuses on the epistemology of the STEM disciplines, which they note could also function as an analytical framework for STEM integration research. Kelley and Knowles (2016) developed a conceptual framework designed to resemble a pulley-system that is linked together by the thread of a community of practice and grounded in situated learning (Lave & Wenger, 1991). The individual pulleys in this model are science inquiry, engineering design, technological literacy, and mathematical thinking, all of which imply the importance of a practical and conceptual knowledge grounded in authentic contexts.

These frameworks are excellent initial thoughts on the practical integration of STEM. However, none of these frameworks discuss potential barriers, to learning or teaching that could exist within the individual STEM fields that could emerge, either individually or as something unique to an interdisciplinary STEM field. This review developed such a framework around one such barrier to both STEM teaching and learning – STEM content anxiety.

Of particular interest during this search were studies that provided novel definitions of anxiety or that identified new antecedents or remediation measures for content anxiety. Once these individual models were constructed, they were subsequently examined with the intent to merge similar or identical components (e.g., if classroom norms were included in both mathematics and science anxiety models, it was only included once in the integrated STEM anxiety model) into an integrated model for STEM content anxiety. Figure 6, below, gives an overview of the antecedents to the individual disciplinary anxieties discussed throughout prior sections.

Figure 6.

Potential contributing factors to STEM anxiety.

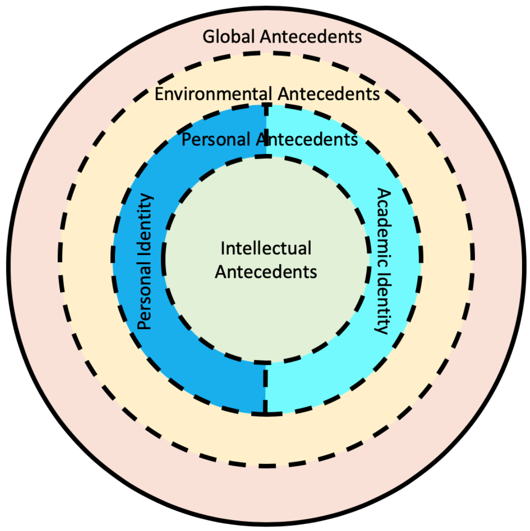


Note. Mathematics attitudes was included in both mathematics and statistics anxiety, and therefore there were a total of 5 instances of content attitudes counted.

These different antecedents were then grouped by the author into four domains: global, environmental, personal, and intellectual. These are organized in Figure 7 below.

Figure 7.

STEM anxiety domains.



These domains were developed as a way to organize the antecedents that have been described throughout this review and will be described below alongside those antecedents that have been categorized within each domain. The models presented here (Figures 7 & 8) are in reference to any individual, so this can be used in reference to a teacher, student, parent, administrator, etc. Those antecedents that are categorized as intellectual or personal are intrinsic to the individual, while environmental and global are extrinsic. Figure 7 gives a broad overview of the different domains that were identified as part of this review, while Figure 8 includes the domains as well as the antecedents that have been categorized into each domain.

Intellectual antecedents are those that are entirely mental or cognitive in nature. These include an individual's background knowledge of the content, the cognitive demand of the tasks, the procedures necessary to utilize their background knowledge or to be successful within the content, and the trait anxiety of the individual. Each of these antecedents is only present in a single disciplinary anxiety as shown in Figure 6.

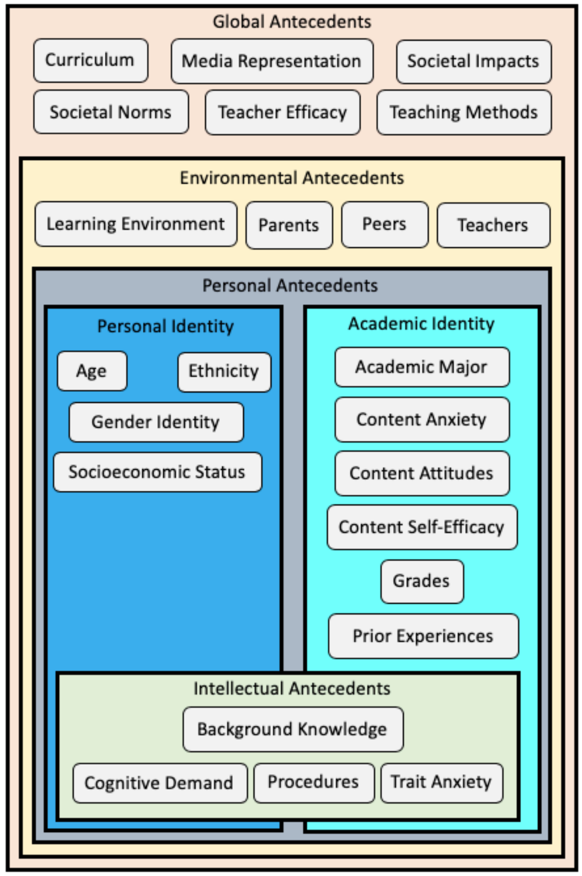
Personal antecedents were further grouped into personal and academic identities. The personal identity follows a model proposed by Galliher et al. (2017), which identifies race, gender, and class as major domains that make up the personal identity. For the framework described here, age, ethnicity, gender identity, and SES are placed in the personal identity domain, as these are equivalent to the domains proposed by Galliher et al. (2017). The antecedents of age, ethnicity, and SES are present in two disciplinary anxieties, as indicated in Figure 6. However, gender identity was included as an antecedent in each of the individual disciplinary anxieties reviewed previously. The academic identity domains were identified using Chan (2016) as a model. Chan (2016) describes academic subject identity as how students are able to find themselves and develop in their chosen fields. This particular study was in literary studies. Other studies in science (Kozoll & Osborne, 2004) and mathematics (Bartholomew et al., 2011) have done similar research within other content areas more relevant to STEM. For this model, the antecedents in the academic identity are the individual's academic major, the presence of other content anxieties, the individual's attitudes and self-efficacy related to the content, and the individual's past academic performance as measured by grades. As shown in figure 6, academic major, other content anxieties, and grades are only presented in one disciplinary anxiety. Attitudes, however, was indicated in each of the disciplinary fields (science attitudes, mathematics attitudes, computer attitudes, and statistics attitudes), while mathematics attitudes were also listed in statistics anxiety. Therefore, in figure 6, this is counted as indicated in five areas, and subsequently was the most reported.

The environmental antecedents are those in direct contact with an individual but are extrinsic to the individual. This category includes the learning environment that the individual is a member of, including the peers and the teacher or teachers that are also members of that learning environment. Science anxiety literature also discusses the importance of the studying environment (Güzellar & Doğru, 2012), which for the purposes of this review is considered synonymous to the learning environment. Because of this, parents are included as an environmental antecedent because of their potential presence in the studying environment.

Finally, global antecedents are those that have an indirect impact on the individual but can mediate the interactions with other levels of this model; likewise, contact with these antecedents can be viewed as mediated by others. For instance, societal norms and societal impacts are included in this category because the individual may not be aware of these antecedents, but society can mediate the interactions that an individual has with those in the environmental level. Society can also have a mediating effect on the curriculum being taught, which can impact the teaching methods and teacher efficacy within the teacher. An individual would not necessarily have direct contact with curriculum or teaching methods or teacher efficacy as the contact would be through the teacher as a mediator.

Figure 8.

The STEM anxiety framework.



Conclusions and Future Directions

As the call for integrated STEM throughout K-16 education proceeds there needs to be more specific focus on both practical and theoretical ways that this integration can be achieved while also managing the affective responses from both teachers and students. In addition to the studies theorizing integration, other studies have theorized the number of disciplines being integrated. Lonning and DeFranco (1997) established the continuum model for the integration of mathematics and science. This laid out five points along the continuum of integration. At the extremes are independent mathematics and independent science, moving inward are points where one discipline is the focus, but activities and concepts of the other are used as support. In the middle is balanced integration. This example, however, is in the context of the integration of 2 disciplines. Theoretically, integrating the STEM disciplines fully should result in a classroom observer being unable to differentiate the individual content disciplines due to complete integration.

As these calls for STEM reform towards STEM literacy and both practical and theoretical integration of the STEM disciplines increase, many are proposing frameworks for integration (Kelley & Knowles, 2016; Ortiz-Revilla et al., 2020). However, as noted by Kelley & Knowles (2016), very little is being theorized in relation to potential barriers to learning in an integrated STEM classroom. The framework developed throughout this literature review provides a theoretical approach to one potential barrier that has been studied in each of the individual STEM disciplines: anxiety.

Anxiety has detrimental effects on both students and teachers and has been found to be socially transmissible in the learning environment. Though this theoretical framework was designed as a framework for the potential anxiety in an integrated STEM setting, as shown in Figure 6, there are numerous instances of overlap in antecedents across the independent STEM disciplines. Therefore, this could also be considered an expanded model for use in each of the individual disciplines as well and could serve as a source of new research on these antecedents within the individual disciplines.

CHAPTER III: A QUANTITATIVE COMPARISON OF K-16 EDUCATOR SELF-EFFICACY FOR TEACHING BIOLOGY CONTENT

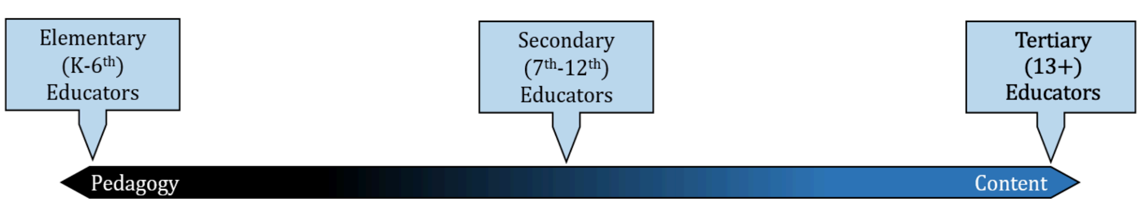
Introduction to Chapter

Classrooms are exceedingly unique spaces, and as such there are numerous contributing factors with the potential to contribute to an individual's anxieties in the classroom, as discussed in chapter 2. The following study was guided by the STEM anxiety conceptual framework proposed in Figure 8 of the dissertation. Specifically, this research aims to explore specific content-based anxieties of elementary, secondary, and tertiary educators related to biology subject-matter knowledge (SMK; Magnusson et al, 1999) through the use of self-efficacy. These distinct teacher populations are trained differently due to the differences in their goal contexts (Tanner & Allen, 2006), with graduate students often receiving the least amount of pedagogical training by comparison (Gardner & Jones, 2011). For reference, the term goal contexts is a reference to the career goal of an individual.

These educator populations represent different points along a hypothetical training continuum (Figure 9) which examines the amounts of training in both pedagogy and a particular content, which has been shown to have an impact on educators' self-efficacy beliefs (Velthuis et al., 2014; Yangin & Sidekli, 2016).

Figure 9.

Training continuum differences between teaching contexts.



The remainder of the chapter is formatted as a research study manuscript that is being planned for submission to the Journal of Science Teacher Education (JSTE), a publication of the Association for Science Teacher Education (ASTE).

Introduction

Classrooms are unique spaces that, when also being used as research spaces, are impacted by any number of confounding variables. However, regardless of the other individual's present in the classroom, the more constant individual is the teacher. Of particular interest for the present study were other empirical studies evaluating teacher efficacy in light of demographic variables and in relation to disciplinary content. Initially, broader work by Koballa and Crawley (1985) found that student attitudes towards a particular academic subject were directly related to the amount of time devoted to it during class. These findings are also directly linked to the findings of Sunal (1980) who found that a negative teacher attitude towards a particular subject often leads to less instructional time spent on that same subject.

These findings around attitude were then connected to teacher efficacy by Carleton et al (2008). Carleton et al (2008) found what many studies would go on to confirm, that there is a connection between attitudes and teaching self-efficacy. The Carleton et al (2008) study was specifically in the context of science, one of the earliest to disciplinarily contextualize these constructs of attitude and teacher efficacy as part of an empirical study. Other discipline-specific studies on teacher efficacy have been done in engineering (Hammack & Ivey, 2017), mathematics (Newton et al, 2012), reading (Leader-Janssen & Rankin-Erickson, 2013), and technology (Lee & Tsai, 2010). Each of these studies found that content training was positively correlated to teacher efficacy, showing that more content training often led to higher teacher efficacy.

In addition to the discipline-specific studies described previously, others have also evaluated teacher efficacy related to their (the teachers') experience. Hoy and Spero (2005) identified the initial years of teaching as being tantamount in the longitudinal development of an individual's teacher efficacy. Additionally, Putman (2012) and Onafowora (2004) identified similar trends in their studies describing differences in teacher efficacy, with increasing efficacy as the teachers gained experience.

The only study relating either of these constructs, again teacher efficacy and to a smaller disciplinary context, specifically biology as opposed to general science, that was found was on populations of teacher candidates (Öztas & Dilmac, 2009). This study, however, examined the effects of value judgements on teacher efficacy, as opposed to grounding the study in any particular group of concepts in the biological sciences. The present study aimed to carry out a study based in biological concepts and in-service teachers, something that seems to be absent in the literature to this point.

The definition of teacher efficacy that was used to orient portions of this study combined, in part, the definitions of self-efficacy proposed by Bandura (1997) and the definition of teacher efficacy used by Tschannen-Moran & Hoy (2001). Bandura (1997) defined self-efficacy as an individual's self-appraisal of their own ability. Tschannen-Moran & Hoy (2001) defined it as a teacher's appraisal of their ability to meet student outcome goals and maintain student engagement. Tschannen-Moran & Hoy (2001) also linked teacher efficacy to a teacher's confidence in teaching a particular content and confidence towards experimenting with novel educational approaches related to content.

Therefore, this study was guided by a synthesized view of teacher self-efficacy that situates teacher efficacy as a self-appraisal of a teacher's own confidence towards biology teaching and all facets therein, such as student success and engagement, and teaching strategies and approaches related to biology content. This view of teacher efficacy, as explained previously, is directly tied to the teaching content. Therefore, this study will likewise focus on a particular instructional content, specifically biology.

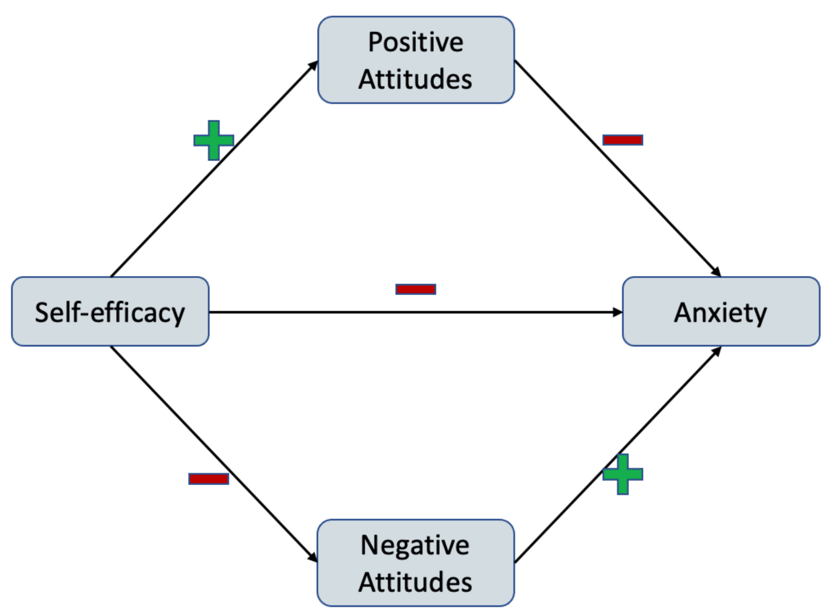
Additionally, Pajares and Schunk (2001) posited that the self-efficacy of teachers, specifically, is directly related to the content they teach because the teachers' efficacy beliefs can be different when comparing multiple content areas. Anxiety has been found to have detrimental effects on student achievement as defined by grades, while low self-efficacy is also predictive of low performance (Barrows et al., 2013; Jameson & Fusco, 2014). Logically then, anxiety levels can be predictive of self-efficacy and vice versa (Usher & Pajares, 2008). While this study focuses specifically on teachers, it should be noted that in the classroom ecosystem, students are also an integral part of the community. Teacher efficacy, broadly, can impact how content is approached, including instructional approaches and personal emotional approaches, or taught. These subtle cues from the teacher can have a likewise lasting impact on how students learn, not only the material, but how to work within the particular discipline.

Though the primary aim for the larger project was the evaluation of biology anxiety, the term *anxiety* was avoided throughout the study in order to mitigate the potentially priming effect of the term on participant responses. Of particular concern was that, by using the term *anxiety* participants may feel as though these are items to gauge anxiety and would therefore feel anxious about the survey overall and consequently skew the responses. Therefore, the terms used throughout the course of the study were either self-efficacy or confidence.

Akin & Kurbanoglu (2011) used structural equation modeling (SEM) to quantify the relationship between self-efficacy and anxiety in mathematics (Figure 10, adapted below). This study was done by giving undergraduate students the Revised Mathematics Anxiety Rating Scale, the Mathematics Attitudes Scale, and the Self-Efficacy Scale. The results of each of these measures was analyzed and correlated using path analysis. This SEM showed that self-efficacy is negatively predictive of negative attitudes and anxiety, while self-efficacy is positively predictive of positive attitudes. It also showed that positive and negative attitudes were each inversely predictive of anxiety.

Figure 10.

The relationship mediating self-efficacy, attitudes, and anxiety. Adapted from Akin and Kurbanoglu (2010).



Data for the present study was gathered through a Likert-style survey of biology topics *a priori* clustered into content groups based upon Scheiner (2010). Using the Akin and Kurbanoglu model described above, higher self-efficacy scores on the survey were interpreted as being indicative of lower anxiety levels. Likewise, lower self-efficacy scores were interpreted as being indicative of higher anxiety levels. This study was guided by the research questions presented below:

1. How does teacher efficacy for teaching biology differ across demographic and instructor-related groups?
2. How does teacher efficacy for teaching biology differ across biology topics within demographics and instructor-related groups?

Methodology

Survey Description

This study utilized a cross-sectional survey research design. The survey was disseminated electronically via Qualtrics (Qualtrics, Provo, UT) to the target population of K-16 educators. This study aimed to evaluate a portion of the STEM anxiety framework (Grimes & Gardner, in preparation), specifically the potential moderation of different demographic antecedents, such as age or college major, with biology teaching self-efficacy. This study focused on biology specifically, as Endler & Hunt (1966) point out that anxiety scales should be developed for specific contexts in order to be more accurate. Additionally, the survey made no reference to anxiety in an effort to avoid psychological priming of the participants which could have led to potentially skewed responses.

The survey used was a list of topics aligned with Scheiner's (2010) conceptual framework for biology. The list of items was generated by the author and reviewed by content area experts. The number of items in each of the domains are presented in Table 1.

Table 1.

Scheiner (2010) domain alignment of items.

Domain	Number of Survey Items
Ecology	10
Genetics	10
Organisms	8
Biology/Life	4
Cells	6
Evolution	10
Total	48

Participants and Sampling

This study sampled K-16 educators due to the differential approaches to training in terms of content. The survey was electronically distributed to multiple educators via social media and professional listservs. The study gathered a total sample of n =310. Participants who did not consent or who failed the attention check questions were removed from the data which resulted in n =308 completed surveys for further analysis.

Data Analysis

All analysis was carried out using RStudio v.1.3.1093 (R Team, 2020) by utilizing packages ***stats*** (R Team, 2020) for statistical analysis and ***ggplot2*** (Wickham, 2016) and ***networkD3*** (Allaire et al., 2017) to generate visualizations.

Whole Set Analysis for Research Question 1

To answer research question 1, analysis was conducted on the whole 48-item survey by calculating averages of Likert scores, across all items, for each participant. The categorical demographic variables used to group for comparison were current teaching context (elementary, secondary, or tertiary education), role in higher education (faculty member, graduate student, or postdoctoral scholar), approximate number of undergraduate biology courses (options were 0, 1, 2, 3, 4, or 5+), years of experience (responses were grouped in 10 year intervals starting with <1 and 1-10), age (responses were in 10 year intervals from 21-60+), and participant-provided race/ethnicity and gender identity (male, female, non-binary, or other). A table containing sample size data for each of these demographics is presented below (Table 2).

Nonparametric analyses were used throughout because Likert-style data is considered ordinal data, and therefore normality cannot be assumed. The Kruskal-Wallis test was performed to test for differences between the mean ranks of each of the above groups, in turn. This analysis was followed by Wilcoxon *post hoc* analysis in each case that there was a significant result and p values were corrected using a Bonferroni correction in the case of multiple comparisons. Boxplots were generated to visualize range and quartiles of the average scores for each of the demographic groups presented below.

Table 2.

Sample sizes for each demographic variable collected.

Age		Years of Experience	
Demographic	**n**	**Demographic**	**n**
21-30	51	<1	10
31-40	109	1-10	143
41-50	82	11-20	101
51-60	43	21-30	31
61+	22	30+	16
Total	307	Total	301
Approximate Number of Undergraduate Biology Courses		**Race**	
0	13	African-American	8
1	32	Asian-American	8
2	19	Caucasian/White	275
3	11	Latino/a/x	7
4	15	Mixed Race	8
5+	217	Other	2
Total	307	Total	308

Table 2 continued.

Sample sizes for each demographic variable collected.

Current Teaching Context		Gender Identity	
Demographic	**n**	**Demographic**	**n**
Elementary	34	Male	50
Secondary	135	Female	257
Tertiary	137	Non-Binary	1
Total	306	Total	308

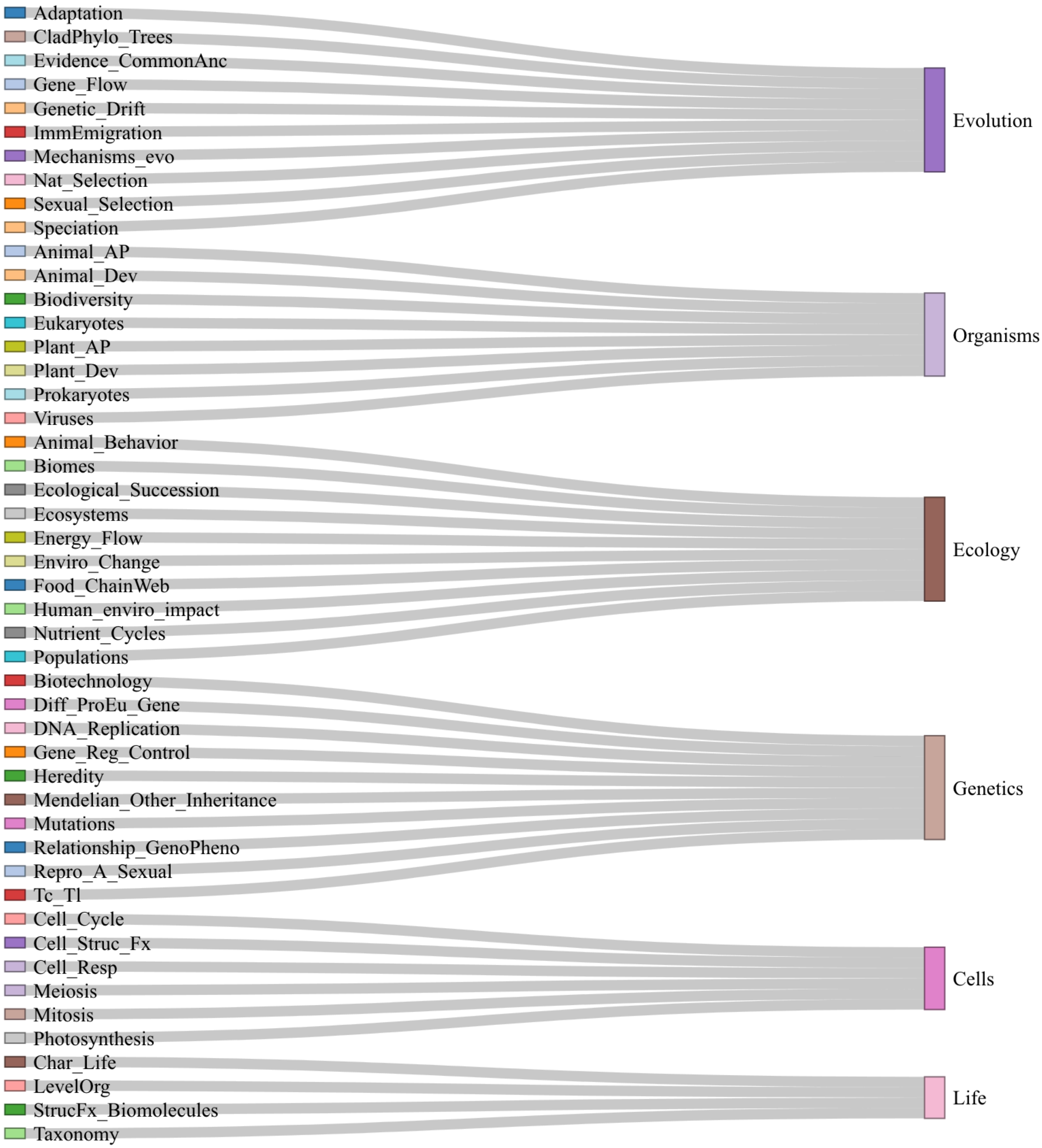
Role in Higher Education	
Demographic	**n**
Faculty Member	103
Graduate Student	24
Postdoctoral Scholar	8
Total	135

Domain-based Analysis for Research Question 2

To answer research question 2, analysis was conducted on the individual domain alignments. Domains were populated by following the grouping of items (e.g., cell cycle was changed to cells, and heredity was changed to gene; a full listing of domain alignment by item is presented in Figure 11) and split into six individual datasets. Averages were calculated for each participant within each of the domains. The averages were compared across demographic groups for each domain. A Kruskal-Wallis test was performed to test for differences in the domain mean ranks between each of the demographic groups. If the Kruskal-Wallis test was significant for a domain, a Wilcoxon test was run as a *post hoc* analysis utilizing a Bonferroni correction. Boxplots were generated to visualize range and quartiles of the average scores for each of the demographic groups across all domains.

Figure 11.

Domain alignment (right) of concept items (left).



Averages of Likert confidence data were calculated and added in columns as described previously. These averages were compared across demographic groups, again, as described previously. The Kruskal-Wallis test was performed to test for differences in the domain averages between each of the demographic groups. The Wilcoxon test was used as a *post hoc* analysis in cases of statistically significant Kruskal-Wallis results. Boxplots were generated to visualize range and quartiles of the average scores for each of the demographic groups above across all domains.

Results

As a reminder, this study was guided by the research questions below:

1. How does teacher efficacy for teaching biology differ across demographic and instructor-related groups?
2. How does teacher efficacy for teaching biology differ across biology topics within demographics and instructor-related groups?

In order to evaluate these research questions, the survey data was analyzed using different approaches, which will be discussed in more detail below. For research question 1, an average across all items in the survey for each participant was calculated and compared using participant-provided demographics as comparison groups. For research question 2, averages across items and within each biology domain listed in Table 1 were calculated for each participant and compared using participant-provided demographics as comparison groups. Statistical analysis and data visualization were done in RStudio. Initial comparisons were statistically evaluated using the Kruskal-Wallis test. Significant Kruskal-Wallis results were followed by *post hoc* analysis using a Wilcoxon Rank Sum test using a Bonferroni correction. Rather than presenting the results for research question 1 followed by the results of research question 2, the results for both research questions will be presented grouped by demographic variables under each heading.

Years of Experience

The below figure (Figure 2) shows the range of overall averages of the of the 48-item Likert-style survey grouped by the reported years of teaching experience. The between group averages were determined to be statistically significantly different per the Kruskal-Wallis test (χ^2 = 11.54, df = 4, p = .01). Wilcoxon results are reported in the table below (Table 3). The results in table 4 are reported after the application of the Bonferroni correction. This resulted in no statistically significant differences in self-efficacy scores. However, there is a visual pattern in Figure 12 (below) showing an increase in self-efficacy score as years of experience increase.

Figure 12.

Comparison of overall average grouped by Years of Experience.

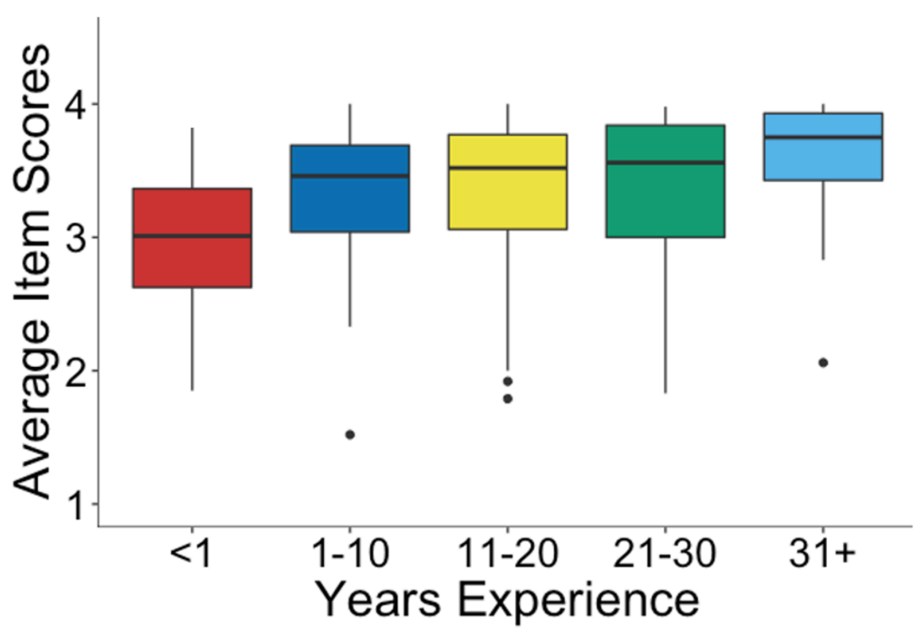


Table 3

Results from each comparison using the Wilcoxon test.

	<1	1-10	11-20	21-30	31+
<1		W = 414.5	W = 277.5	W = 90.5	W = 32
1-10			W = 6624	W = 1964	W = 762.5
11-20				W = 1513	W = 590
21-30					W = 189

After comparisons were made on the basis of the whole survey, comparisons were made on the basis of the averages of the individual domains of the biological concepts evaluated in the survey. The Kruskal-Wallis test was used to analyze the data to see if there were statistically significant differences within the domains across the groups defined by years of experience. Self-efficacy towards the domains of Biology/Life ($\chi^2 = 8.30$, df $= 4$, $p = .08$), Evolution ($\chi^2 = 6.87$, df $= 4$, $p = .14$), and Genetics ($\chi^2 = 6.07$, df $= 4$, $p = .19$) were not statistically significantly different between years of experience as determined by the Kruskal-Wallis test. However, Cells ($\chi^2 = 9.50$, df $= 4$, $p = .05$), Ecology ($\chi^2 = 23.27$, df $= 4$, $p < .001$), and Organisms ($\chi^2 =$ 10.54, df $= 4$, $p = .03$) were statistically significant and were followed by *post hoc* analysis using the Wilcoxon test and Bonferroni correction, the results of which are shown in Figure 3 and Table 4 below. In particular, the domain Ecology averages showed statistically significant differences between the self-efficacy averages of participants reporting either <1 year or 1-10 years of experience when comparing to 11-20 years of experience ($p = .004$, .02 respectively). Domains Cells and Organisms had no statistically significant results. These findings, as well as the box plots below, echo the visual pattern found in the comparisons of the overall survey, specifically that more experience leads to higher self-efficacy, and by extension lower anxiety.

Table 4

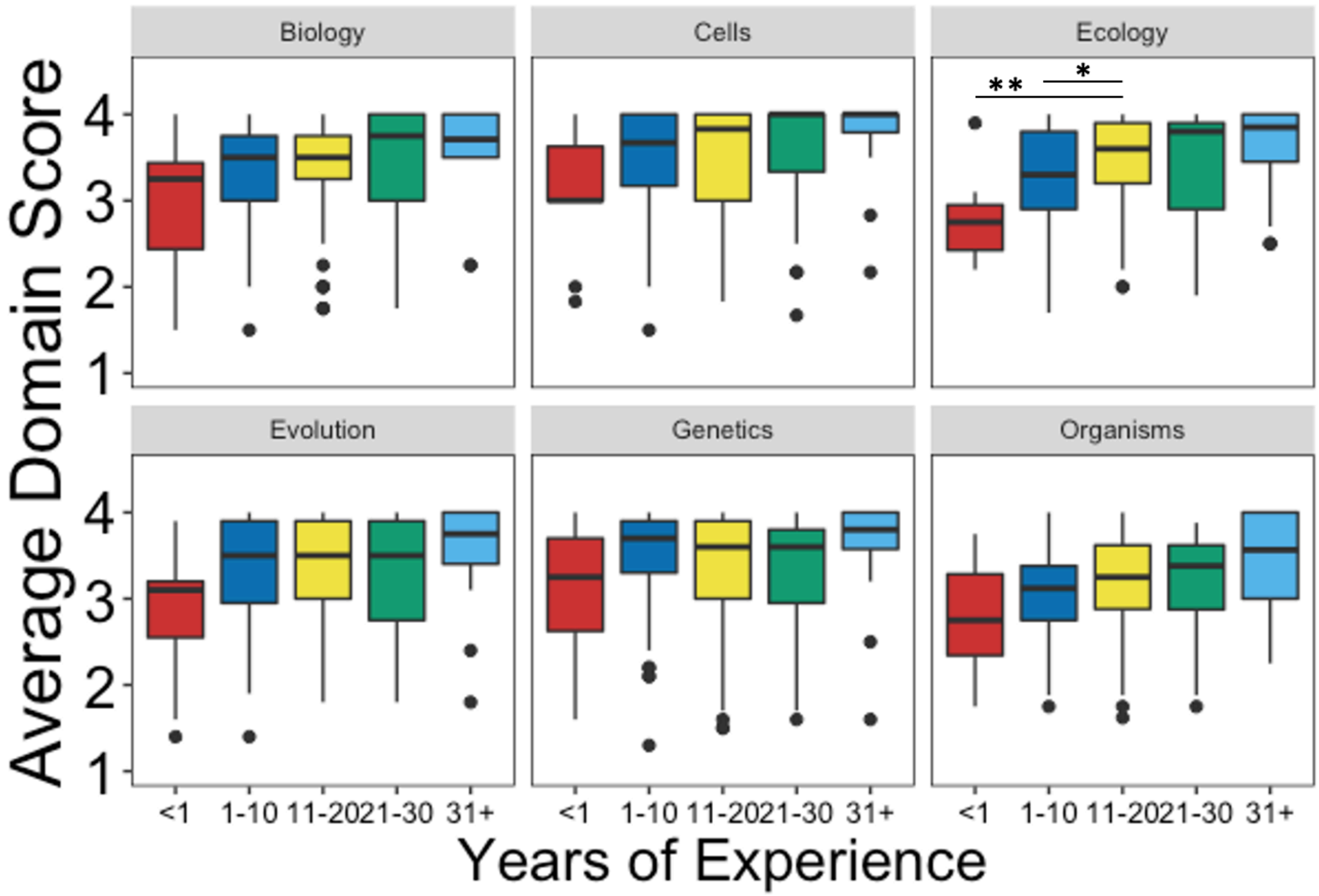
Levels of significance from each comparison using the Wilcoxon test

	<1	1-10	11-20	21-30	31+
			Cells		
<1		W = 449.5	W = 163	W = 765	W = 30.5
1-10			W = 7214	W = 1959.5	W = 793.5
11-20				W = 1398	W = 586
21-30					W = 210
			Ecology		
<1		W = 365.5	W = 277.5**	W = 90.5	W = 32
1-10			W = 5507*	W = 1798	W = 710.5
11-20				W = 1574	W = 630.5
21-30					W = 189
			Organisms		
<1		W = 486.5	W = 336	W = 103	W = 32.5
1-10			W = 6730.5	W = 1872	W = 724
11-20				W = 1437	W = 548.5
21-30					W = 175.5

*$p < .05$, **$p < .01$

Figure 13.

Domain analyses by years of experience. Statistically significant comparisons are indicated.



Age

In addition to analysis based upon years of experience, overall Likert averages were also compared based upon the respondents' reported age. These comparisons are shown below in Figure 14. Again, the Kruskal-Wallis results indicated statistically significant differences between self-efficacy scores ($\chi^2 = 9.73$, df = 4, p = .04) and the Wilcoxon results for individual comparisons are shown in Table 5 below, including the Bonferroni correction. The only difference identified by the Wilcoxon test was the comparison of self-efficacy scores between age range 21-30 compared to 31-40 (p = .05). This could be indicative of older teachers being more confident than younger teachers.

Figure 14.

Comparison of overall averages grouped by respondent age.

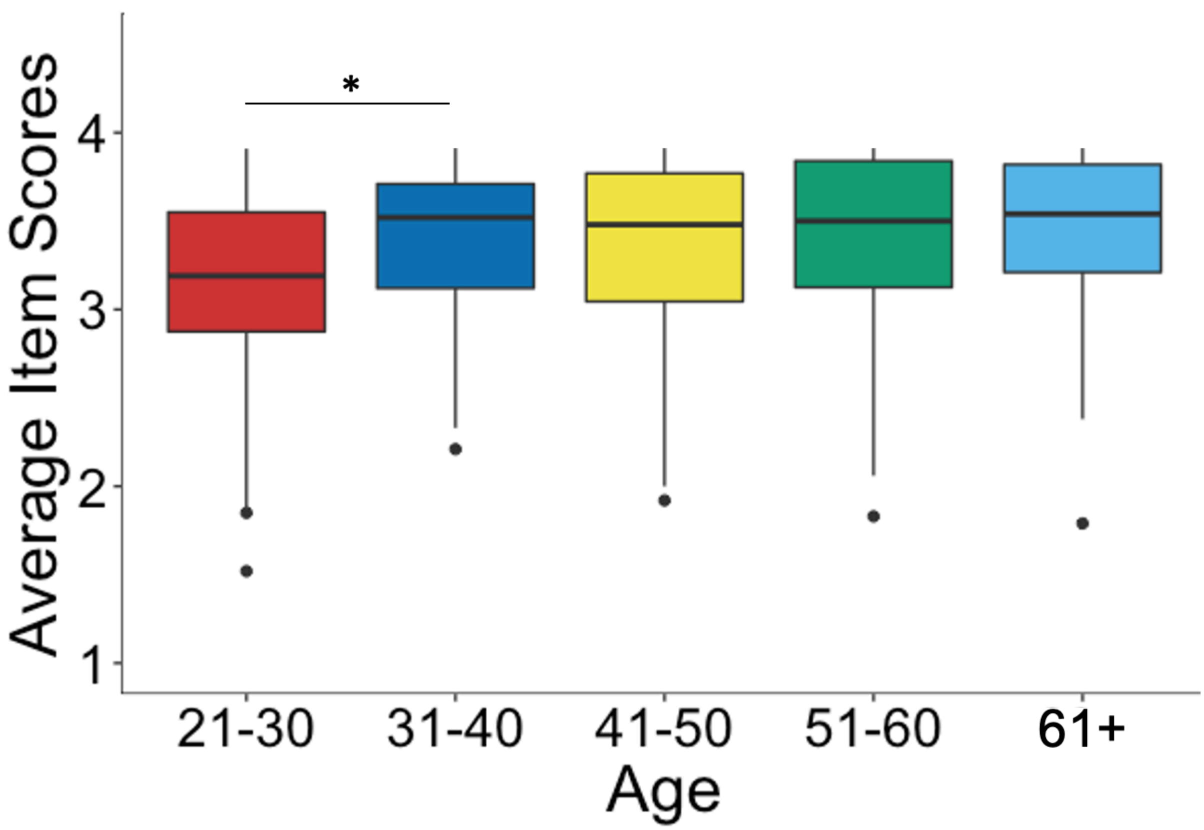


Table 5

Levels of significance from each comparison using the Wilcoxon test

	21-30	31-40	41-50	51-60	60+
21-30		W = 2015*	W = 1609	W = 816	W = 381.5
31-40			W = 4532.5	W = 2265.6	W = 1073.5
41-50				W = 1729	W = 830
51-60					W = 472

*$p < .05$

After the comparing the total self-efficacy averages across age, the average of self-efficacy across the individual domains were also compared. Again, the Kruskal-Wallis test was used to analyze the data to see if there were statistically significant differences within the domains across the groups defined by age. Evolution ($\chi^2 = 5.52$, df = 4, $p = .24$), and Genetics ($\chi^2 = 3.69$, df = 4, $p = .45$) showed no statistically significant differences in self-efficacy scores as determined by the Kruskal-Wallis test. However, Biology/Life ($\chi^2 = 10.25$, df = 4, $p = .04$), Cells ($\chi^2 = 12.39$, df = 4, $p = .01$), Ecology ($\chi^2 = 11.65$, df = 4, $p = .02$), and Organisms ($\chi^2 = 12.38$, df = 4, $p = .01$) were statistically significant and were followed by *post hoc* analysis using the Wilcoxon test, the results of which are shown in Figure 15 and Table 6 below. Domain Biology/Life showed significant differences between self-efficacy averages of respondents reporting their age as 21-30 when compared to both 31-40 and 41-50 year old respondents (p = .05 for both comparisons). Domain Cells showed statistically significant differences similar to that of Domain Biology/Life when comparing self-efficacy averages for respondents self-identifying in the 21-30 and 31-40 age ranges ($p = .04$). Domain Organisms repeats this pattern within the same comparison ($p = .04$). Domain Ecology, however, does not repeat this pattern but does exhibit statistically significant differences in self-efficacy scores when comparing 21-30 year olds to 51-60 year olds ($p = .02$). Domains Biology/Life, Cells, and Organisms seem to follow the pattern of the overall self-efficacy averages in that younger teachers exhibit lower self-efficacy scores than older teachers. However, Domain Ecology exhibited lower self-efficacy scores until the 51-60 age range.

Table 6.

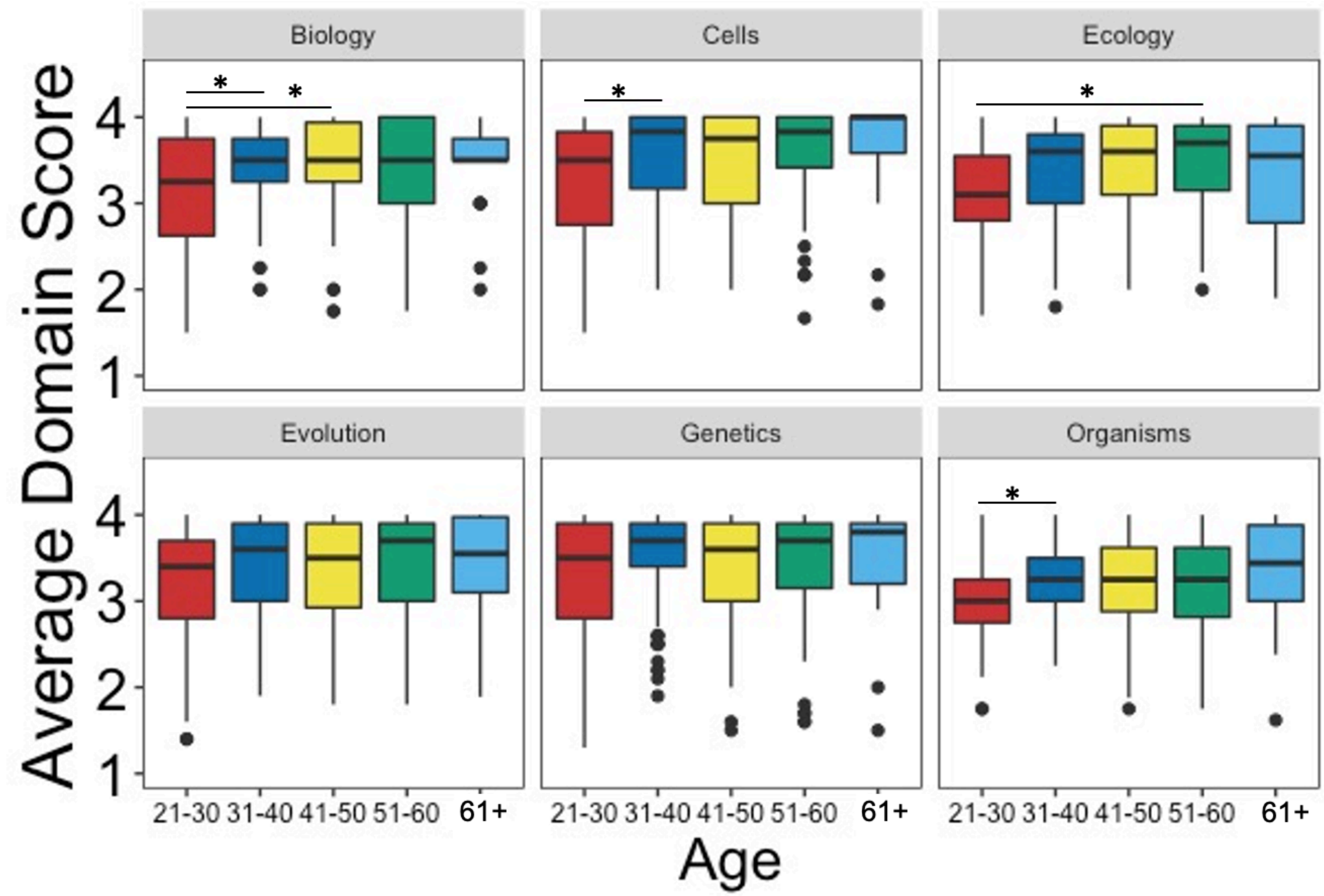
Wilcoxon analysis across the domains grouped by age.

	21-30	31-40	41-50	51-60	61+
			Life		
21-30		*W* = 2025*	*W* = 1495*	*W* = 812.5	*W* = 403.5
31-40			*W* = 4291	*W* = 2171	*W* = 1201.5
41-50				*W* = 1705	*W* = 932
51-60					*W* = 504
			Cells		
21-30		*W* = 2012*	*W* = 1577.5	*W* = 787.5	*W* = 336.5
31-40			*W* = 4593.5	*W* = 2274.5	*W* = 998
41-50				*W* = 1675	*W* = 734.5
51-60					*W* = 418.5
			Ecology		
21-30		*W* = 2116	*W* = 1513	*W* = 690*	*W* = 445.5
31-40			*W* = 4222.5	*W* = 1965.5	*W* = 1175.5
41-50				*W* = 1578.5	*W* = 932.5
51-60					*W* = 533.5
			Organisms		
21-30		*W* = 1992*	*W* = 1493.5	*W* = 829.5	*W* = 342.5
31-40			*W* = 4336.5	*W* = 2271	*W* = 967
41-50				*W* = 1758	*W* = 739
51-60					*W* = 504.5

*$p < .05$

Figure 15.

Boxplot displaying average domain scores grouped by age.



Teaching Context

Of particular interest was the comparison of overall averages grouped by the teaching context. As a reminder, teaching context was defined as either elementary (K-6, ELED), secondary (7-12, SECED), or tertiary (13+, HIED) educational settings. The comparisons of these groups is shown in Figure 16 below. The Kruskal-Wallis results comparing the self-efficacy scores were statistically significant ($\chi^2 = 62.06$, df = 2, $p < .001$). The results of the succeeding Wilcoxon test are shown in Table 7 and Figure 16. The results indicate statistically significant differences in the self-efficacy scores for every comparison (all $p < .001$). The interesting pattern here is that those in SECED (again, respondents teaching in 7^{th}-12^{th} grades) exhibited higher self-efficacy scores, on average, than those teaching in HIED (undergraduate+). This could indicate an impact of pedagogical training that those in secondary licensure programs typically receive, as that training would, in theory, be the main difference in training between those two groups.

Figure 16.

Comparison of overall averages grouped by teaching context.

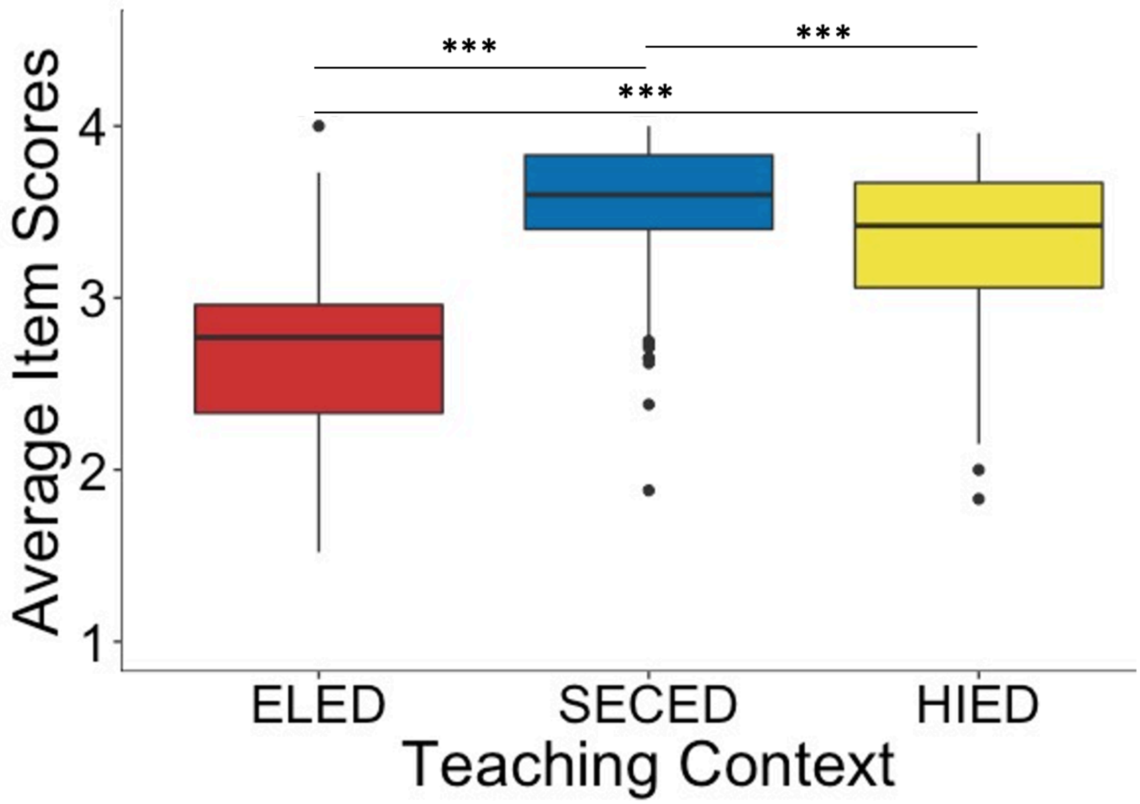


Table 7

Levels of significance from each comparison using the Wilcoxon test

	ELED	SECED	HIED
ELED		$W = 525.5$***	$W = 828.5$***
SECED			$W = 6538.5$***

***$p < .001$

After the comparing the total averages across teaching context, the average across each of the individual domains were compared as well. The Kruskal-Wallis test identified statistically significant differences within the domains across the teaching context groups. Each of the domains were identified as having statistically significant differences within self-efficacy scores: Biology/Life ($\chi^2 = 56.96$, df = 2, $p < .001$), Cells ($\chi^2 = 54.60$, df = 2, $p < .001$), Ecology ($\chi^2 =$

61.68, df = 2, $p < .001$), Evolution ($\chi^2 = 49.91$, df = 2, $p < .001$), Genetics ($\chi^2 = 55.87$, df = 2, $p < .001$), and Organisms ($\chi^2 = 36.79$, df = 2, $p < .001$). Wilcoxon *post hoc* analysis is presented in Table 8 below, and the overall averages are graphically shown in Figure 17 below. These results indicate that almost every comparison exhibits the same pattern as the overall comparison with decreasing self-efficacy averages from SECED to HIED to ELED, respecitvely.

Table 8.

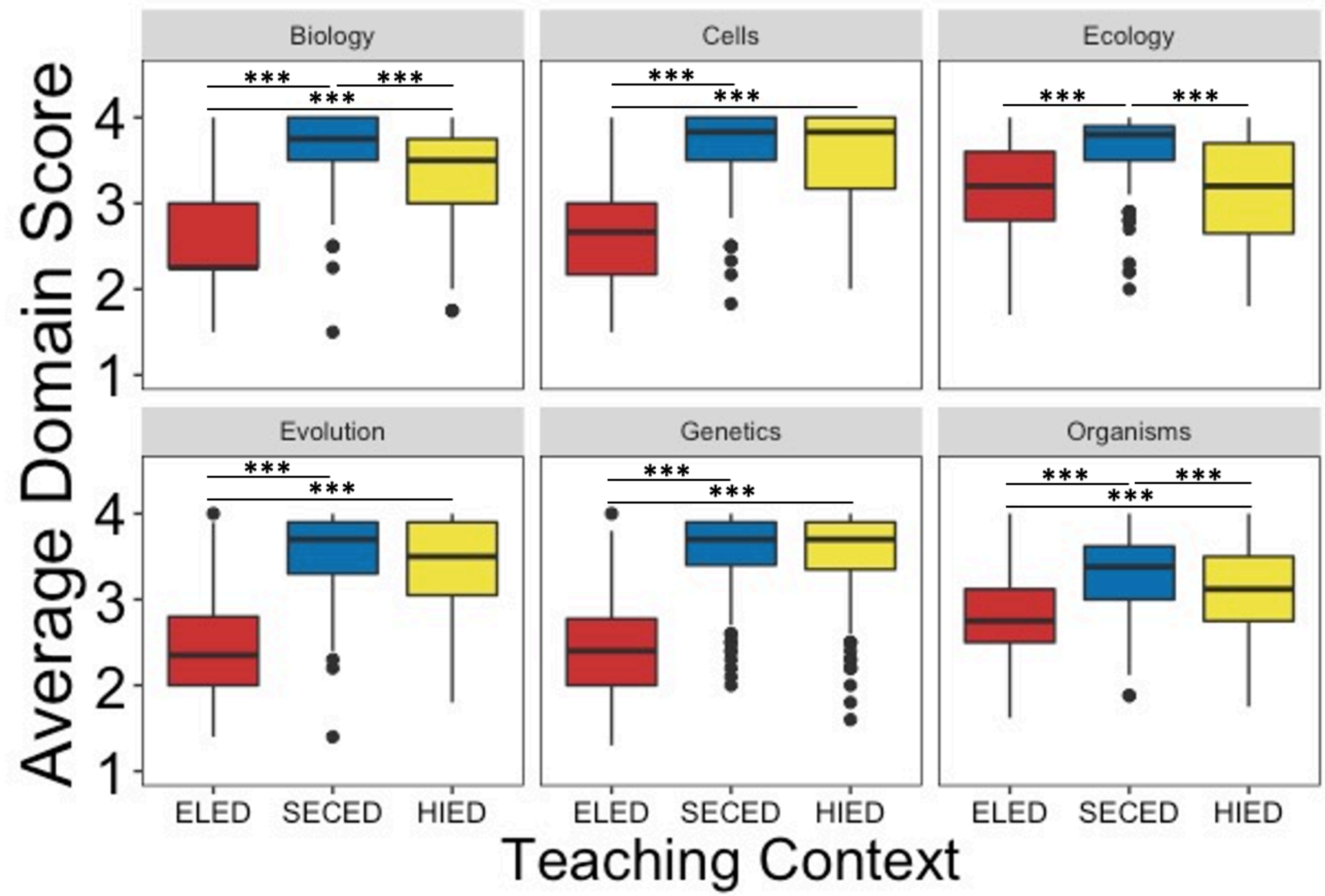
Results of the Wilcoxon test between teaching context groups

	ELED	SECED	HIED
	Life		
ELED		*W* = 552.5***	*W* = 856***
SECED			*W* = 6910.5***
	Cells		
ELED		*W* = 486.5***	*W* = 687***
SECED			*W* = 8725.5
	Ecology		
ELED		*W* = 970.5***	*W* = 2285.5
SECED			*W* = 4588***
	Evolution		
ELED		*W* = 564.5***	*W* = 779.5***
SECED			*W* = 7905
	Genetics		
ELED		*W* = 468***	*W* = 538.5***
SECED			*W* = 9366
	Organisms		
ELED		*W* = 914.5***	*W* = 1464.5**
SECED			*W* = 6679.5***

**$p < .01$, ***$p < .001$

Figure 17.

Domain-based analyses of self-efficacy.



Approximate Number of Undergraduate Biology Courses

In conjunction with teaching context, the approximate number of undergraduate biology courses was also found to be significant ($\chi^2 = 80.14$, df = 5, $p < .001$), the comparisons are shown in Figure 18. It should be noted that approximate number of undergraduate courses was used as opposed to graduate level courses due to an undergraduate degree being the only guaranteed common credential of the respondents. An additional *post hoc* analysis was performed, specifically a Wilcoxon rank sum test, with a Bonferroni correction, against each of the possible comparisons between the number of undergraduate biology course categories above. These statistics are presented in Table 9 below with the ranges shown in Figure 18. These results showed that those who reported 0, 1, or 2 undergraduate biology courses had statistically significantly lower self-efficacy averages than those reporting 5+ undergraduate biology courses (all comparisons $p < .001$). This is indicative of a range of courses that could lead to higher self-efficacy.

Figure 18.

Comparison of overall averages grouped by approximate number of undergraduate biology courses.

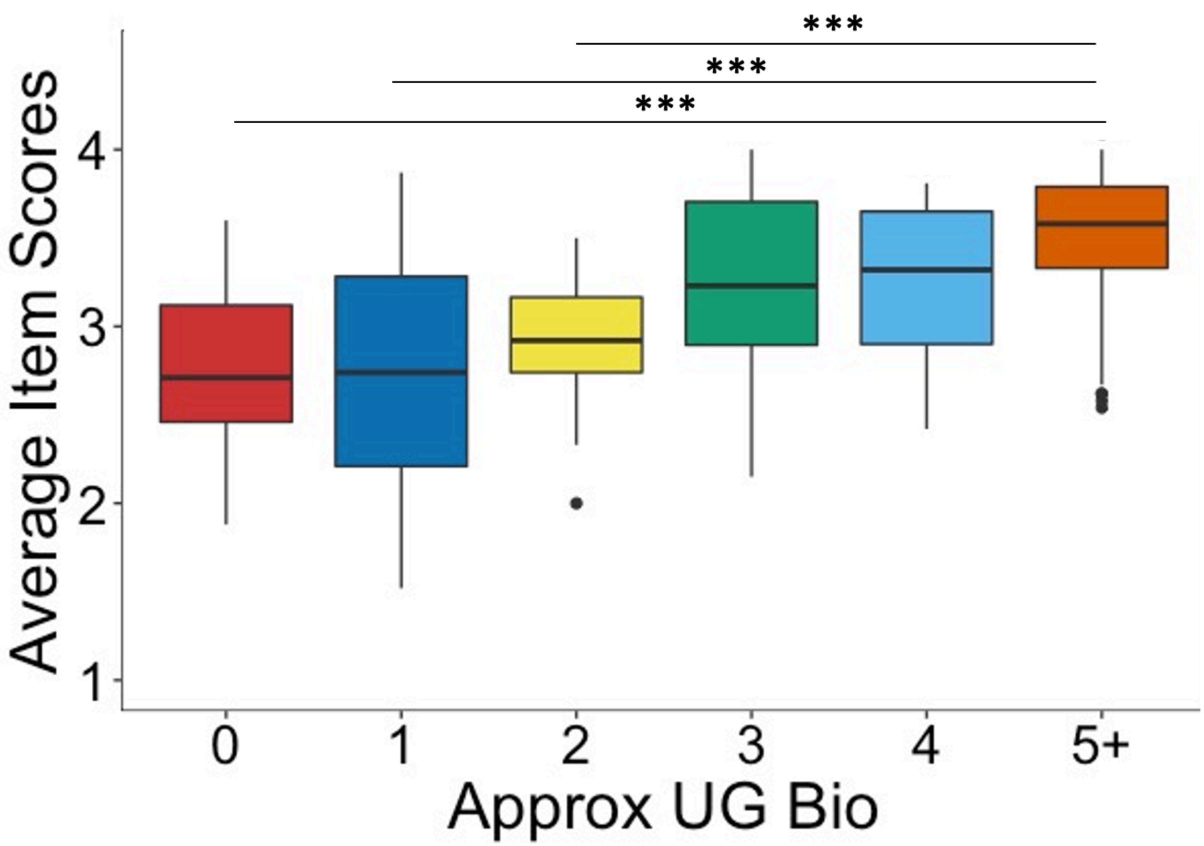


Table 9

Levels of significance from each comparison using the Wilcoxon test

	0	1	2	3	4	5+
0		$W = 215.5$	$W = 102.5$	$W = 38$	$W = 44.5$	$W = 307$***
1			$W = 258$	$W = 108$	$W = 134$	$W = 1164$***
2				$W = 69.5$	$W = 80.5$	$W = 473$***
3					$W = 85$	$W = 853$
4						$W = 1034$

***$p < .001$

After the comparing the total averages across the groups where respondents reported an approximate number of undergraduate biology courses, the average across each of the individual domains were compared as well. The Kruskal-Wallis test identified statistically significant differences within the domains across the teaching context groups. Each of the domains was identified as having statistically significant differences: Biology/Life ($\chi^2 = 80.9$, df = 5, $p < .001$), Cells ($\chi^2 = 72.76$, df = 5, $p < .001$), Ecology ($\chi^2 = 14.28$, df = 5, $p = .01$), Evolution ($\chi^2 = 83.73$, df = 5, $p < .001$), Genetics ($\chi^2 = 106.16$, df = 5, $p < .001$), and Organisms ($\chi^2 = 45.38$, df = 5, $p < .001$). Wilcoxon *post hoc* analysis is presented in Table 10 below and the overall averages are graphically shown in Figure 19 below. These again include the Bonferroni correction. Domain Biology/Life exhibited statistically significant differences starting when 2 courses is compared to 4 courses ($p = .03$) and also when comparing 0, 1, or 2 courses to 5+ courses (all $p < .001$). This echoes the pattern seen in the comparison of the overall self-efficacy averages. Domains Cells, Evolution, Genetics, and Organisms also showed the pattern when comparing 0, 1, or 2 courses to 5+ courses (each $p < .001$). Additionally, Domain Genetics showed statistically significant differences when comparing 4 courses to 5+ courses ($p < .001$). Domain Ecology showed no statistically significant differences in self-efficacy scores. These results showed that self-efficacy can be related to declared majors and minors, as those with declared majors typically take 5+ courses in the discipline.

Table 10.

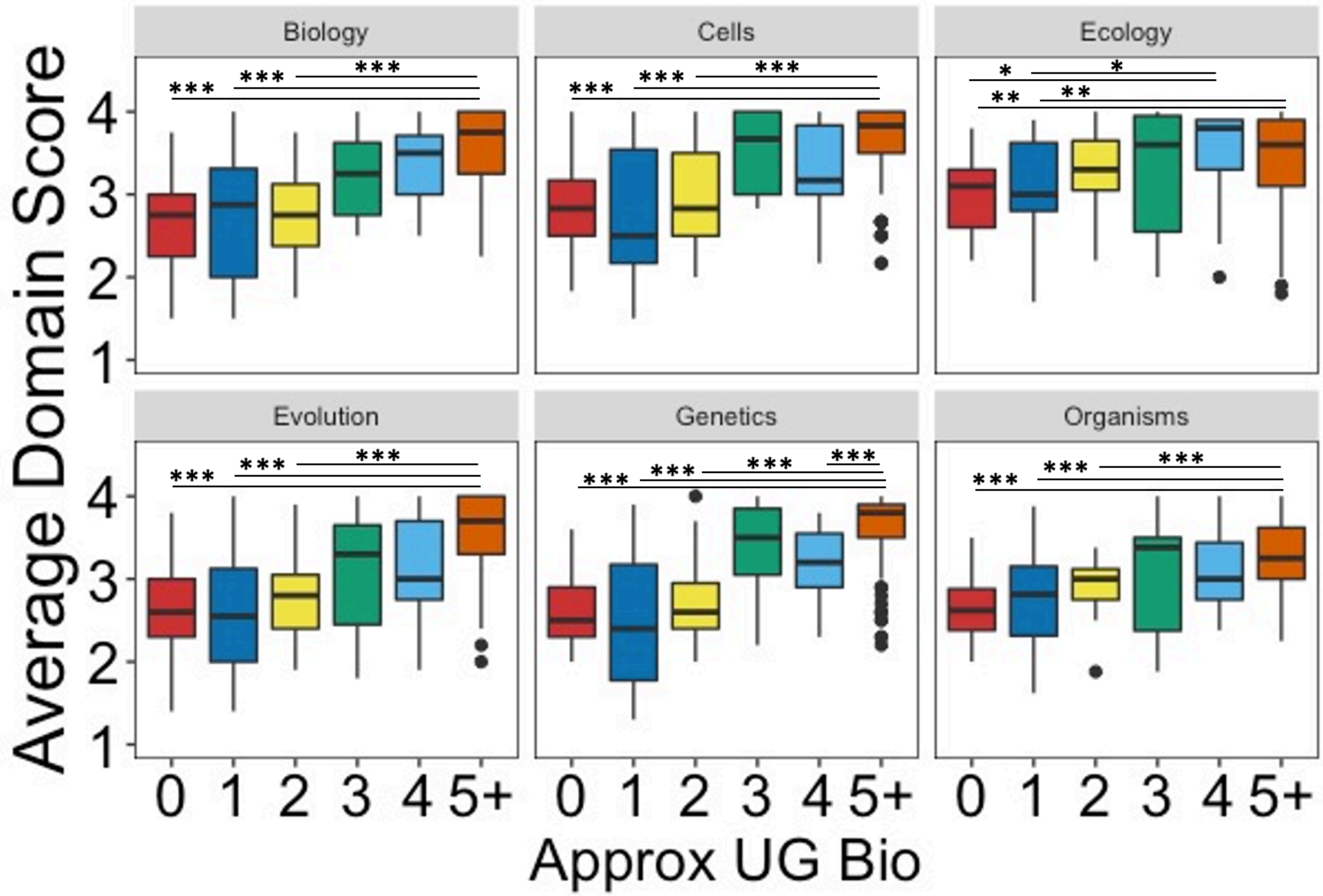
Wilcoxon analysis between the domain averages grouped by the approximate number of undergraduate biology courses.

	0	1	2	3	4	5+
			Life			
0		*W* = 202.5	*W* = 109.5	*W* = 38	*W* = 37	*W* = 355***
1			*W* = 286.5	*W* = 106	*W* = 117.5	*W* = 1160***
2				*W* = 60.5	*W* = 53.5*	*W* = 496***
3					*W* = 70.5	*W* = 757.5
4						*W* = 1120.5
			Cells			
0		*W* = 229	*W* = 113	*W* = 29.5	*W* = 49	*W* = 405***
1			*W* = 260.5	*W* = 85	*W* = 133	*W* = 1306.5***
2				*W* = 52.5	*W* = 85.5	*W* = 680***
3					*W* = 89.5	*W* = 895.5
4						*W* = 991.5
			Ecology			
0		*W* = 181	*W* = 86	*W* = 57.5	*W* = 48*	*W* = 835**
1			*W* = 247.5	*W* = 154.5	*W* = 148*	*W* = 2422.5**
2				*W* = 104.5	*W* = 109	*W* = 1728.5
3					*W* = 74	*W* = 1125.5
4						*W* = 1827.5
			Evolution			
0		*W* = 213	*W* = 111.5	*W* = 46	*W* = 57	*W* = 343.5***
1			*W* = 264.5	*W* = 115	*W* = 147.5	*W* = 1083***
2				*W* = 71	*W* = 89.5	*W* = 479.5***
3					*W* = 80.5	*W* = 738
4						*W* = 908.5
			Genetics			
0		*W* = 231.5	*W* = 113	*W* = 29.5	*W* = 45	*W* = 188***
1			*W* = 251	*W* = 77.5	*W* = 133	*W* = 804***
2				*W* = 49	*W* = 72	*W* = 420.5***
3					*W* = 102.5	*W* = 846
4						*W* = 560.5***
			Organisms			
0		*W* = 195	*W* = 82	*W* = 50	*W* = 51	*W* = 473.2***
1			*W* = 255.5	*W* = 129	*W* = 158	*W* = 166.3***
2				*W* = 80	*W* = 110	*W* = 1006.5***
3					*W* = 81	*W* = 980.5
4						*W* = 1262

*$p < .05$, ***$p < .001$

Figure 19.

Domain-based analysis of self-efficacy.



Other demographics

In addition to the previously discussed results, overall averages were also compared grouped by the respondents' role in higher education ($\chi^2 = 2.51$, df = 2, $p = .28$), gender identity ($\chi^2 = 0.02$, df = 2, $p = .99$), and race ($\chi^2 = 7.32$, df = 9, $p = .99$) and its relationship to their disciplinary teaching self-efficacy. However, none of these demographics yielded statistically significant results upon initial comparison, so *post hoc* analysis was not performed. Additionally, none of them were statistically different when compared across domains. This indicates that in this sample a respondents' role in higher education, gender identity, and race did not significantly relate to their self-efficacy for teaching biology content. However, of note, these particular demographics exhibited smaller subsamples (see Table 2), which could be related to the lack of significant results.

Discussion

To this point, all of the demographics have been discussed in isolation. However, in the succeeding sections similar demographics that have logical connections will be discussed pairwise and the interpretations will be intertwined. Specifically, the grouped demographics are years of experience and age, and teaching context and the approximate number of undergraduate biology courses.

Years of Experience & Age

The analysis of the overall self-efficacy averages show that teachers in the 21-30 age range exhibit statistically significantly lower levels of confidence related to biology content. In making a logical inference concerning these demographics, those in the 21-30 age range could be inferred to be those with the least amount of experience as well, which also show the lowest self-efficacy averages in the years of experience demographic, though not statistically significantly lower. When analyzing the individual domains, parallel patterns emerged between both the years of experience and age demographics. Remembering that Domain Ecology was the only domain to exhibit statistically significantly different self-efficacy scores across both years of experience and age demographics, and additionally Biology/Life, Cells, and Organisms in the age demographic, were identified as statistically different according to the Kruskal-Wallis test and were further analyzed by using the Wilcoxon test *post hoc*.

The Ecology domain results indicate that the first 10 years are instrumental in developing confidence, with the comparison of <1 and 1-10 years compared to 11-20 years of experience being the most significant results in the Ecology domain. This is the same pattern that is seen in the age demographic groups when the younger demographics, particularly the 21-30 year old group, are compared to 31-40, 41-50, or 51-60. Like years of experience, respondents were grouped by age in 10-year intervals.

All of the results that were discussed here show that a teacher's years of experience have a positive impact on their confidence, a finding confirmed by other empirical studies (Hoy & Spero, 2005). Even those comparisons which did not exhibit statistical significance show a general upward trend in the both the overall averages and the domain-based averages, again confirming findings by others (Onafowora, 2004; Putman, 2012). This shows that familiarity and confidence can increase with repeated exposure to the content, in this context that can be seen as potentially through the act of teaching. These results could also be due to the learning curve associated with being a first year teacher in general. However, also of note, those that reported less than a year of experience in the classroom, and again potentially those who reported ages in the youngest demographic, directly implies that their entire leading experience in the classroom, and potentially the end of their educational residency, has been in the context of the 2020 COVID-19 pandemic.

Teaching Context & Approximate Number of Undergraduate Biology Courses

Before beginning the discussion of these demographics, remember that the teacher education and teacher training categories are differentiated based upon the licensure level. Those being trained in elementary education are broadly trained in all academic disciplines and have coursework that largely focuses on pedagogy and pedagogical approaches and may not adequately prepare teachers for the disciplinary demands of the classroom (National Council of Teacher Quality; NCTQ, 2019). Those being trained in secondary education are often trained in the licensure discipline(s); for instance, secondary mathematics teacher candidates often carry a mathematics major and a secondary education minor or double major, which serves as their formalized training in pedagogy. Those that teach in higher education may or may not have any formalized pedagogical training, this is largely dependent upon the hiring context. However, broadly speaking, those who teach in higher education have at least an undergraduate degree and one or more advanced or professional degrees in the discipline; again, formalized pedagogical training is not a guarantee of an instructor with a position in higher education.

The results of the Wilcoxon test show that the each of the teaching contexts have statistically significantly averages when compared to each of the other teaching context groups. Respondents who teach in the elementary context exhibited the lowest overall averages, followed by tertiary and secondary respondents, respectively. This could indicate a link between teaching self-efficacy and content training, which in the case of this study is specifically biology. Additionally, by secondary respondents scoring higher, on average, than those in higher education, it seems likely that pedagogical preparation in conjunction with content-based training may potentially impact teaching efficacy.

The results of the Wilcoxon test show that we see very little in terms of statistically significant differences in the averages of individuals reporting 0-4 biology courses. However, we do see significant differences when individuals have taken 5 or more biology courses. This brings an interesting observation to the forefront in that many of the programs for licensure in the lower grades only require 1 or 2 science courses beyond the general requirements and that those may not be required to be in any particular discipline. For example, local pre-service students take two biology and two physical science courses, but one of each of these is written for that specific population. However, those that have taken 5+ biology courses are more likely to be those in a secondary licensure program or in a biology major towards some other degree or headed to a research-based advanced degree, which is typical of those eventually seeking faculty positions in higher education. This deep and prolonged experience of coursework taken through part of a major could be seen as increasing an individual's experiences, and therefore shifting this demographic to the discussion of increasing experience leading to higher efficacy (Hoy & Spero, 2005; Onafowora, 2004; Putman, 2012).

Other Demographics

As previously discussed, other demographic data, particularly race, gender identity, and role in higher education, were also collected but there was no statistically significant difference as determined by the Kruskal-Wallis test in the initial analysis. This is not indicative of there not being any differences in the broader population as determined by these demographics, but instead should be seen as areas for further research.

Limitations

Data was collected as part of the survey in an attempt to quantify the limitations of the study. Much of the data collected this way was related to the educational issues highighted by the COVID-19 pandemic. Overall, n =225 participants did not feel as though their responses were influenced by educational issues centered on the pandemic. Other responses to the limitations questions are reported in Table 11 (below). Please note that these are not mutually exclusive groups, and therefore respondents had the option to select multiple items.

Table 11.

Responses to the survey questions dealing with limitations.

Limitation Factor	n
COVID-19	11
Current administrative decisions	9
Remote teaching and learning	20
None	225

Aside from the limitations portion of the survey reported here, there was an additional direction prior to the concepts portion of the survey directing participants to answer as if in a normal, face-to-face school year.

Other limitations became clear as data analysis continued. Because no questions were required to be filled out, there are some sub-samples that have uneven sample sizes (Table 2). Particularly race and gender identity had either some sub-samples with a very low sample size, or sub-samples with very large sample sizes, either of which was disproportional to the data collected, which made analysis difficult or impossible.

Conclusions and Future Directions

The aims of this study were two-fold. First, this study aimed to explore any differences in K-16 teacher efficacy related to the teaching of biological concepts. Second, this study aimed to evaluate a portion of the STEM anxiety framework (Grimes & Gardner, in preparation) in the context of biology teaching. This study evaluated the impact of different demographics, such as gender identity, age, and teaching context, on self-efficacy for teaching biology. Each of these was presented in the STEM anxiety framework. These results were analyzed both on the basis of the whole 48-item survey, as well as the *a priori* classifications of the concepts on the basis of the domains of biological sciences proposed by Scheiner (2010). These analyses revealed that there were numerous demographics exhibiting statistically significant differences. In particular, years of experience, age, teaching context, and approximate number of undergraduate biology courses were found to be the significant demographics.

Implications for Further Research

This study focused on the context of biological concepts. The biological sciences are only a small component of the overall science content that teachers are expected to teach. The NGSS additionally includes physical science, earth and space science, and engineering, technology, and applications of science standards. Therefore, this study methodology can be used as a guide in order to develop similar surveys to take steps towards fully evaluating the science education landscape across in-service teachers and subsequently used to inform teacher education in the sciences.

Additionally, future studies utilizing these methods may wish to focus specifically on underrepresented minorities, as the population for the current study was a majority white female respondents, matching the gender gap (Sax et al., 2018). There were also a number of studies cited throughout that were done in the context of foreign programs or individuals. Comparative work could give insight into foreign and domestic teacher educational practice and ways that we, again teacher educators, can improve educational practice.

Implications for Teacher Education Practices

The results of this study, while in the context of in-service teachers, has implications in the area of pre-service teacher education and in-service teacher professional development. First, teachers with between 0 and 2 undergraduate biology courses reported lower efficacy as compared to those with 3 or more courses, as well as those trained in elementary reporting the lowest efficacy followed by tertiary educators and secondary trained teachers, respectively. This is particularly informative because these findings can be seen as being indicative of the same thing. Elementary training programs often have the fewest numbers of disciplinary courses with secondary training and those aiming for higher education positions being declared majors. Therefore, the elementary educators and those reporting between 0 and 2 courses were likely the same group. This is troubling as many students' initial exposure to the sciences and foundational science learning occur in these contexts where the teachers are the least confident about the material. Likewise, teachers with the fewest years of experience as well as those reporting younger ages report the lowest confidence. Both of these instances highlight the importance of early intervention both in terms of pre-service education and in-service professional development. These results have broad implications for the practice of teacher education, both in- and pre-service.

CHAPTER IV: A QUALITATIVE EVALUATION OF K-16 EDUCATOR ATTITUDES TOWARD BIOLOGY USING A PERSONIFICATION PROMPT

Introduction to Chapter

There are numerous contributing factors to students' anxieties in the classroom, as discussed in chapter 2. This study was guided by the STEM anxiety conceptual framework proposed in Figure 7 of chapter 2 specifically aiming to explore specific content-based anxieties of elementary, secondary, and tertiary educators related to biology subject-matter knowledge (SMK; Magnusson et al., 1999) through the use of attitudes as a proxy. Attitudes have been shown to have an inverse relationship with anxiety, and therefore can be extrapolated from data pertaining to attitudes.

The remainder of the chapter is formatted as a research study manuscript that is being planned for submission to the Journal of Science Teacher Education (JSTE), a publication of the Association for Science Teacher Education (ASTE).

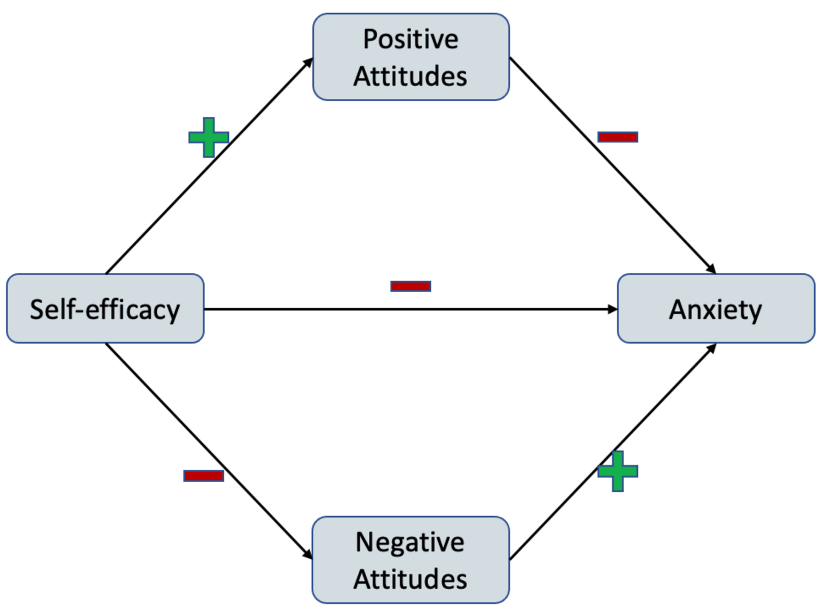
Background

Numerous factors can impact teacher behavior in the classroom, and these behaviors can have profound effects on their students. For instance, Beilock et al (2010) investigated the impact of elementary teachers, who identified as mathematically anxious, on their student's perceptions of mathematics. The findings of that particular study were that teachers who identify as mathematically anxious were more likely to socially transmit that anxiety to their students, especially if the students shared identity traits, such as gender, with the teacher. Research such as this and others (Koballa & Crawley, 1985; Sunal 1980) indicates that there is a strong correlation between teacher affective dimensions, such as anxiety, and their students' perception of and affective direction toward, the content.

The affective construct of attitudes have been shown to be related to anxiety, where positive attitudes are typically associated with lower anxiety and negative attitudes are associated with higher anxiety (Akin & Kurbanoglu, 2011; Figure 20 below). Attitudes toward science, in particular, are developed in part by prior conceptions about, prior experiences with, and beliefs about the content in question. These attitudes, both positive and negative, are typically rooted within emotional responses (e.g., enjoyment or fear). Adverse responses can exacerbate anxious feelings towards both learning and teaching science. These feelings, again either positive or negative, may potentially be socially transmitted from the teacher to their students when in the classroom as discussed previously (Beilock et al., 2010).

Figure 20.

The relationship between self-efficacy, attitudes, and anxiety. Simplified and adapted from Akin & Kurbanoglu (2011).



Campbell (1963) originally posited that attitudes were in the mind of the individual and were behavioral responses constructed in response to past experiences. Additionally, Eagly and Chaiken (2007) proposed a definition of attitude that is contingent upon a personal evaluation of an item, a person, a situation, or a context. This evaluation also exhibits interplay with an individual's either implicit or explicit biases, or preconceived opinions about something. Both attitudes and biases are developed in tandem through past experiences, and biases have the potential to alter one's ability to think critically and rationally (Stanovich, Toplak, & West, 2008), and therefore logically links to emotional responses. These emotionally-rooted attitudes, either positive or negative, can also impact an individual's ability to evaluate different relationship-related components (Frye & Karney, 2004).

In educational contexts, Koballa and Crawley (1985) found a relationship between teacher's classroom decisions, such as disciplinary time-allotment during class, and student attitudes toward disciplinary content. Specifically, the study found that students often exhibited negative attitudes towards subjects that were given less class time and positive attitudes towards subjects that were given more class time. This study extended the findings reported by Sunal (1980), which were teachers were more likely to allot less instructional time to subjects towards which they personally exhibited a negative attitude. Together, these findings imply that teacher negative attitudes can be implicitly socially transmitted to students in their classroom, mirroring findings by Beilock et al (2010).

Of particular interest to this study is attitudes towards science. As previously stated, attitudes are developed largely in response to an individual's experiences. Klopfer (1971) was one of the earliest researchers to elaborate attitudes towards science as a construct and identified different behaviors of those who adopt positive attitudes towards science. Other studies reviewed by Osborne et al (2003) identified other contributors to the development attitudes towards science such as anxiety, self-efficacy, motivation, and achievement. It should also be noted that Gardner (1975) differentiated attitudes towards science as feelings resulting from the evaluation of science as a discipline, and science attitudes as those characteristics exhibited by pre-professional or professional scientists.

Additionally, there have been studies examining individual's attitudes towards specific scientific disciplines. Multiple studies have examined attitudes toward biology within varying populations, specifically both elementary (Prokop et al., 2007ab) and secondary students (Prokop et al., 2007b; Taraban et al, 2006). Prokop et al (2007b) found that student interest in biology was directly proportional to attitude and dependent upon the biology topic being taught. Prokop et al (2007a) aimed to evaluate student attitudes toward biology through student out-of-school interests as a proxy. This was done by giving the students a survey asking about future career choice, hobbies, and reading and television habits. There was no statistical difference when non-biology careers were compared to biology careers in terms of gender or grade level. Students did show a statistically significant preference for biology-based hobbies and matched patterns exhibited when compared to those students who reported that biology was a favorite subject. Likewise, gender was not a significant predicator of students' preference for natural history books or television programs. Additionally, Prokop et al (2007b) found that student age was a significant predictor of student attitudes using a biology attitudes survey with students in the fifth through ninth grades. Finally, Taraban et al (2006) found that inquiry-based experiences in biology classes were most often associated with students who had positive attitudes toward biology.

The studies described above utilized quantitative measures in order to evaluate student attitudes toward science, specifically surveys. However, there have been instances of studies utilizing qualitative methods to evaluate attitudes. One such qualitative method that has been used to elicit research participants' attitudes, is a personification prompt. Personification, or anthropomorphism, is the description of a non-human entity using human characteristics, including emotional or physical descriptors (Kallery & Psillos, 2004). Personification related to attitudes towards particular brands have been explored in marketing research (Cohen, 2014). Nevid and Pastva (2014) used personification to explores students' views and attitudes toward Apple and PC products through descriptions of the students' described relationships with the personified brands. This study also noted that by using the personification method, the researchers are able to potentially elicit attitudes or views that participants may be either unable or unwilling to disclose under more traditional methods. Personification, as a method, forces a respondent to anthropomorphize some non-human subject. This anthropomorphizing process has the potential to allow respondents to relate to the personified subject, brand in the case of the Cohen (2014) study, as a human and therefore giving insight into implicit emotions. While the value of personification in determining attitudes towards disciplines in education is largely unexplored, there have been studies, though few, in STEM disciplines.

Specifically, in the STEM disciplines, Taber and Watts (1996) used personification to explore student conceptions of matter and Zazkis (2015) used personification to explore pre-service teacher attitudes towards mathematics. The study by Taber and Watts (1996) focused on how a student's use of anthropomorphic language could give insight into the student's understanding of scientific phenomena, specifically chemical bonds. This study simply aimed to propose that anthropomorphism in science can be used as a way to gauge student understanding in the sciences. Taber and Watts (1996) end their manuscript by calling for other science educators to begin studying student's understanding of abstract phenomena by evaluating students' use of anthropomorphic language, as they were able to glean valuable information about their student's understanding of chemical bonding in this way. The use of anthropomorphic language is common in biology, particularly in the classroom as pertaining to evolution (Legare et al, 2013). The Legare (2013) study was done with elementary-aged children. These children were read different narratives concerning the process of evolution. These narratives differed in the type of language used throughout to describe the process of evolution. These narratives were written either with language implicating natural selection based, needs-based, or desire-based evolution. Children were asked to recall the stories with as much detail as possible and their responses were coded. The study found that children most often used the same language in the recall that they were initially presented with, also exhibiting that the manner in which young children are taught evolution, potentially other topics as well by extension, is often the explanation that persists. This study also found that the desire-based explanations were more likely to be repeated or used when talking to younger children, shifting to needs-based and then natural selection based as age increased. Of note, this is a cross-sectional study, not longitudinal. Longitudinal work should be done to see how persistent these particular explanations are. Legare (2013) used the desire-based narrative to illustrate anthropomorphic language in evolution conceptions, but there can be more to nuance to anthropomorphic descriptions than simply conceptualizations. Zazkis (2015) uses the personification methodology as an extension of anthropomorphizing. Rather than solely describing mathematics using anthropomorphic language, Zazkis' (2015) study used the eliciting personification methodology to gain insight into the perceptions of mathematics in the eyes of his students, who were pre-service teachers. This study by Zazkis (2015) was a written as a proof-of-concept for the use of the eliciting personification method as a more adult oriented alternative to the draw-a-mathematician (Picker & Berry, 2000). In Zazkis (2015) study, he analyzed the personifications through the use of character summaries and conceptual blending. The initial character summaries were used to summarize the spectrum of characters that were described by the personifications. This analysis was followed by conceptual blending, as a way to combinatorically synthesize different dimensions of the personifications. Zazkis (2015) was able to discuss, in detail, three different broad personas that were presented in a single response.

Additionally, a pilot study using the prompt for the present study was able to discern the attitudes, through descriptions of relationships as a proxy, in 40 of the 45 student participants' narratives (Grimes et al, 2019). Attitudes were able to be inferred from those portions of the prompt discussing how biology acts or behaves, as well as the descriptions of the relationship over time. For example, the verbatim excerpt below describes a negative attitude toward biology as inferred from the description of the relationship:

> *"In high school you started backstabbing me…I got about a three year break from you, until college came. Then you were a pain in my butt once again"* [Student 1869]

While the verbatim excerpt below is a positive attitude, again inferred from relationship:

> *"Biology and I have been friends for a very long time."* [Student 2282]

There is also the potential to be able to evaluate attitudes from descriptions of the behavior. The verbatim excerpt below is an example of a negative attitude inferred from behavior:

> *"The relationship that I have always had with biology have not been exciting for me and I wish I could break free from him."* [Student 2608].

Interestingly, the pilot with pre-service elementary and middle grades teachers showed that 57.5% of them described biology as a friend, which is contrary to what was expected. This was also attached to the final exam, and though they were told this portion was graded on completion, they may have been writing to appease the instructor, thus introducing a response bias. Therefore, the present study was aiming to expand the sample and evaluate this prompt in a new context, that of in-service K-16 educators, which has not been done to this point.

The present study evaluated the attitudes of K-16 educators using a personification prompt. The operational definition that this study used for attitudes toward biology was the individual's positive or negative evaluation of biology as a discipline, adding the personal dimension to the prompt allows for data gathering related to an individual's experiences with biology.

This study was guided by the single research question presented below:

1. What does a personification of biology prompt reveal about K-16 educators' attitudes towards biology?

Methodology

Overview and Prompt

Data for this study was collected as part of a broader cross-sectional survey research study and personification data was separated from other survey data prior to analysis. This study utilized a reflective personification prompt modified from mathematics education (Zazkis, 2015), and a previous iteration was administered to pre-service elementary teachers (Grimes et al., 2019). As in study 1, this study will use the STEM anxiety framework proposed in Chapter 2.

The prompt reads as follows:

> *What if Biology was a person? Write a paragraph about who Biology is. This paragraph should address things such as: How long have you known each other? How did you meet? What does he/she/it look like? What does he/she/it act like? How has your relationship with Biology changed over time? These questions are intended to help get you started – they shouldn't constrain what you choose to write about.*

Participants and Sampling

This study sampled K-16 educators. The prompt was electronically distributed to multiple educators via social media and professional listservs as part of a larger survey. The writing prompt gathered a total sample of n=164, excluding participants who did not consent or who failed to respond to the prompt or the demographic questions used to group the responses. Demographics collected for this study were the respondents' current teaching context (either elementary, secondary, or tertiary) and the respondents' self-identified gender. These demographics are presented in Table 12 below.

Table 12.

Demographics collected. ELED indicates elementary, SECED indicates secondary, HIED indicates tertiary.

Gender Identity		**Teaching Context**	
Demographic	**n**	**Demographic**	**n**
Male	26	ELED	12
Female	138	SECED	69
		HIED	83
Total	164	Total	164

Demographic Analysis

All analyses pertaining to demographic variables were carried out using RStudio v.1.3.1093 (R Team, 2020) by utilizing packages ***tidyverse*** (Wickham, 2019) for statistical analysis and ***ggplot2*** (Wickham, 2016) to generate visualizations.

Qualitative Coding Analysis

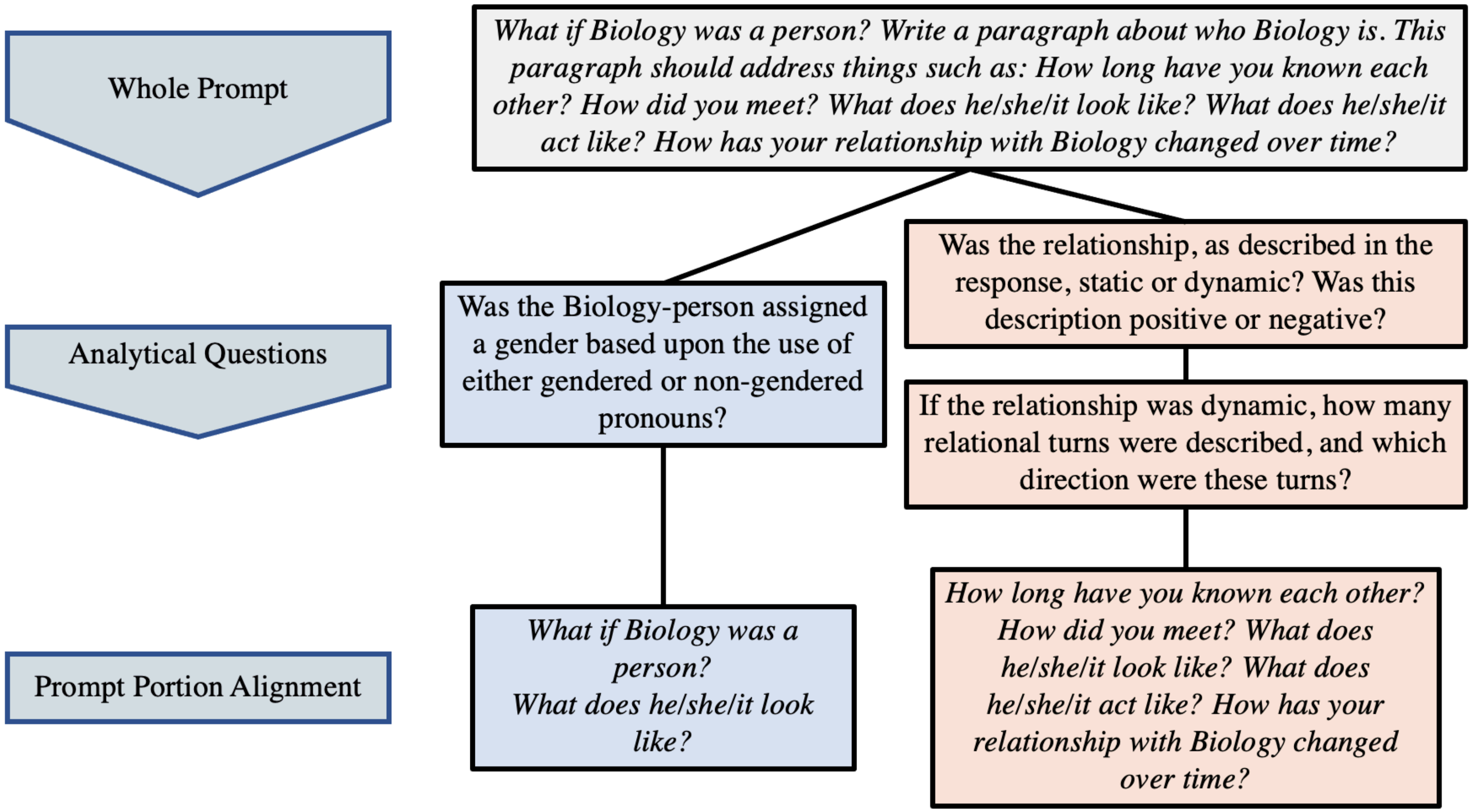
There were a number of *a priori* guiding questions driving the qualitative coding during analysis. These individual questions, each had the goal of ascertaining the attitude of the participants and are listed below. These questions are all in reference to the individual respondents' Biology-character, or the personified Biology construct described in the response.

- Was the Biology-character assigned a gender based upon the use of either gendered or non-gendered pronouns?
- Was the relationship, as described in the response, static or dynamic? Was this description positive or negative?
- If the relationship was dynamic, how many relational turns were described, and which direction were these turns?

These questions were developed as part of the pilot study described earlier (Grimes et al., 2019) and in response to particular portions of the prompt. These questions were also chosen as ways to both implicitly and explicitly evaluate educator attitudes toward biology. The question about gender was used because of the particular implicit information that can be gleaned from this aspect of the Biology-character. For instance, if a respondent described the Biology-character as an ex-husband or ex-boyfriend, there are relational connotations associated with those terms. Others described a teacher from some point in their formal education, and the personification carried the same gender as this teacher. The questions pertaining to the relationship were the larger basis for the evaluation of attitudes. As described by Cohen (2014), eliciting personification as a method is very useful in eliciting relationship data that can be used to infer attitudes toward the character described. Figure 21, below, shows the alignment of the above questions to portions of the prompt.

Figure 21.

This figure shows the breakout and alignment of the whole prompt as related to the analytical questions described above.



Each of the n=164 responses were independently coded, using each of the above questions as an *a priori* analytic guide, by two independent researchers. When coding for gender, the gender of the Biology-character was determined through the respondents' use of pronouns. Gendered pronouns (he/him/his, she/her/hers) were coded as male or female, respectively. Responses using non-binary pronouns (they/them/theirs) or switching the use gendered pronouns throughout the response were coded as transitional.

When coding for relationships as static or dynamic, the researchers were looking for language that described relational turns. For this study, the idea of relational turns references changes in relationship. Some examples of words that would have indicated relational turns would be *better*, *worse*, *soured*, *improved*, etc. Any instances of words such as these were coded as dynamic. Responses that included no language indicative of any relational turns were coded as static, rather than looking for specific terms here, these were largely coded due to a lack of terminology.

Following the static or dynamic coding, the relationships were secondarily coded as either positive or negative. Because static relationships indicated no relational turns, the static responses were singularly coded as either positive or negative based upon any present combination of language, loaded terms which implicitly indicated a nature of the relationship in context (e.g., ex-boyfriend, lover, divorced), or other implicit meanings of the relationship throughout the narrative responses. Dynamic relationships were also coded as positive or negative as described above. However, instead of coding the entire relationship as was done in the static relationships, each relational turn in the dynamic relationship was coded as positive or negative.

In addition to the above coding schemes, there were also instances where participants may not have responded to a portion of the prompt that was being analyzed for particular codes, such as not describing the Biology-character as a gender and instead describing the discipline. These responses were coded as unresponsive in respect to whichever of the *a priori* coding questions was unable to be answered. The independent coders met periodically throughout the coding process in order to compare and discuss coding differences toward a consensus code for those instances of disagreement.

Results

The goal of this study was to ascertain the attitudes of K-16 educators in relation to biology by using a personification prompt. All vignettes provided below will be presented verbatim as written by the respondent, without any correction to grammar or spelling, unless where it is necessary to clarify meaning and interpretation. The discussion of these results will be organized by the guiding questions used during the coding process. Unfortunately, the prompts solicited through the prompt used for this study did not rise to the detail of those presented by Zazkis (2015), and therefore the analysis and succeeding interpretation was limited. Again, these are:

- Was the Biology-character assigned a gender based upon the use of either gendered or non-gendered pronouns?
- Was the relationship, as described in the response, static or dynamic? Was this description positive or negative?
- If the relationship was dynamic, how many relational turns were described, and which direction were these turns?

Gendering Biology

Gender was identified by the use of either gendered pronouns (he/him/his; she/her/hers) or by neutral pronouns (they/them/theirs) as opposed to implications of language or descriptions of the Biology-character's physical traits or characteristics, due to the lack of physical traits without accompanying pronouns. There were some responses, coded as *T* (for transitional), where the use of gendered pronouns switched through the course of the prompt. Of particular interest was the potential for differences based upon teaching context, therefore analyses were conducted using teaching context as the grouping variable. A reminder, the different teaching contexts were elementary, secondary, and tertiary. The frequency counts of each of the possible codes, grouped by teaching context are presented in Table 13 and Figure 22 below.

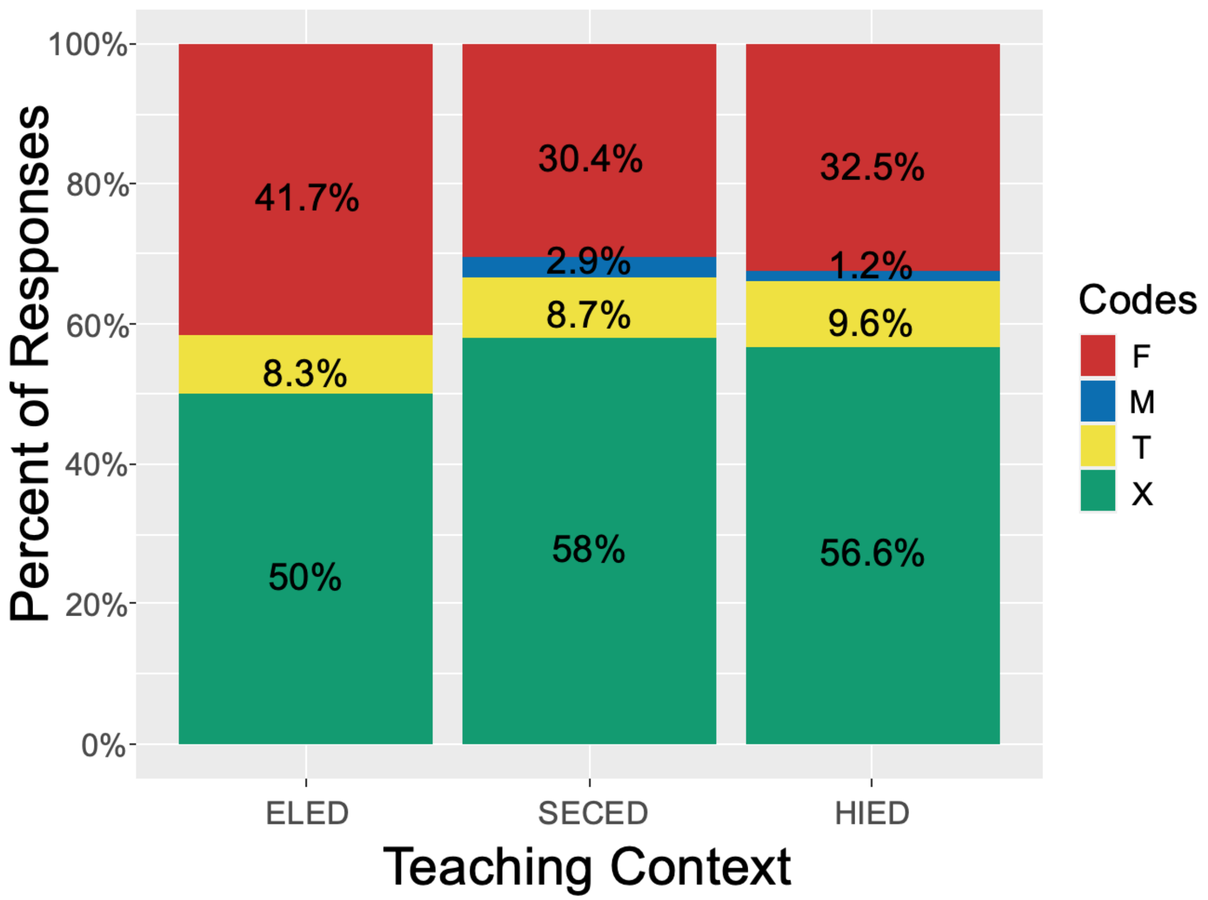
Table 13.

Frequency counts of the gendered categories for each of the pronoun groups, also grouped by teaching context.

Neutral Pronouns		Gendered Pronouns				Unresponsive	
They/Them/Theirs or Transitional		Male Pronouns (he/him/his)		Female Pronouns (she/her/hers)			
ELED	1	ELED	0	ELED	5	ELED	6
SECED	6	SECED	2	SECED	21	SECED	39
HIED	8	HIED	1	HIED	27	HIED	47
Total Responses	15	Total Responses	3	Total Responses	53	Total Responses	93

Figure 22.

Percentage of code usage across teaching context groups. X indicates unresponsive.



There were a total n=163 responses to be coded for gender of the Biology-character and he overall demographics of respondents were 16% male and 85% female. As a reminder, those who did not describe anything in line with this portion of the prompt were coded as unresponsive (56%). Of the remaining entries, 4% were coded as male, again due to the language of the response, such as the following:

"*. . . I have known him all my life. . .*" [R. 1343]

75% were coded as female, such as the following Biology-character:

"*I met Biology in high school. . . [y]ou could tell she was really smart.*" [R. 1094]

Finally, 21% were coded as transitional. An example of a transitional code stemming from the use of neutral pronouns (they/them/theirs) is below:

". . . *I learned a lot about them and really enjoyed spending time with them*. . ." [R. 1244]

Additionally, a transitional code was used when multiple gendered pronouns or other gendering language was used interchangeably throughout the prompt or through the description of physical characteristics. For instance:

". . . Biology used to look like an "old white dude," . . . Nowadays . . . biology looks like women. . . " [R. 1032]

Relational Cues

After gender, the personification prompts were analyzed for the kind of relationship with the Biology-character. This analysis was done in two phases. The initial phase was to simply define the descriptions of the relationship as either dynamic or static by looking for described instances of a change or shift in the relationship or lack thereof, respectively. The second phase was done with the goal of identifying the number and nature of relational turns described. Static relationships were identified as either positive or negative. Dynamic relationships were coded in the following way. Those personifications that had only one relational turn, an instance where the participant describes a change in the relationship, were coded as either increasingly positive, increasingly negative, positive-to-negative switch or negative-to-positive switch. Those that had 2 or more relational turns were described as cyclical. The individual codes for each of these categories, grouped by teaching context, are presented in Figures 22 and 23 below. Figure 23 shows the results of the second round of coding, and therefor does not include those individuals who are listed as unresponsive in Figure 11.

Figure 22.

Description of static or dynamic relationship. X is indicative of unresponsive.

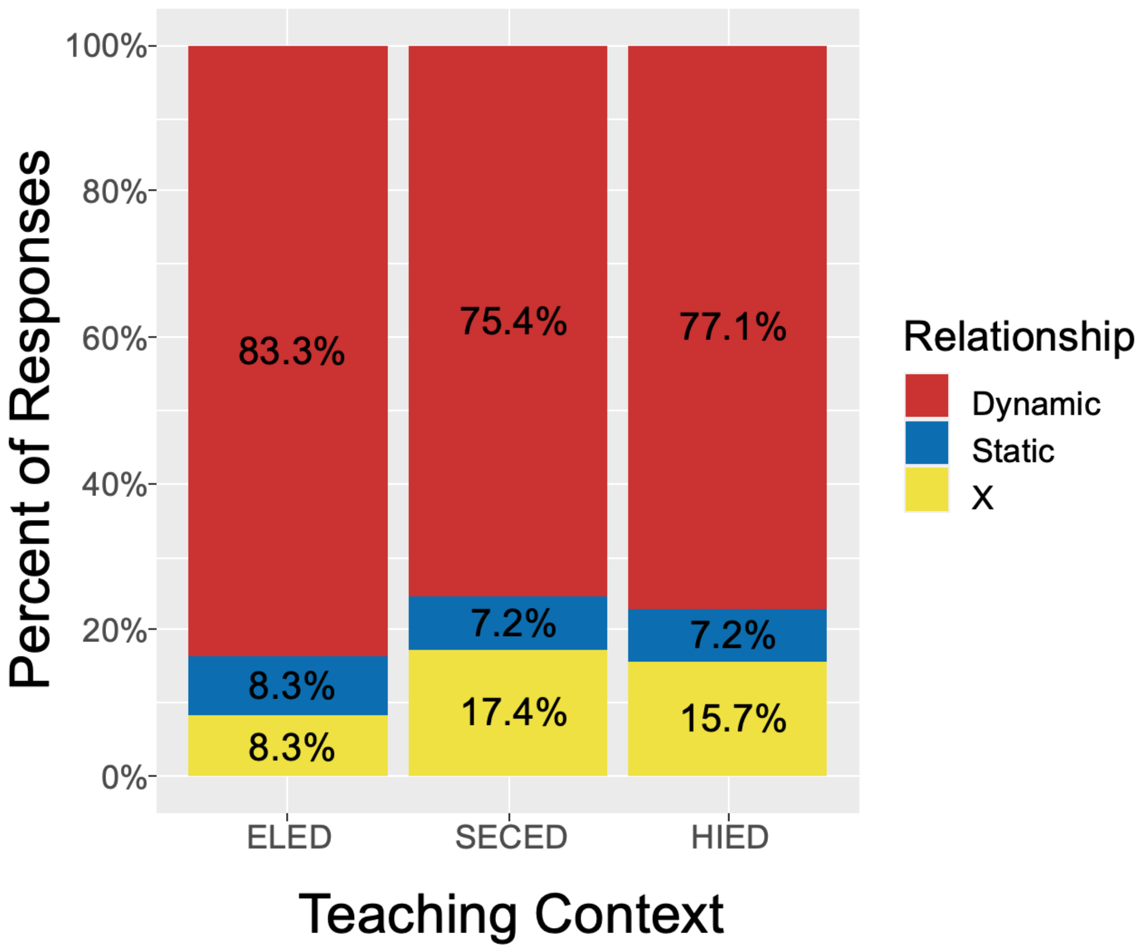
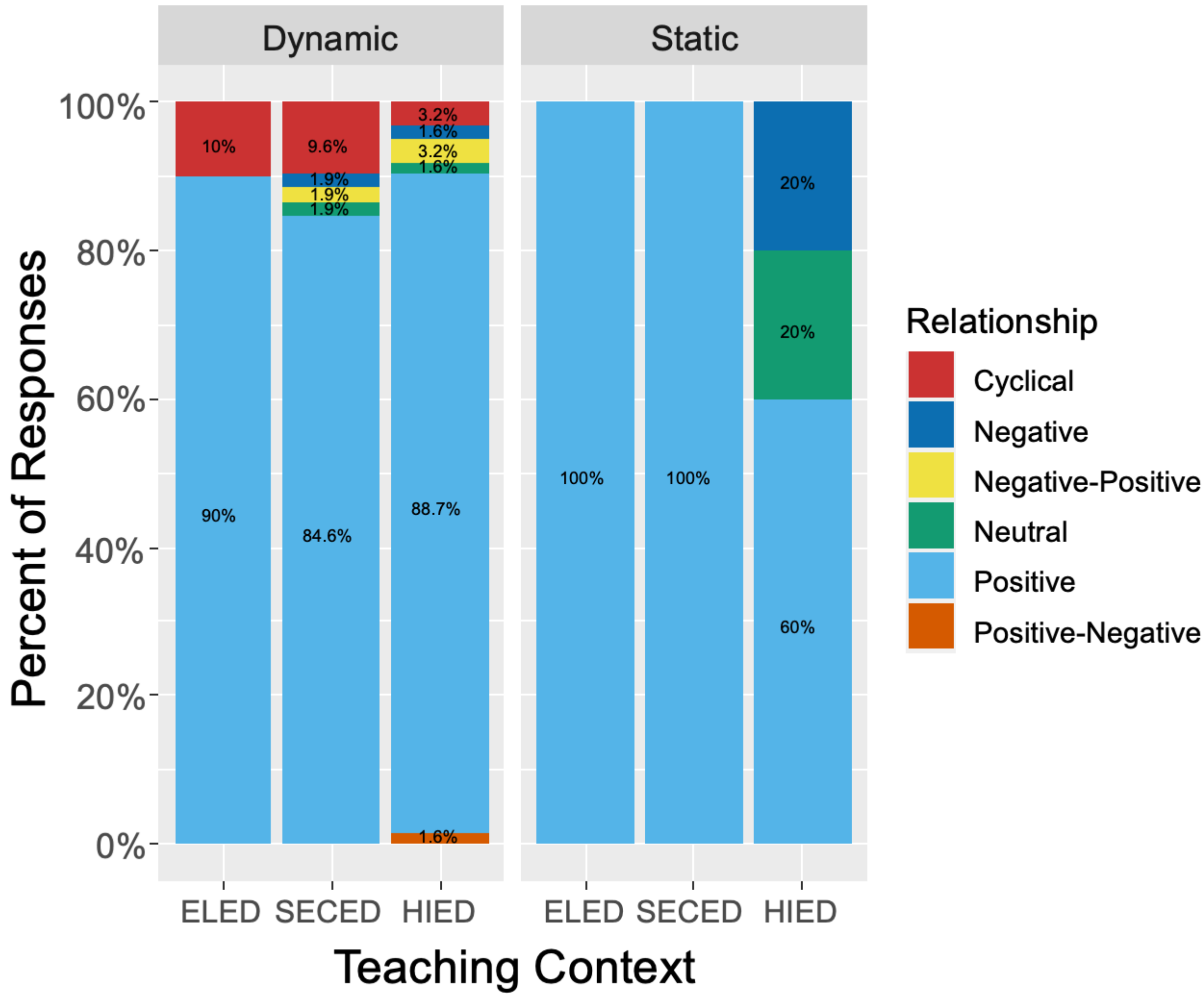


Figure 23.

Different relationship codes and their frequency grouped by teaching context.



Again, coding for relational cues was done in stages. Initially, relationships were coded as static or dynamic with the researchers looking for language indicative of relational turns. Static relationships were those that described no change in relationship, while dynamic relationships were those that did have language indicating changes in a relationship. Second, the responses were coded as either positive or negative. Static relationships were singularly coded as positive, negative or neutral. Following are examples of each code.

"Biology itself is messy although governed by natural cycles, limitations from genetic code, but seems to want to be more than genetic type. Within Biology, I prefer it's plant component-easier to follow. While there are physical and genetic constraints the addition of behavior makes biology messy. I accept biology but am not always excited about its behavioral lack of control" [R. 1287]

The above excerpt is an example of the neutral code. Neutral was used when relational descriptions were not particularly definitive in a positive or negative direction. In the statement above, the neutral code is rooted in the statement that says that the respondent "accepts biology but [is] not always excited about its behavioral lack of control." This leads to an inference of ambivalence related to the respondent's attitude. The above statement, as with the statement to below, were largely coded based upon a behavioral description within the response.

"Biology is a long lost acquaintance. I have mutual friends with her, but she and I don't speak. We met in high school and got along for 1 year. I didn't see her again until one semester in college. She and I don't get along well. We see the world differently. I see the universe as a whole, but she's focused solely on the living things on Earth." [R. 1255]

This excerpt is an example of a negative code. This was coded as a negative relationship because of the description of the respondent and their Biology-character not being on speaking terms and that they "don't get along well."

"I meet Biology long time ago when I was a sophomore in high school. I enjoyed it because I had an interesting teacher (my basketball coach) who knew the material very well. That was over 35 years ago. I then was introduced again to it my sophomore year in college. More details and more information was given to me. If I had to choose from the science subjects that I have had, biology is/was probably my favorite next to the astronomy class I had to take in college. Having taught primarily in the lower grades, our science curriculum is very simple due to the age of our students. As I said, many years have past since first meeting biology and a lot if not most of the facts I have learned are very hard for me to remember." [R. 1085]

Finally, the above response is an example that was coded as a positive relationship. The respondent identifies biology as their favorite science, indicating positive experiences. They also use language indicating positive feelings, such as *enjoyed*. Interestingly, all ELED and SECED static relations were coded as positive. However, HIED individuals were the only group who exhibited neutral or negative codes in static relationships.

Dynamic relationships were coded following the same scheme as static relationships, with the difference being that the dynamic relationships exhibited multiple relational turns, and each of the turns was coded. This leads to the potential codes for dynamic relationships being increasingly positive or negative, negative-positive, positive-negative, or cyclical if there were two or more relational turns described.

"TO me Biology is a lifelong friend. AS the child of a physician I spent my youth around hospitals and medical conversations. By middle school I had developed a passion for human origins and felt a real kinship with my new friends like "Lucy" and the Turkana Boy. Biology served as something of a mirror to help define who I was as a young man. I got a real feel for my identity and felt I could share that with others through teaching about biology. AS such I use evolution as a way to introduce my students to the humanity that is biology." [R.1055]

The above responses was coded as an increasingly positive relationship. The Biology-character is described as a "lifelong friend" and includes that they, the respondent, even mention avenues through which their relationship advanced, in particular Lucy and the Turkana Boy as mediators from their past experiences. It also highlights the important role that parents can play in the development of attitudes. Another respondent highlighted a teacher, but this was in a negative context:

"…Biology can be my worst nightmare if I don't understand it well…Biology intimidates me at times but this is a direct result of a poor teacher in high school who was prejudiced against honor students, girls, and freshmen; I was all three." [R. 1209]

The previous response was identified as increasingly negative. This is through the language around the description of the Biology-character as their "worst nightmare" and being "intimidating." There is also the reference to the teacher that seems to be the ignition point of this negative attitude toward biology. This is one of the very few dynamic relationships that gets increasingly negative. Many of the dynamic relationships that began negative eventually shift to positive, such as the next respondent.

"Biology is a friend without boundaries. We met in 1985 in college and I fell in love. I hated biology in high school, but college biology was fascinating. She is every changing and our relationship grows deeper and deeper over time. The more I learn, the more I"m fascinated and enamored. And like the expanding universe, biology seems to have no end. She continues to intrigue and surprise." [R. 1061]

This respondent mentioned that they "hated" biology in high school, but that changed to "love" in college. This individual was able to overcome the negative past experiences, but this is not always that case, as seen in the earlier response for increasingly negative response or the static negative. However, in the overall responses, negative was a minority. However, there was a single response that was coded as positive-negative.

"Biology is a large character that is the basis of all studies involving living beings. We have known each other for a while, but the more I progressed in my graduate training the less confident I became in our friendship. Now I don't view us as friends at all." [R. 1280]

The above individual, a self-identified HIED educator, is the only individual in the sample who exhibits the positive-negative shift in attitude. This does not indicate that this individual was the only one who experiences a shift, rather the only one whose relationship did not experience a rebound. All individuals who were coded as cyclical, or those that indicated at least 2 relational turns, were coded as positive-negative-positive. An exemplar is below:

> *"I met Biology growing up on a farm. I fell in love with Biology when I first visited a tidepool at the beach. I grew annoyed with Biology when I had to learn all the vocabulary in school. We almost broke up as I felt useless. Now we are stable, and I introduce Biology to everyone I meet. Every walk I take, I marvel at Biology's beauty."* [R.1275]

In the above response, the relation turns occur at the initial "fell in love", when the respondent describes becoming "annoyed" nearly leading to a "break up", and finally becoming "stable" enough to tell others about. This kind of response was typical of those respondents who indicated a decline in the relationship.

Discussion and Conclusions

The overall goal of this study was to evaluate what, if any, differences in educator attitudes toward biology could be discerned from a personification prompt. While gender was found to not be significant in a study relating to brand preferences (Nevid & Pastva, 2013), Gong et al (2018) found that teacher gender and student gender were positively correlated in that female students exhibit more confidence and more positive outcomes when taught by a female teacher. The same was true for males. Therefore, the findings that a majority of the relationships are positive and a majority of the respondents are female mirrors those findings by Gong et al (2018). The proportion of male and female identified Biology-characters follows with the expectation as the biological sciences, when compared to the other sciences, typically have more females working in the discipline (Sax et al., 2018). Additionally, teaching across elementary, secondary, and tertiary contexts is also typically an overall female-dominated field. This could account for the 75% female identified Biology-characters since both the broader educational landscape and that of the biological sciences is often female-dominated, then it is likely that the respondents had meaningful interactions with female educators that influenced the appearance of their Biology-character (Eagly & Chaikin, 2007). The goal of examining respondents' Biology-character genders was to gain insight through descriptions using the loaded language described previously. Ultimately, this was not something that was able to be directly linked to respondent's attitudes due to the lack of overall responses lending themselves to this level of analysis and interpretation. It was, however, possible to logically infer that these responses were connected to their previous experiences in the context of biology, much like the studies in brand marketing (Huang & Mitchell, 2014; Nevid & Pastva, 2014).

Upon completion of analysis, an interesting pattern emerged. Looking at code diversity, in both static and dynamic relationships, HIED respondents exhibited the highest diversity of relationship codes. In dynamic relationships, specifically, SECED followed in code diversity. This could indicate that more dynamic relationships occur in those that choose to delve into the biological sciences academically. ELED in both static and dynamic relationships were the least code diverse, but those in ELED are most likely to take the least number of biology-specific courses.

Implications for Further Research

The results of this study were not as descriptive as those presented by Zazkis (2015) or as seen by the author in a previous study (Grimes et al., 2019). It is not currently clear what could be causing this difference. Of note, both previously cited studies were in pre-service teacher populations and the prompts were given as part of course assignments. This could indicate that when the prompt is high or medium stakes, as typically seen in assignments, that the prompt is taken more seriously. Additionally, a methodological approach that could prove useful for future studies is either pairing the personifications with a cognitive interview or eliciting the personification as an interview instead of a writing prompt. Each of these methodological alterations could give richer and fuller insights into individual's responses.

Limitations

The main limitation with the potential to affect this study is a response bias. This is not said to cast doubt on the results, but rather to highlight the necessity of repeating this study as an independent study, as opposed to being presented as part of a different survey. There is the potential that those with negative attitudes towards biology did not wish to continue past the first portion of the survey, therefore leading to the response bias.

CHAPTER V: CONCLUSIONS

The studies described that were done as part of this dissertation together had multiple parallel aims. First, the literature review aimed to develop a model of STEM anxiety that can be used to evaluate anyone interacting with STEM at any level. This framework was constructed much of the same way that STEM was developed, through the combination of anxiety research into each of the different disciplines under the STEM umbrella. This framework, which was developed as part of Chapter 2, was used to guide the design and execution of the other two research studies described previously in Chapters 3 and 4.

Overall, the studies described herein illuminate different components to the proposed STEM anxiety framework. Both studies evaluate the effects of different demographics. These specific demographics are age, number of undergraduate biology studies, teaching context, gender identity, ethnicity, and role in higher education, if applicable. While many of these are represented verbatim in the STEM anxiety framework, number of undergraduate biology courses and teaching context are used as proxy representations for content background.

The anxiety antecedents from the STEM anxiety framework being studied were teacher efficacy (Chapter 3) and attitudes toward biology (Chapter 4). Additionally, these were compared across multiple demographics including age, teaching context, and gender identity, also taken from the STEM anxiety framework. The results from this pair of studies indicate that training in the life sciences for elementary teacher candidates may not be sufficient, which is potentially true across other areas of science preparation as well (NCTQ, 2019). Additionally, the results indicate that there is a significant positive impact of teacher training on self-efficacy in disciplinary contexts. This was apparent when comparing secondary educators to tertiary educators. Both secondary and tertiary educators, in theory, receive the same training at the undergraduate level, specifically a degree in the major field. However, secondary educators also receive either a major or minor in education and therefore teacher training.

The studies that I have described here show that much of the training we are doing across elementary, secondary, and tertiary educator training programs is inadequate, mirroring findings based upon state licensure standards (NCTQ, 2019). Elementary educators exhibited the lowest self-efficacy scores of all contexts, followed by tertiary and secondary, with secondary having the highest self-efficacy scores. We also see that, qualitatively, tertiary educators show the highest code diversity followed by secondary educators, possibly indicating that more content-based training can lead to more relational turns and changes. This could strengthen the relationship. However, this relational evolution is absent in elementary educators since they do not receive enough training to develop a relationship that can survive hardships.

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APPENDICES

APPENDIX A: MTSU IRB APPROVAL NOTICE

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
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Murfreesboro, TN 37129
FWA: 00005331/IRB Regn. 0003571

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Wednesday, August 26, 2020

Protocol Title	***A Mixed Method Evaluation of Anxiety Antecedents Related to Biology Content Among K-16 Educators***
Protocol ID	**21-20097q**
Principal Investigator	**Zachary Grimes** (Student)
Faculty Advisor	Grant Gardner
Co-Investigators	NONE
Investigator Email(s)	*ztg2e@mtmail.mtsu.edu; grant.gardner@mtsu.edu*
Department	Mathematical Sciences (PI) and Biology (FA)
Funding	**NONE**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU IRB through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior*. A summary of the IRB action is tabulated below:

IRB Action	**APPROVED for ONE YEAR**		
Date of Expiration	**8/31/2021**	*Date of Approval*: 8/26/20	*Recent Amendment*: NONE
Sample Size	FIVE HUNDRED (500)		
Participant Pool	*Target Population:* Primary Classification: **Healthy Adults (18 or older)** Specific Classification: **Elementary/Secondary teachers, Biology GTAs and Biology college/university faculty**		
Type of Interaction	☒ Virtual/Remote/Online interaction ☐ **In person or physical interaction – Mandatory COVID-19 Management**		
Exceptions	Qualtrics informed consent followed by online survey is permitted.		
Restrictions	**1. Mandatory ACTIVE Informed Consent.** **2. Other than the exceptions above, identifiable data/artifacts, such as, audio/video data, photographs, handwriting samples, personal address, driving records, social security number, and etc., MUST NOT BE COLLECTED.** **3. Mandatory Final report (refer last page).** **4. CDC guidelines and MTSU safe practice must be followed**		
Approved Templates	*IRB Templates:* Qualtrics Informed Consent and Recruitment Email *Non-MTSU Templates:* Social media recruitment script using approved email		
Funding	NONE		
Comments	NONE		

APPENDIX B: LIST OF BIOLOGY TOPICS FROM THE SELF-EFFICACY STUDY

The following lists of topics were administered as a single list in alphabetical order as part of the self-efficacy study. Scheiner (2010) domains are indicated in bold type.

Ecology
Animal behavior (innate and learned)
Biomes
Ecological succession
Ecosystems
Energy Flow
Environmental changes
Food chains and food webs
Human impacts on the environment
Nutrient Cycles
Populations

Genetics
Biotechnology
Differences between prokaryotic and eukaryotic genetics
DNA Replication
Gene regulation and control
Heredity of traits
Mendelian genetics and other patterns of inheritance
Mutations
Relationship between genotype and phenotype
Reproduction (sexual and asexual)
Transcription and translation

Organisms
Animal anatomy and physiology
Animal development and life cycles
Biodiversity
Eukaryotes
Plant anatomy and physiology
Plant development and life cycles
Prokaryotes
Viruses

Biology/Life
Characteristics of life

Levels of organization
Structure and function of biomolecules
Taxonomy

Cells
Cell cycle
Cell structure and function
Cellular Respiration
Meiosis
Mitosis
Photosynthesis

Evolution
Adaptation
Cladograms/Phylogenetic trees
Evidence of common ancestry
Gene Flow
Genetic Drift
Immigration/Emigration
Mechanisms of evolution
Natural Selection
Sexual selection/Non-random mating
Speciation