Sowing the Seeds for Equity in Science Education: A Cross Case Mixed Methods Study of Pre-Service Elementary Teachers and Their Self-Efficacy Related to Equitable Science Teaching

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DEDICATION

This dissertation is dedicated to my family, whose unwavering support and belief in my abilities have been the cornerstone of my perseverance and success. To my parents, thank you for instilling in me the values of hard work and dedication. To my partner for the endless encouragement, patience, and love that gave me the strength to continue despite challenges. Finally, this is dedicated to my son. I want to present myself as an excellent role model to demonstrate what it truly means to pursue one's dreams with passion and integrity.

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Executive Summary

Dr. Robert Tai

This dissertation investigated the self-efficacy of pre-service elementary teachers concerning equitable science education. The investigation was conducted over two phases, in the autumn of 2022 and the spring of 2023, utilizing the Self Efficacy Beliefs About Equitable Science Teaching (SEBEST) instrument (Ritter et al., 2001) and interviews for data collection. The SEBEST instrument assesses pre-service elementary educators' self-efficacy in delivering science education equitably to a diverse student population, encompassing variations in race/ethnicity, gender, socioeconomic status, language proficiency, and gender. The study disseminated surveys within five teacher education programs in a Mid-Atlantic State, employing a pre-survey/post-survey design within the context of elementary science methodology courses. Ninety-seven participants completed the survey.

The study used a parallel convergent mixed methodology, which included quantitative and qualitative data that was collected and analyzed separately and then merged in a final discussion section. Quantitative examination investigated the association between the demographic characteristics of the field placement environments (characterized by the school-level racial/ethnic composition of the student body, the percentage of students receiving free or reduced lunch, the percentage of students classified as English language learners, and the percentage of females) and the pre-.

service elementary teachers' responses on the SEBEST survey. The additional quantitative analysis examined the association of teacher education coursework experiences in explicit Diversity, Equity, and Inclusion courses and participants' responses on SEBEST survey measures. The qualitative analysis included interviews with eight pre-service elementary teachers and investigated participants' conceptualizations of equitable science instruction. Methodological integration occurred in the discussion phase of this work.

Results indicated a significant association between participants' self-efficacy related to equitable science teaching and the number of Diversity, Equity, and Inclusion courses included in their teacher education program experiences. Additionally, there were significant associations between the predictor variables of the race (white[i]) of pre-service elementary teachers and the demographics of their field placement experiences on the outcome variable of post-SEBEST survey scores. The qualitative analysis demonstrated multifaceted conceptualizations of equitable science within a continuum of understanding. The integration of methodologies in the discussion exposed additional nuances to this work. This research contributes to and broadens the existing body of knowledge regarding the impact of educational experiences within teacher training programs on pre-service elementary teachers' perceived competence and assurance in facilitating equitable science education.

CHAPTER 1: INTRODUCTION

Background

Teaching is complex and challenging work (Lampert, 2001). At the elementary level, these challenges are multiplied for teachers in various ways. For example, most elementary teachers are tasked with being responsive to students' academic and socio-emotional needs across multiple subject areas, including mathematics, reading, writing, social studies, and science. In terms of the science curricula, elementary teachers teach life science, earth science, astronomy, physics, chemistry, and engineering while specializing in a few, if any, of these disciplines (Haverly & Davis, 2023). Perhaps because of this, most elementary teachers do not feel well-prepared to teach science (Plumley, 2019). In 2018, results from the National Survey of Science and Mathematics Education (NSSME) indicated that only 23% of elementary teachers (N= 919) surveyed felt prepared to develop students' conceptual understandings of science, and only 31% felt well prepared to encourage the participation of all students in science (Plumley, 2019).

Additionally, science education is not typically prioritized in elementary classrooms, compounding teachers' feelings of unpreparedness (National Academies Science Engineering and Mathematics, 2021; National Center for Educational Statistics, 2019). Elementary teachers often forgo science instruction, succumbing to the pressures of high-stakes accountability testing in reading, writing, and mathematics (Blank, 2012). For example, teachers spend an average of 18 to 27 minutes on science compared with 82

to 89 minutes of reading daily (Banilower et al., 2018). This prioritization affects instructional time and limits the number of instructional resources available, including professional development funds and access to high-quality curricula materials (Banilower et al.). Limiting instructional time for science impacts students' success with science learning later in their schooling (Haverly & Davis, 2023). When science instructional time is limited, the focus often becomes the memorization of vocabulary, and this limits the connections that historically underserved students (including marginalized racial, ethnic, language, and ability groups) can make between science and their cultural backgrounds (Bang et al., 2017; Calabrese et al., 2000).

There are a variety of reasons schools should prioritize science in elementary schools. Science education supports the development of language and logic skills. It helps students develop their curiosity and wonder towards their surroundings and helps scaffold critical thinking and problem-solving skills that will assist students in functioning as scientifically literate citizens (Krajcik et al.,1999; National Science Teachers Association, 2014). Educators often silo academic disciplines into separate categories of instruction, but science education can be interdisciplinary, especially at the elementary level, supporting literacy and numeracy throughout the curricula (Zembal-Saul et al., 2020). Given all these assets, science education should be a priority in our elementary schools (National Academies of Sciences, Engineering, and Mathematics**;** NASEM, 2022).

Some elementary teachers report that they lack the confidence needed to support the participation of all students in science (Plumley, 2019). Given that most of the United States school-aged population will be comprised of historically underserved students in

the coming years (U.S. Census Bureau, 2020), teachers must help students make meaningful racial, cultural, and linguistic connections in science instruction to understand and participate in scientific discourse (Brown, 2017). One way to support the participation of all students in science discourse is to create equitable spaces in science classrooms.

Equitable learning opportunities value students' prior knowledge, including cultural and linguistic experiences (Lee & Buxton, 2008). They do not provide a one-size-fits-all model to curricula (such as equal education experiences). Instead, they enable students to see themselves, their families, and their cultures as part of science (Agarwal & Sengupta-Irving, 2019). When teachers provide equitable learning opportunities, students from all backgrounds (in terms of race, ethnicity, language, socio-economic levels, and abilities) can learn challenging science curricula and achieve various science outcomes (Lee & Buxton). In equitable science classrooms, students can expand their roles and share epistemic authority, thus creating a space for co-creating knowledge with their teachers (Calabrese-Barton & Tan, 2010). Equitable science education positions students not only as knowledge producers but also as users of scientific knowledge (Calabrese-Barton & Osbourne, 2001).

Creating science classrooms with equity in mind is challenging, even for experienced teachers (Carlone et al., 2011). Ensuring the participation of all students requires a shift from normative teacher-centered curricula to a more equitable space for students' sensemaking and the sharing of scientific ideas (Carlone et al.). This shifting of authority takes practice to cultivate in a classroom community and can feel chaotic to beginning teachers (Carlone et al.). Practicing equitable discourse should be a

cornerstone of the mastery experiences afforded to novices so that they have the tools to enact equitable practices in their science lessons (Haverly et al., 2020).

An additional challenge to creating equitable spaces for students (especially historically underserved students concerning race, ethnicity, and language) in elementary contexts is the central role that elementary schools play in the cultural reproduction of white heteronormative gender roles that are valued within the teacher workforce (Zembal-Saul et al., 2020). In terms of equity, the teaching workforce is predominantly white and monolingual. Eighty percent of teachers identify as white and non-Hispanic, and in schools where most students are not white, most teachers tend to identify as white (Spiegelman, 2020). As a result of this cultural reproduction, elementary teachers are often valued for their compliance, nurturing personalities, and hesitance to go against established norms. What is seen as ordinary school discourse is based on white middle-class values, and this can be against the assets and values that students bring into the classroom (Zembal-Saul et al.).

This context adds additional challenges for teachers who are seeking to establish teaching practices that are more inclusive and expansive, creating spaces for students' knowledge to be showcased and valued against what is traditionally thought of as exemplary in elementary classrooms. Critically evaluating what makes a "good" teacher or what "good teaching" looks like in an elementary classroom can be incorporated into teacher preparation experiences where pre-service teachers should have the opportunities to build upon their practices as efficacious, equitable science educators.

Current Research and Opportunities

Turning the focus to teacher preparation, a recent synthesis of empirical work with pre-service elementary science teachers concludes that they come into the profession

with varying degrees of readiness to teach science (Haverly & Davis, 2022). Pre-service elementary teachers typically have low self-efficacy related to science teaching. Self-efficacy is a well-established theoretical concept that refers to an individual's belief that they can perform specific actions leading toward desired outcomes (Bandura, 1995). As a result of having low science self-efficacy, some pre-service elementary teachers report feeling more confident about all other aspects of teaching outside of science education (Haverly & Davis).

Despite these well-documented deficit orientations, pre-service elementary teachers bring certain assets to science teaching. These assets often include productive dispositions that may help to compensate for weaker science content knowledge, strong inquisitiveness, the capability to learn through teaching, and a willingness to use novel instructional approaches despite having weaker subject matter content knowledge (Haverly & Davis, 2022) Leveraging these assets in teacher education experiences is necessary to support the confidence and attitudes of pre-service elementary teachers before they enter elementary classrooms.

These findings also highlight an opportunity for further research. Haverly and Davis (2022) point out that although we know pre-service elementary teachers share varying degrees of readiness regarding their preparation for science teaching, there is limited research on their experiences in teacher education programs that support their development as equitable science educators. There are a few studies that show that when given opportunities, pre-service elementary teachers can skillfully respond to student sense-making (Haverly et al., 2020), and they can expertly leverage culturally responsive teaching strategies (Mensah et al., 2018; Yoon & Martin, 2019). Less research has been

published considering teacher preparation experiences' role in supporting pre-service elementary teachers' conceptual understanding of the nature of equitable science instruction and how to plan and enact equitable science lessons within elementary teacher education experiences. Two contexts within teacher preparation programs that could support equitable science education are science methods courses and field placement experiences.

Science Method Courses

Science method courses that focus on the pedagogy of science education have a positive association with increasing pre-service elementary teachers' self-efficacy related to teaching science (Bleicher, 2007**;** Bleicher & Lindgren, 2002; Cantrell et al., 2003; Jarrett, 1999; Settlage, 2000). Less is understood about the association between these course experiences and pre-service elementary teachers' self-efficacy related to equitable science instruction. Cone (2009) compared a university science methods course to a community-based service-learning experience using the Self-Efficacy Beliefs About Equitable Science Teaching (SEBEST) instrument (Ritter et al., 2001). Cone used a pre-post research design with thirty-two pre-service elementary teachers. Half of the pre-service elementary teachers took a science methods course at the university, and half participated in a community service-based course. The community-based service course had a positive association with the pre-service elementary teachers' self-efficacy related to equitable science teaching, and this impact was statistically significant. Given the small sample size of this study, there are opportunities to expand this work with more participants and across programs.

Field Placements

There has also been some empirical research about the diversity of field placements (in terms of school-level percentages of racial/ethnic demographics in students) and the association of these experiences with pre-service elementary teachers' awareness and preparedness to teach science to all students. Settlage et al. (2009) examined diverse field placements and the association of these placements with pre-service teachers' self-efficacy for teaching science to diverse students. Settlage et al. found no direct effects of diverse field placements on pre-service teachers' understanding of equity in science education. This research had a small cohort of pre-service elementary teachers (twenty-four participants) and only considered the racial demographics of elementary students as an indicator of diversity. The limited definition of diversity in Settlage et al. 's work presents an opportunity to expand the parameters of how pre-service elementary teachers think about equitable science teaching. For example, what about equitable science instruction for students from economically disadvantaged backgrounds, students who are English language learners, or males and females? How might these demographic domains influence elementary teaching candidates' views of equitable science instruction?

The changing demographics of classrooms in the United States make it critical that teachers help create connections between their students' racial, cultural, and linguistic experiences and the science curricula (Brown, 2017; U.S. Census Bureau, 2020). To connect with students, science educators need to be focused on creating meaningful lessons that promote science learning for all students. Support for these practices should be provided to novice teachers through their teacher education program experiences.

Previous research has concluded that pre-service elementary teachers come into the profession with varying degrees of readiness to teach science, but less is known about how they are being prepared to conceptualize and enact equitable science practices (Cone, 2009; Haverly & Davis, 2022; Settlage et al., 2009). Thus, an opportunity exists for a comprehensive exploration of elementary teaching candidates' beliefs regarding their self-efficacy related to equitable science teaching.

Purpose

This work aimed to understand how pre-service elementary teachers conceptualized equitable science teaching across five teacher education programs. A convergent mixed methods design was utilized in which qualitative and quantitative data were collected in parallel, analyzed separately, and then merged (Creswell & Plano-Clark, 2018). This integrated approach provided novel insights into how pre-service elementary candidates envisioned equitable science teaching. The following research questions guided this work:

Research Questions

1. How do pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science change over their field placement and science method coursework experiences?

2A. What are the associations between pre-service elementary teachers' program coursework (which includes both science content courses and courses on diversity, equity, and inclusion) and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science?

2B. What are the associations between field placement characteristics (which included % SES, % ELL, and % historically marginalized students and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science?

3. How do pre-service elementary teachers conceptualize equitable science education?

The subsequent chapter will outline the conceptual and theoretical frameworks that scaffolded this study. Building off these models, an extensive literature review will focus on self-efficacy concerning science teaching and cultural frameworks in science education. This next section motivates the need for this scholarly endeavor and anchors the research to empirical scholarship in science education.

CHAPTER 2: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Conceptual Frameworks

This work is conceptually structured around two theoretical models. The initial framework, as depicted in Figure 1, offers a comprehensive perspective on this study, representing the qualitative aspect of this project. Conversely, the subsequent framework, illustrated in Figure 2, delineates the quantitative analysis, focusing on Bandura's (1995) self-efficacy theory.

In developing the comprehensive conceptual model (Figure 1), this study integrates Bandura's self-efficacy theory (1995) to support conceptualizing equitable science education among pre-service elementary teachers. Furthermore, the significance of cultural awareness in science education is underscored through the lens of multicultural education (Atwater, 1993; Banks, 2013) and culturally sustaining pedagogy (Paris & Alim, 2014). Equity awareness shapes pre-service teachers' perceptions of equitable science instruction (Kolonich et al., 2018; Milner, 2010). Additionally, Critical Whiteness (Mathias & Boucher, 2023) examines the positionality of predominantly white[ii] pre-service elementary teachers, emphasizing the importance of deep reflexive work in their approach to equitable science education. The constructs of science self-efficacy, cultural awareness, equity awareness, and Critical Whiteness constitute the theoretical underpinnings of this study's exploration into pre-service elementary teachers' conceptualization of equitable science instruction.

Figure 2 delineates the conceptual framework employed for the quantitative analysis within this study, focusing on Bandura's theory of self-efficacy (1995). This framework posits that teacher education program coursework experiences influence the outcome variables of personal self-efficacy and outcome expectancy in courses explicitly addressing diversity, equity, and inclusion. Furthermore, the model incorporates predictor variables related to the demographics of school-level field placement experiences, including the proportion of historically under-served students, English Language Learner (ELL) students, students from low socio-economic statuses (SES), and the percentage of female students. Additionally, the self-reported race of pre-service elementary teachers serves as a predictive factor within the conceptualization of self-efficacy as it pertains to equitable instruction.

The following section will enumerate these conceptual models, starting with the quantitative framing using self-efficacy regarding equitable science instruction (Figure 2). I will then apply self-efficacy to the overall conceptual framework (Figure 1) and explain the multiple components of this model. This chapter culminates with a literature review of self-efficacy related to supporting pre-service elementary teachers in science education and cultural pedagogies that support pre-service elementary teachers in science education.

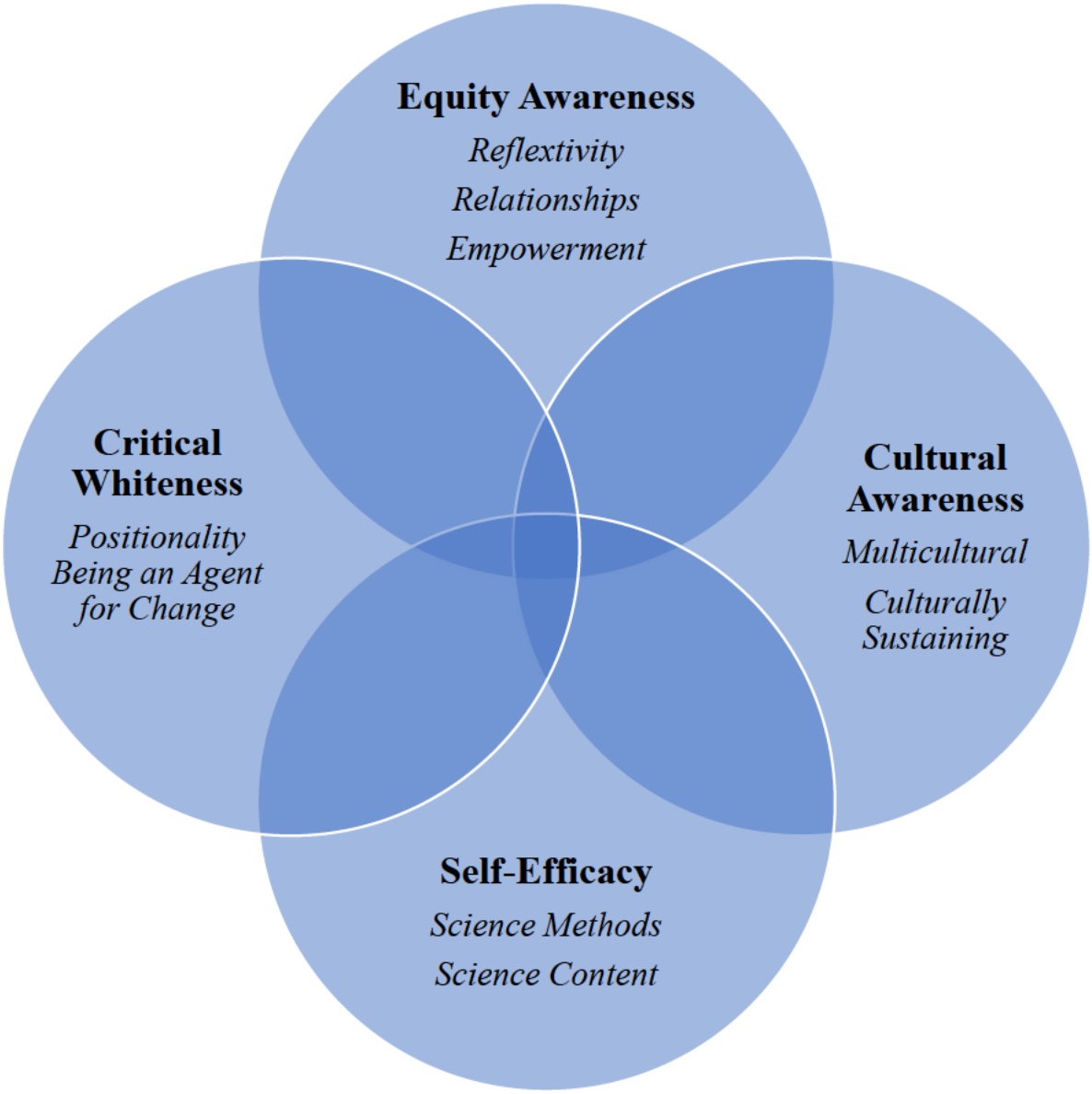


Figure 1. Pre-Service Elementary Teachers' Conceptualization of Equitable Science Comprehensive Conceptual Framework

Note. Self-efficacy includes personal self-efficacy and outcome expectancy(Bandura, 1995). Cultural awareness incorporates multicultural education (Atwater, 1993; Banks, 2013) and culturally sustaining pedagogy (Paris and Alim, 2014). Equity awareness incorporates Milner's (2010) work with pre-service teachers and highlights the importance of relationships and empowerment adapted from Kolonich et al.,2018. Critical Whiteness is framed within the work of Mathias and Boucher (2023). It highlights teachers' positionalities and roles within classrooms. These components support equitable science instruction with pre-service elementary teachers in elementary settings.

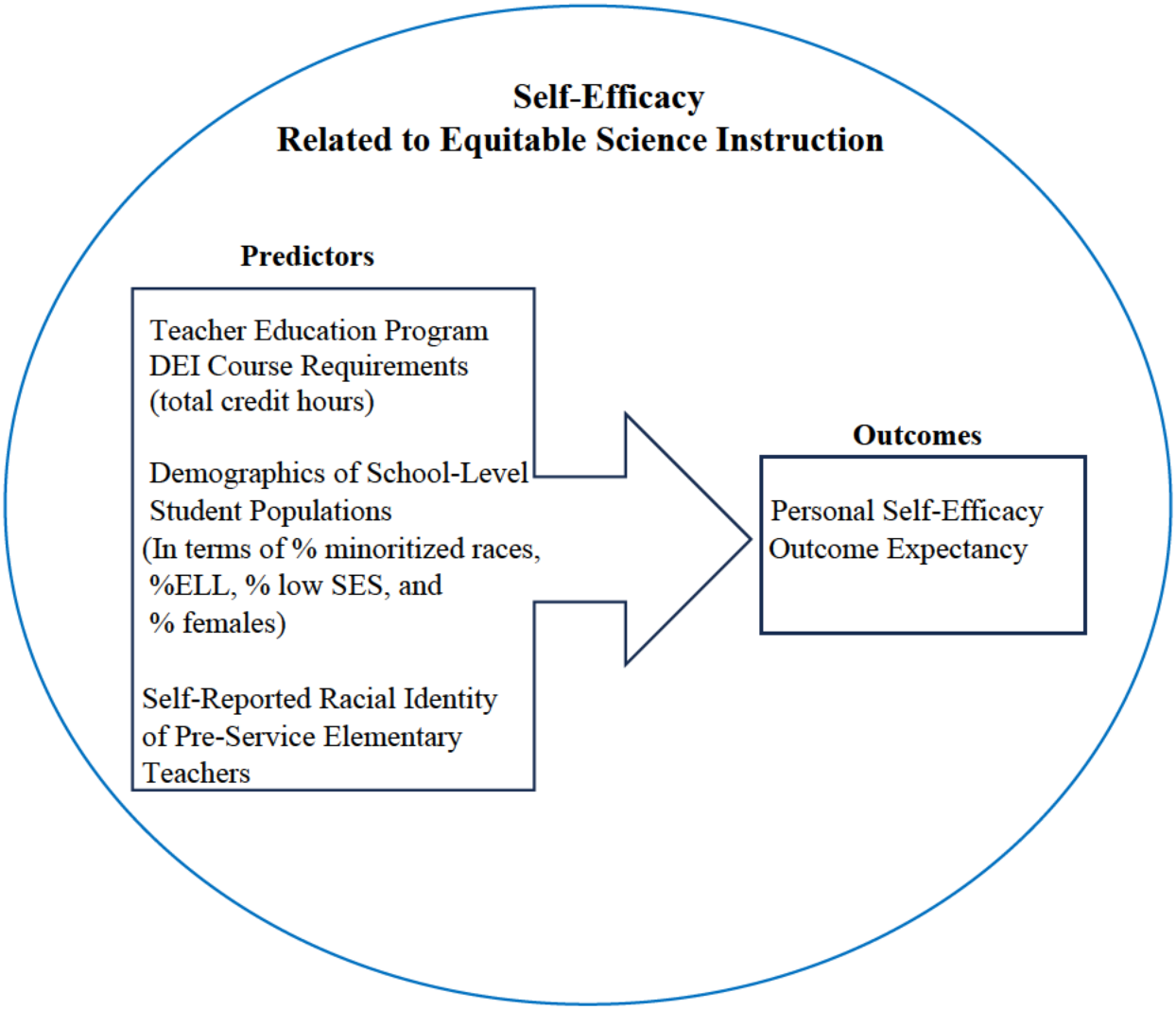


Figure 2. Self-Efficacy Related to Equitable Science Instruction.

Self-Efficacy

If pre-service elementary teachers feel confident in their work, they will report higher levels of self-efficacy. Self-efficacy is a well-established theoretical concept that refers to an individual's beliefs that their actions will lead toward desired outcomes (Bandura, 1995). Self-efficacy is an influential construct for many disciplines, including education, because it suggests that beliefs tend to change while individuals interact with the environment in which they function (Bandura, 1982). This section begins with an

overview of self-efficacy as a theoretical construct. Since I apply many of Bandura's (1995) concepts to both conceptual models (Figures 1 and 2), I will provide an extensive overview of the theoretical construct here and then highlight the application of self-efficacy theory for the quantitative portion of this work (Figure 2), and the application to the comprehensive conceptual framework (Figure 1), separately.

Overview of Self-Efficacy as a Theoretical Construct

According to Bandura (1995), self-efficacy consists of two distinct dimensions: personal self-efficacy and outcome expectancy. Personal self-efficacy is an individual's ability to organize and execute actions to achieve desired goals. Outcome expectancy, on the other hand, is an individual's estimate that certain behaviors will produce anticipated results. Bandura (1986) stated that individuals can believe that a course of action will produce specific outcomes (personal self-efficacy). However, they may not act on this outcome belief if they question whether their behaviors will yield anticipated results (outcome expectancy).

Outcome expectancy and personal efficacy are essential components of educational research; when applied to pre-service elementary teachers, they can help scholars understand how they develop self-efficacy concerning teaching science (Gibson & Dembo, 1984). In teacher education research, outcome expectancy is a teacher's belief that they can attain educational goals or outcomes for their students. A high outcome expectancy indicates that the teacher strongly believes that effective science instruction could generally overcome factors compromising student learning and that they have the skills to reach educational goals for their students. In contrast, personal efficacy describes the strength of a teacher's conviction in their abilities to influence student learning.

Personal efficacy describes the teacher's beliefs that they have had adequate experiences that will help them engage students in science learning. In another example, some teachers believe teaching can powerfully affect student learning (outcome expectancy). However, they lack personal self-efficacy about their teaching and do not think they can make an impact (personal self-efficacy). Teachers with high levels of personal efficacy "expend great effort to reach goals, will persist longer in the face of adversity, and rebound from temporary setbacks'' (Cantrell et al., 2003, p. 177). Both outcome expectancy and personal efficacy are used in educational research to help support the development of science self-efficacy with pre-service elementary teachers.

Self-efficacy is a powerful predictor of performance. Originating from Bandura's (1977) social cognitive theory, self-efficacy influences behaviors and environments, and, in return, self-efficacy is also affected by behavior and environments (Bandura, 1986; 1995). Students who feel more efficacious about learning will be more apt to self-regulate their goals and create learning environments that support engagement. Bandura linked self-efficacy to motivation, achievement, education, and self-regulation. Individuals with solid self-efficacy concerning a particular task will likely persistently try to succeed. However, those with low self-efficacy will likely give up after minimal effort (Palmer, 2006). Applied to education settings, if pre-service elementary teachers feel more self-efficacious about teaching science, this is likely to predict their classroom performance.

Sources of Self-Efficacy

Self-efficacy develops from four sources: mastery experiences, vicarious experiences, verbal persuasion, and physiological stress or emotion (Bandura, 1995). Mastery experiences represent a person's experiences of being successful in the past and

can increase one's self-confidence moving forward. Experiences that increase pre-service elementary science teachers' self-efficacy include the teacher's practicum and student teaching experiences (Bautista, 2011; Cantrell et al., 2003; Gunning & Mensah, 2011; Palmer, 2006), reflective writing activities (Brand & Wilkins, 2007), engagement in inquiry-based science, classroom discussions (Gunning & Mensah, 2011; Jarrett, 1999; Mulholland & Wallace, 2001; Soprano & Yang, 2013), and collaborative lesson planning (Brand & Wilkins, 2007; Mulholland & Wallace, 2001; Rice & Roychoudhury, 2003). When pre-service elementary science teachers have successful experiences, this should increase their science teaching self-efficacy. The experiences interpreted as failures are likely to lower their self-efficacy.

Another source of self-efficacy comes from vicarious experiences. During vicarious experiences, students do not experience a given phenomenon first firsthand; instead, they experience it vicariously by watching others in similar situations succeed. Vicarious experiences allow students to observe and interact with a model and compare themselves to that model. People often seek models with qualities they admire and the capabilities they aspire to. Examples of vicarious experiences for pre-service elementary science teachers include observing other teachers or watching videos of teachers using effective teaching models (Bautista, 2011; Gunning & Mensah, 2011).

Verbal persuasion is another source of self-efficacy. It specifically refers to the impact of positive feedback on individuals as they are recognized for an outcome. Effective persuaders cultivate people's beliefs in their capabilities while at the same time ensuring that the envisioned success is attainable (Schunk & Pajares, 2009). Examples of verbal persuasion for pre-service elementary science teaching candidates include positive

feedback from instructors, peers, school supervisors, mentor teachers, and family (Bautista, 2011).

Physiological stress or emotion is the fourth source of self-efficacy (Bandura, 1995). This refers to one's state of mind during an event or experience. If stress or emotion is overwhelming, this can lead to a decrease in self-efficacy and can negatively impact personal outcomes. One way to increase self-efficacy is to improve emotional and physical well-being and reduce physiological stress (Schunk & Pajares, 2009). For pre-service elementary science teachers, the ability to navigate challenging situations in a classroom, including the management of inquiry lessons, can affect their competency concerning teaching science (Bautista, 2011; Gunning & Mensah, 2011).

Bandura argued that mastery experiences are most effective in increasing self-efficacy, but other studies have found that vicarious experiences can also have a powerful influence on pre-service elementary teachers' self-efficacy beliefs (Bautista, 2011; Mulholand & Wallace, 2001; Palmer, 2006; Settlage, 2000; Yoon et al., 2006). Yoon et al. (2006) found that vicariously watching exemplary videos of effective science instruction allowed pre-service elementary teaching candidates to establish meaningful connections, and these connections increased their self-efficacy concerning teaching science. Vicarious experiences, such as participating in discussions about teaching, were also found to be essential sources of science teaching self-efficacy (Bautista, 2011; Settlage, 2000).

Palmer (2006) proposed three additional sources of science self-efficacy: cognitive pedagogical mastery, cognitive content mastery, and simulated modeling. Cognitive pedagogical mastery outlines the importance of understanding effective

teaching methods and strategies. Pre-service elementary teaching candidates would develop this efficacy through their elementary science methodology coursework and classroom teaching experiences (practicums or field placements).

Cognitive content mastery outlines the importance of science content in science learning experiences. Specific examples include content coursework, exams, or other demonstrations of science content knowledge (performance tasks or summative science projects). For example, pre-service elementary science teachers can gain content experiences during their teacher education programs, through specific science content courses, or during their schooling experiences outside of teacher education.

Simulated modeling highlights the importance of role-playing. It allows pre-service elementary teachers to experience science learning through the lens of an elementary student. For example, to model what a lesson might feel like in the classroom, pre-service elementary candidates might teach a science lesson for elementary students to a class of peers. This type of role-playing increases confidence and self-efficacy concerning teaching science (Palmer, 2006).

Palmer (2006) argued that teaching candidates gain confidence directly from success in understanding content and pedagogy, which makes them distinctive mastery experiences. Simulated modeling, on the other hand, would be a vicarious experience. Palmer concluded that cognitive pedagogical mastery and cognitive self-modeling (imagining oneself teaching) were the two most common sources of science self-efficacy for pre-service elementary teachers. Table 1 summarizes sources that promote self-efficacy for pre-service elementary science teachers.

Table 1

Experiences that Promote Science Self-Efficacy with Preservice Elementary Science Teachers

Types of experiences	Description of experiences	Examples of experiences
Mastery (Bandura, 1995)	Provide students with an activity that can measure the level of competency regarding a particular skill.	Practicum, discussions, reflections, inquiry-based experiences, collaborative lesson planning
Vicarious (Bandura, 1995)	Provide students with an opportunity to observe and interact with a model and compare themselves to a model.	Observing a teacher, watching a video of a classroom teacher, videotaping their teaching (self-modeling), or imagining themselves teaching science
Verbal persuasion (Bandura, 1997)	Feedback (positive or negative) that affects one's confidence	Positive feedback from instructors, peers, supervisors, mentors, and family
Physiological reactions (Bandura, 1997)	Responses to experiences and stress (positive or negative)	The physical and emotional reactions to teaching activities
Cognitive content mastery (Palmer, 2006)	Understand the content of science	Content exams, demonstrations of knowledge
Cognitive pedagogical mastery (Palmer, 2006)	Opportunities to demonstrate how to teach science	Classroom teaching experiences
Simulated modeling (Palmer, 2006)	Role play in a simulated environment	Teaching a science lesson for elementary students to a class of peers

Summary

In summary, self-efficacy refers to an individual's confidence in performing specific actions to produce desired outcomes (Bandura, 1995). There are two components of self-efficacy: personal self-efficacy and outcome expectancy. Personal self-efficacy measures one's confidence in teaching a subject or doing a task. Outcome expectancy is whether one believes their actions will lead to desired outcomes, such as increasing students' enthusiasm for science. According to Bandura, there are four sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and exposure to physiological stress. Mastery and vicarious experiences provide opportunities for the most significant gains to increase self-efficacy (Bandura, 1995; Mulholland & Wallace, 2001; Palmer, 2006; Settlage, 2000). Mastery experiences for pre-service elementary science teachers include science content coursework, coursework in science pedagogy, and practicum or field placement experiences (Palmer, 2006).

Application of Self-Efficacy to Conceptual Framework Figure 2

Pre-service elementary teachers' self-efficacy development is influenced by various experiences, among which mastery experiences are particularly significant (Bandura, 1995). This study conceptualizes the engagement in explicit Diversity, Equity, and Inclusion (DEI) courses within teacher education programs as a mastery experience expected to enhance personal self-efficacy and outcome expectancy related to equitable science instruction. Furthermore, the demographics of students in field placement settings, characterized by percentages of historically underserved populations, English Language Learners (ELL), students from low socio-economic statuses (SES), and female students, are considered another avenue of mastery experience because these settings

offer pre-service elementary teachers direct opportunities to interact with diverse student populations and enact equitable science curricula through their field placement settings.

Additionally, this study posits that the race of pre-service elementary teachers and their self-awareness concerning their racial identity in their role as equitable science educators predicts changes in personal self-efficacy and outcome expectancy. The acknowledgment of systemic oppression and the introspective confrontation with one's racial positioning within a system that may perpetuate racism are viewed as potentially emotionally taxing experiences. The physiological responses elicited by racial cognizance are considered influential factors in pre-service elementary teachers' self-efficacy and outcome expectancy toward equitable science instruction.

Application of Self-Efficacy to Conceptual Framework Figure 1

For my comprehensive conceptual framework, I am using the context of the science methods course and pre-service elementary teachers' teacher education program experiences (including science content coursework) as mastery experiences that can increase their self-efficacy related to teaching equitable elementary science. Within these experiences, pre-service elementary teachers might have had other experiences (for example, verbal persuasion, vicarious experiences, and physiological reactions). However, this framework focuses on the mastery experiences embedded within science methods courses and teacher education program experiences, including science content coursework. I envision these experiences directly impacting the enaction of science curricula in elementary spaces. Suppose pre-service elementary teachers do not feel confident in teaching science. In that case, they will center their instruction on reading and math, leaving science as an extra activity. Self-efficacy is critical to supporting pre-

service elementary teachers' science instruction. Thus, it is essential to incorporate self-efficacy within the larger conceptual model of how pre-service elementary teachers think about equitable science instruction.

Cultural Awareness

Another critical component of equitable science instruction is cultural awareness. I use cultural awareness to frame science education as a cultural construct (Atwater, 1993; Atwater & Riley, 1993; Banks, 2013) and to highlight the importance of sustaining and including multiple epistemologies, languages, cultures, sexes, ethnicities, and races in the study of science (Paris & Alim, 2014). This next section will highlight elements of multicultural education (Atwater, 1993; Atwater & Riley, 1993; Banks, 2013) that I think are critical to incorporate with culturally sustaining pedagogy (Paris & Alim, 2014) to create a cultural awareness that supports equitable science instruction. I begin with re-framing science education from realism towards a social constructivist view of science, including the idea that science education should support multiple epistemologies (Aikenhead, 2006; Bang & Medin, 2010; Emdin, 2010). Extending from this plurality of experience, I highlight culturally sustaining pedagogy as an asset-based framework that pre-service elementary teachers should consider when conceptualizing equitable science practices.

Social Constructivism and Multiple Epistemologies

In social constructivism, multiple realities exist in the social construction of knowledge. There is no one realism, as knowledge is created through the culmination of numerous realities and from various perspectives. Science epistemology, in contrast, is embedded within realism (Atwater, 1996). This promotes a discord between societies'

Eurocentric values of realism counting as scientific knowledge and multicultural educators' goal to encourage multiple realities as scientific truth (Mensah, 2022). As a result, students from diverse backgrounds, based on their race, ethnicity, language, economic status, or gender, may have cultural knowledge bases or life experiences that conflict with Western epistemologies. This divergence in what is considered accurate and valuable in science knowledge makes these diverse students feel alienated or othered in science curricula (Moje et al., 2004).

To combat this, Atwater (1996) proposed critically evaluating science teachers' and students' roles and interactions in learning. Whose knowledge is being positioned as the authority in the interaction, and how can we center students' understandings? Applying social constructivism, students do not need their teachers to be the authority in science; instead, teachers should serve as coordinators, facilitators, and resources for science education. This shift in roles is an essential cornerstone for equitable science instruction.

Building from social constructivism, it is crucial to incorporate multiple epistemologies into cultural awareness. Aikenhead (2006) recommended using students' cultural and linguistic backgrounds to ease the border crossing between the dominant cultural practices of mainstream schooling and those practiced at home. This allows science teachers to continue teaching the Eurocentric canons of science knowledge while incorporating students' linguistic and cultural wealth. Viewing students' cultural and linguistic backgrounds as assets for instruction is essential for pre-service teachers to build cultural awareness. For example, Emdin (2010) incorporates a reality framework into science curricula and uses hip-hop and rap to incorporate urban students' "life

worlds" into science. He argues that this should be done not to breach culture but to reconnect students to science and school. Celebrating multiple life experiences, languages, and cultures in science instruction helps to promote the incorporation of numerous epistemologies, thus centering students' understanding as the goal of instruction.

Social constructivism and multiple epistemologies are critical components of cultural awareness because they shift the power dynamics of whose authority is centered in the classroom. Realism is still embedded within science, but how one acquires knowledge can come from multiple perspectives, not just white, middle-class "norms "of truth. Accepting this shift in epistemology challenges the dominant narrative of White supremacy in our curricula. It allows teachers to highlight the students in the curriculum instead of positioning the teacher as the center of knowledge.

Culturally Sustaining Pedagogy

Culturally sustaining pedagogy (Paris & Alim, 2014) explicitly supports multilingualism and multiculturalism among students and educators. This pedagogical approach aims to uphold and foster cultural diversity within educational settings, emphasizing the importance of enabling young individuals to preserve their cultural and linguistic identities while also gaining proficiency in navigating the dominant societal culture. Paris (2012) states, "The long struggle against dehumanizing deficit approaches to education, and toward humanizing resource, approaches have never been easy… I offer the term, the stance, and the practice of culturally sustaining pedagogy as a needed step in this struggle" (Paris 2012, p. 96).

Culturally sustaining pedagogy promotes cultural diversity in education and critically addresses the prevailing monocultural and monolingual biases inherent in educational policies. It critically examines privilege and power within educational systems, presenting culture as a fluid and ever-changing entity bridging the gap between past and present community life. This theoretical framework advocates for a progressive, asset-based approach that emphasizes social justice and challenges educational institutions' hegemonic structures, organizational practices, and epistemological assumptions. Engaging with culturally sustaining pedagogy involves a critical praxis whereby pre-service elementary teachers are encouraged to scrutinize educational outcomes, question the underlying purposes of schooling systems, and reflect on their roles within these structures, as Sleeter (2018) highlighted. This approach seeks to transform educational practices and aims to empower educators and students to actively participate in creating more inclusive, equitable, and culturally responsive learning environments.

Summary

Science education is often viewed as objective and devoid of connections to culture, which has implications for science education and equity (Mensah, 2022). The scholars in this theoretical review advocate for students, teachers, and researchers to develop a more critical consciousness of culture in the science classroom. To advocate for students, there is a need for a paradigm shift in epistemology away from realism towards a social constructivist view of knowledge (Atwater, 1996), where multiple epistemologies are heard and respected within the science classroom (Aikenhead, 2006; Bang & Medin, 2010; Emdin, 2010). Paris and Alim (2014) advocate for plurality and

deconstruction of deficit narratives in our education systems. Together, these theoretical frames support a cultural awareness that pre-service elementary teachers need to support equitable science instruction.

Application of Cultural Awareness to Conceptual Framework (Figure 1)

In applying cultural awareness to my framework, I am reminded that children come to classrooms with various cultural schemata that help them understand the world. These schemata reflect their experiences, skills, knowledge, values, beliefs, and ways of thinking developed in their home and community environments. Students' cultures can conflict with the culture of science education, which typically represents a single historically dominant cultural view of the science curriculum while ignoring historically underserved students' range of rich cultural knowledge and experiences (Milner, 2010; Wynter-Hoyte et al., 2019). This often causes the science curriculum to be less accessible and relevant to the lived experiences of children from historically underserved backgrounds.

Cultural awareness allows teachers to validate students' cultures and viewpoints in conceptualizing equitable science practices. These experiences enable students to feel connected to the culture of science. Otherwise, classrooms will frequently remain sites of cultural conflict and feature power imbalances, where children from historically underserved backgrounds will continue to experience gaps in opportunities that negatively affect their learning (Gouvea, 2018; Norman et al., 2001). Cultural awareness helps humanize students' role in science learning and is integral to creating equitable science instruction.

Equity awareness

Equity begins with an understanding that there is no equality in education. Educational disparities in test scores and graduation rates correlate with skin color, ethnicity, and linguistic and social class status. For example, the average white 13-year-old reads higher and performs better in math than the average Black or Latinx 17-year-old (Carter & Welner, 2013). The difference in educational outcomes between groups of students is not due to an "achievement gap"; instead, the disparity in educational experiences highlights an "opportunity gap" that stems from the societal inequities in our communities and institutions. Combating the systemic nature of educational equity is often described as leveling the playing field so that students from various backgrounds are afforded a fair chance to succeed in school and their future lives. In contrast to equality, where all students receive the same treatment, equity ensures access to meaningful and connected learning opportunities by providing appropriate support and resources based on the student's background and access to educational resources (Lee & Buxton, 2010). Historically, science education has privileged students from white, high-income families (Norman et al., 2001), and this has disadvantaged students from historically underserved communities (Lee & Fradd, 1998; Parsons, 2008). These disadvantages continue from early schooling experiences and impact students' success rate in securing science-related careers (National Research Council, 2012).

The following section will frame equity awareness using Milner's (2010) work with pre-service teachers and equitable science instructional approaches proposed by Kolonich et al. (2018). It builds from the foundation outlined in the previous section on

multicultural and culturally sustaining pedagogies. I will begin by reviewing Milner's five diversity issues, including color blindness, cultural conflict, the myth of meritocracy, deficit conceptions, and lowered expectations. To combat these issues, I advocate for reflexivity with pre-service elementary teachers. Next, I will unpack the equitable science approaches highlighted by Kolonich et al., focusing on the need for pre-service elementary teachers to concentrate on building supportive relationships with their students and work to empower them to see science's utility as a lever for change. I will conclude with a summary of these equity practices and apply these practices to my conceptual understanding of equity awareness.

Overview of Diversity Issues

Colorblindness

In his work as a teacher educator, Milner (2010) noticed five areas where his mostly white pre-service teachers struggled with diversity. The first concept that they struggled with was colorblindness. Teachers who profess colorblindness do not consider how racially diverse students experience the world in and outside the classroom. For example, one assertion of colorblindness is that if pre-service teachers acknowledge the racial or ethnic backgrounds of either themselves or the students in their class, then they may be considered racist or politically incorrect. Another assertion is to assume that all people experience the world similarly, regardless of race or ethnicity. One issue with diversity is the propensity not to want to see how race and ethnicity are connected to power and privilege, and this is a task equitable science educators must take on to leverage equitable practices.

Cultural Conflicts

A second issue with diversity involves cultural conflicts (Milner, 2010). Framing science education as a cultural investigation, this issue is apparent in how we teach science. Researchers have found that conflicts or mismatches between primarily white teachers and students of Color can limit students' learning opportunities (Banks, 2001; Ford, 2006; Foster, 1997; Howard, 2001). When teachers operate primarily from their cultural references or the dominant canonical knowledge of science, the content can seem foreign to students of Color, students from lower socioeconomic backgrounds, students whose first language is not English, and students who live or have lived in different regions of the country or world (Milner). These cultural conflicts can negatively affect historically underserved students because there are few points of reference and convergence between students and teachers.

Myth of Meritocracy

Milner (2010) identifies the myth of meritocracy as a significant challenge in addressing diversity issues within education. This myth is manifest when educators attribute student failure exclusively to individual factors such as choice, ability, and effort without recognizing the influence of systemic privileges (McIntosh, 1990) associated with whiteness and socioeconomic status. Instances of this perspective include the erroneous belief that some students inherently lack the aptitude, ability, or skill necessary for academic success, disregarding the role of systemic factors in shaping educational outcomes.

Deficit Conceptions

Deficit conceptions are when teachers frame the experiences of their students as lacking compared to their own experiences (Milner, 2010). Along with the myth of meritocracy, deficit conceptions make it difficult for teachers to develop learning opportunities that challenge culturally diverse students. For example, Milner asserts that teachers feel sorry for their students using a deficit conception. Teachers think that if they expect too much, they are setting their students up for failure instead of framing the students' cultural knowledge as an asset that they bring into the classroom.

Lower Expectations

Stemming from deficit framing, Milner (2010) also points out how teachers lower their expectations of students because they do not recognize students' brilliance, mainly when cultural mismatches exist between them. For example, when teachers feel that they are building self-esteem with "easy" work for their students, they add to the mediocracy myth, highlighting their deficit framing and lowering their expectations of what their students can do. These lowered expectations only hurt students as they reinforce the narrative that historically underserved students are still underserved because of an inherent "lack" on the student's part instead of the schooling system's lack of equitable resources for their education.

Pre-service elementary teachers need to work against being colorblind, having cultural conflicts, the myth of mediocracy, deficit conceptions, and lowering expectations. This requires science educators to consider the social, historical, and institutional contexts that influence learning and access to learning within our schools

(Rodriquez, 1998). According to Rodriquez, reflexivity (becoming aware of one's social location) is a vital part of multicultural science and, I argue, a critical part of equity awareness.

Equitable Science Instructional Approaches

Shifting the focus to students, equitable science instruction should provide opportunities for all children to learn science while widening their pathway to science knowledge and skills (Kolonich et al., 2018; Phillip & Azevedo, 2017). In their framework for equitable science classrooms, Kolonich et al. (2018) highlight the following components: (a) students need to be positioned in classrooms as epistemic agents in the co-construction of science knowledge; (b) students should use their cultural knowledge to understand science; (c) students should be provided with opportunities to use and share multiple languages; (d) the learning environment should values students' lived experiences as evidence; and (e) the learning environment should promote the use of students' critical lens to solve problems. These approaches view children's various backgrounds as assets that can make science curricula accessible, relevant, and meaningful to all. Teachers' instruction should capitalize on children's rich knowledge and lived experiences to build a bridge to connect with science knowledge. These equitable approaches promote the academic success of all children and promote equity in science learning while affirming students' experiences (Gouvea, 2018; Kolonich et al., 2018)

To enact these instructional approaches outlined above (Kolonich et al., 2018), pre-service elementary teachers must build meaningful relationships with their students. Supportive solid relationships between pre-service elementary teachers and students

allow students to feel safe being positioned in classrooms as epistemic agents. When pre-service elementary teachers understand their students' interests and cultures, they can create spaces where students can employ their cultural knowledge to understand science concepts. Centering students' interests, cultures, languages, and ways of understanding starts with pre-service elementary teachers emphasizing the importance of building meaningful relationships with their students and their students' families.

According to Kolonich et al.(2018), equitable science instruction should promote using students' critical lenses to solve problems. I conceptualize pre-service elementary teachers creating this lens by empowering their students through their science knowledge. Connecting students with real-world applications of science in their everyday lives helps them to see the utility of their understanding. This utility allows students to apply their knowledge in novel ways, perhaps even becoming social change agents advocating for their communities through their knowledge of science. By leveraging students' interests and solving real-world community problems, pre-service elementary teachers can create and advocate for equitable classroom science practices.

Summary

I consider Milner's (2010) work with pre-service teachers and the diversity issues when I envision how pre-service elementary teachers conceptualize equitable science instruction. Starting with colorblindness, pre-service elementary teachers should be given opportunities to challenge the dominant narrative that the demographics of race and ethnicity do not matter in terms of educational opportunities. Pre-service elementary teachers should challenge the mediocracy myth, which assumes historically underserved groups do not try hard enough despite the present power and opportunity imbalances.

This myth of mediocracy leads to deficit perspectives and a lowering of expectations for historically underserved populations. Pre-service elementary teachers should practice reflexivity to combat the potential of perpetuating these issues (Rodriquez, 1998). When considering equity awareness, I consider all these parameters in how pre-service elementary teachers conceptualize equitable instruction.

Kolonich et al. (2018) argue that we need to value students' languages, culture, and racial experiences as valuable knowledge in science classrooms. Co-constructing what scientific knowledge is and sharing epistemic authority are vital components of equitable science instruction. I highlight the importance of building strong, supportive relationships as a lever to center students' lived experiences in classrooms. Additionally, Kolonich et al. (2018) support the development of students' critical lens to solve problems with science. Students need to feel empowered to use their science knowledge as agents for change in their communities. I argue that pre-service elementary teachers should think about empowering their students to push past rote memorization to see the utility of their understanding. Building relationships and creating spaces for empowerment are crucial components of the ways pre-service elementary teachers should conceptualize equitable science instruction.

Application of Equity Awareness to Conceptual Framework (Figure 1)

In focusing on racial, gender, language, and socioeconomic inequity in education, I think about how white pre-service teachers commonly lack awareness of themselves as cultural beings (Schmidt, 1999). This creates an assumption that white beliefs and behaviors are the only norms (Valli, 1995). Sleeter (2018) states that if white pre-service teachers see themselves as "normal" but not cultural, they will use their unexamined

frames of reference to judge students, student's families, and their communities. Unsettling this deficit narrative in science education is the first step to creating equitable spaces.

I frame equity awareness as acknowledging that specific historically underserved communities will have fewer resources and access to opportunities than other privileged demographic groups (in terms of race and ethnicity, gender, socioeconomic status, and multiple languages). Within this, pre-service elementary teachers need explicit opportunities to address colorblindness, combat deficit frames, acknowledge the myth of mediocracy, and reflect on lowered expectations (Milner, 2010). One way to address these issues is to practice reflexivity (Rodriguez, 1998), accepting your social position in inequitable systems, and remaining reflective of your presumptions about historically underserved students. Finally, according to Kolonich et al. (2018), equitable science education positions students as problem solvers who are not afraid to challenge the status quo critically with their scientific knowledge. To create spaces to enact this, pre-service elementary teachers should develop respectful relationships with their students and center empowerment and utility as part of the curricula. Considering all these threads, I envision equity awareness as comprising reflexivity, focusing on building relationships, and centering utility and empowerment as agents for change.

Critical Whiteness

The last construct in my comprehensive conceptual framework is Critical Whiteness. According to the National Center for Education Statistics (NCES), in 2020-2021, 80% of all teachers (across elementary and secondary settings) were white. Comparatively, 54% of students in elementary and secondary settings self-identify as a

race other than white (NCES, 2021). The demographic differences between teachers and their students create a polarizing force that implicitly and explicitly impacts what happens in elementary classrooms. For this reason, I apply Critical Whiteness as a lens to my comprehensive conceptual framework.

According to Critical Whiteness (CW), whiteness and white supremacy are the underlying mechanisms that maintain racist systems, and ignoring whiteness contributes to the permanence of race and racism (Allen, 2004; Leonardo, 2009). Critical Whiteness operates from the basis that 1) race, racism, and white supremacy are continuously operating, and 2) the study of whiteness intrinsically enables society to understand better how people of Color are racially oppressed (Matias & Boucher, 2023). According to Matias and Boucher, CW should examine the impact of whiteness on People of Color, as well as the effects of whiteness on people who identify as white. It is the interconnectivity of racial groups under a system of white supremacy that binds our collective liberation. The study of whiteness has shifted from understanding how people of Color suffer whiteness to how whites understand their favor and privilege under it. To dismantle white supremacy, we must also understand how whites, too, are racialized under a white supremacist system.

Whiteness can be operationalized in a variety of ways, and in a white supremacist society, many of the privileges that white people have are invisible, unearned, and not consciously acknowledged (Picower,2009). It is as if whites are passively handed advantages in an ‘invisible knapsack’ (McIntosh, 1990). Without deep attention to white supremacy and privilege, white teachers might unknowingly or knowingly participate in this mystified system of invisible benefits and ultimately work to maintain it (Picower).

To disrupt the hegemonic power of whiteness, white people must challenge the norms of whiteness and dig deep into their white histories to understand the issues around white privilege that need to be disrupted. Pre-service teachers might have a deep sense of emotional turmoil and guilt once confronted with the inadvertent consequences of their privilege (Matias et al., 2014). This becomes problematic because equity work must move beyond guilt (Matias, 2014) to a place where whites understand their positionality and actively confront and combat how privilege disenfranchises some groups while promoting others.

In Matias's (2023) work with pre-service teachers, she employs direct instruction about emotional intelligence in her pedagogical strategies to prepare her mostly white-identifying teacher candidates to take racial responsibility for their whiteness. Through this work, the pre-service teachers were able to translate their identity from a position of being white saviors to becoming and embracing racial social justice through advocacy. Once you recognize and notice your positionality within the white supremacy system, you can work to dismantle the systemic racial injustices that create racialized barriers and work to center the experiences of people of Color. According to Matias, until we are willing to break down whiteness, there is no real hope for racial justice and anti-racism.

Summary of Critical Whiteness

Given the recent national trends in Diversity, Equity, and Inclusion (DEI) movements in higher education and the perpetuation of colorblind rhetoric, the need for research about how best to prepare a predominantly white teaching force to educate an increasingly diverse student population is salient and urgent. We must move beyond "performative wokeness" (Marshall & Wilson, 2023) to a place where white teachers can

critically examine their positionalities and feel empowered to de-center their own experiences and center the lives and experiences of people of Color. Critical Whiteness names white supremacy in our racialized systems and calls attention to the interaction between whiteness and the dehumanization of people of Color (Matias & Boucher, 2023). It acknowledges that if racism is a nuanced, complex, and entrenched ideology, then we must work with all people, especially white people who are privileged within the system, to dismantle systemic oppression and re-center the stories of people of Color (Matias, 2014).

Application of Critical Whiteness to Conceptual Framework (Figure1)

The racial imbalances between teachers and their students highlight the racialized and systemic differences between pre-service teachers and their students. To counteract this, pre-service elementary teachers must consider their positionalities within elementary classroom spaces before they can genuinely enact equitable science instruction. This work moves beyond reflexivity and calls for pre-service elementary teachers to evaluate the effects of white supremacy. To do this work, we must critically examine the privileges perpetuating this racial imbalance and provide pre-service teachers the emotional awareness to de-center their experiences and re-center the lived experiences of their students of Color (Matias, 2014). Using a Critical Whiteness lens, I think that pre-service elementary teachers should be conceptualizing their own visible and invisible privileges in classroom spaces because of white supremacy. By confronting our positionalities, we can better understand how people of Color are racially oppressed (Matias & Boucher, 2023) and become social advocates for justice movements. Once we see race, we cannot un-see race. We must move beyond recognition to a place where we

can be empowered to change. Critical Whiteness provides an essential lens for pre-service elementary teachers to consider racial inequities in their classroom spaces. I envision this as integral to how pre-service teachers conceptualize equitable spaces.

Connecting Theories to Conceptual Frameworks

Self-efficacy measures how confident one feels about doing something (Bandura, 1995). Research shows that when teachers feel efficacious during their pre-service education experiences, this translates into their classroom experiences (Tschannen-Moran et al., 1998). Suppose pre-service elementary teachers can increase their self-efficacy related to equitable science instruction through various experiences in their teacher education programs. In that case, these experiences should translate into the enactment of equitable instruction once they are in-service teachers. For this reason, self-efficacy is an essential theoretical framework for both the quantitative portion of this work (Figure 2) and the qualitative portion (Figure 1).

Cultural awareness stems from multicultural science education (Banks, 1995) and culturally sustaining pedagogy (Paris & Alim, 2012) in that it frames knowledge as co-constructed. Challenging whose epistemic authority is valued in practice is the first step to becoming equitable educators. Realizing that science is embedded within a cultural context allows pre-service elementary teachers to see the human side of the discipline and challenge their cultural identity. Advocating for a plurality of experience and working to sustain cultural knowledge is an essential lens to the way pre-service elementary teachers conceptualize equitable science instruction.

Equity awareness attempts to address the opportunity gaps that are prevalent within historically underserved communities (including minoritized students concerning

race/ethnicity, gender, socioeconomic status, and language). To promote equity, pre-service elementary educators and science methods instructors need to address issues of diversity (Milner, 2010) through reflexivity (Rodriquez, 1998) and apply equitable science instructional practices (Kolonich et al., 2018) in their classrooms. Centering the importance of supportive relationships and empowering students through the utility of their science knowledge leverages equitable practices within students' brilliance. These tools, reflexivity, relationships, and empowerment, are crucial components of my comprehensive conceptual framework.

Critical Whiteness challenges hegemonic structures by de-centering whiteness and focusing on the counter-narratives of people of color (Matias, 2014). By providing white pre-service teachers the emotional intelligence to question their white privilege, we can empower them to become change agents and advocates for people of Color. I highlight Critical Whiteness in my comprehensive conceptual framework to frame the interconnectivity of racialized experiences through the structure of white supremacy. We cannot create equitable spaces without critically acknowledging privileges afforded to some and not others based on the color of our skin. I apply a lens of Critical Whiteness to interrogate the privileges that whiteness brings. I envision pre-service elementary teachers grappling with their positionalities to conceptualize equitable science instruction.

These components collaboratively contribute to a depiction of how pre-service elementary educators conceptualize equitable science instruction. While they function as independent yet intersecting constructs, each lens offers a distinct contribution, with thematic commonalities interwoven throughout. Consequently, it is posited that these

constructs synergistically intersect to facilitate how pre-service elementary teachers imagine themselves cultivating equitable educational environments for their students.

Literature Review

This literature review will examine the empirical research underpinning the development of teaching self-efficacy among pre-service elementary teaching candidates. It will specifically review studies investigating self-efficacy related to science learning developing within the context of science methods courses and as a result of broader teacher education program experiences. Subsequently, the review will concentrate on empirical investigations that underscore the conceptualization of science education as a cultural construct. This delineation will motivate the impetus for the present scholarly work**.**

Developing Science Self-Efficacy with Pre-Service Elementary Candidates

According to Palmer (2006), cognitive content mastery and cognitive pedagogical mastery are distinct mastery experiences that affect science self-efficacy. Two examples of these experiences include science methods courses and prac field placements. These experiences can increase science self-efficacy for preservice elementary science teachers and become tangible indicators of their capabilities in the classroom (Schunk & Parjares, 2009). I will review the empirical research that examines the experiences of pre-service elementary science teachers in science methods courses and field placements.

Science Methods Coursework

Science methods coursework is an example of a cognitive pedagogical mastery experience (Palmer, 2006). Courses that focus on the pedagogy of science education generally positively impact pre-service elementary teachers' self-efficacy related to teaching science (Bleicher, 2007**;** Bleicher & Lindgren, 2002; Cantrell et al., 2003; Jarrett, 1999; Settlage, 2000). Jarrett (1999) studied a field-based elementary science teaching methods course and concluded that interest, self-efficacy, and confidence in teaching science increased after participation in science methods coursework. Settlage (2000) measured self-efficacy related to teaching science with pre-service elementary candidates using new instructional approaches before and after participation in a methods course. He found that both personal efficacy and outcome expectancy increased significantly in part because of the course. Cantrell et al. (2003) found that preparing and teaching science lessons as a modeled practice during a methodology course was an important component that helped increase pre-service elementary teachers' self-efficacy. Bleicher and Lindgren (2002) examined the association between success in learning science in a methods course and the development of self-efficacy. Results indicated a positive association between science concepts taught in the methods course and science self-efficacy. Bleicher (2007) reported significant increases in science conceptual understanding, personal efficacy, and outcome expectancy after participation in a science methods course. This research supports a strong connection between science methods coursework and pre-service elementary teachers' self-efficacy related to teaching science.

Teacher Education Program Experiences

Teacher education program experiences, including field placements, are examples of cognitive pedagogical mastery experiences (Palmer, 2006). Research on teacher education program experiences, including field placements, has produced mixed results (Cantrell et al., 2003; Ginns et al., 1995; Wingfield et al., 2000). Two longitudinal studies examined teacher education programs and self-efficacy and reported conflicting outcomes (Cantrell et al., 2003; Ginns et al., 1995). Ginns et al. (1995) measured science self-efficacy among pre-service elementary candidates over three semesters of a teacher preparatory program (which included science content coursework and science methodology coursework). They found significant increases in outcome expectancy but not personal science self-efficacy. This suggests that the teachers believed that teaching could have a powerful effect on student learning, but they felt a lack of personal self-efficacy concerning students. Cantrell et al. (2003) studied a three-semester-long teacher education program that combined science methodology, content, and field placement experiences. Interestingly, Cantrell et al. came to an opposite conclusion to that of Ginns et al.; no significant differences were observed in outcome expectancy beliefs, but self-efficacy scores in personal science teaching increased significantly. Webb and Ashton (1986) suggested that efficacy might change throughout a teacher education program, increasing when experiences are successful and decreasing when experiences are viewed as unsuccessful. The conflicting results from Ginns et al. (1995) and Cantrell et al. (2003) might reflect these cycles of efficacious experiences.

Research on field placements has also produced mixed results (Cantrell et al., 2003; Wingfield et al., 2000). Wingfield et al. (2000) measured the impact of field placements on pre-service elementary teachers' self-efficacy concerning teaching science

at the end of their first year of teaching. Participants reported higher levels of teaching confidence and maintained higher levels of science self-efficacy at the end of their first year of teaching partly because of their intense field placement experiences, including a solid mentoring component. Additional verbal persuasion, a source for efficacy (Bandura, 1995), from mentors who work with student teachers possibly added to the success of the field placements. Cantrell et al. (2003) found that pre-service teachers who were in field placements the longest had a decrease in their self-efficacy. This could be due to physiological stress from the workplace, a negative source of efficacy, according to Bandura (1995). Cantrell et al.'s study also lacked mentoring support from the teacher education program during the extended field placement, which could have compounded the loss of science efficacy among the pre-service candidates. Self-efficacy is a situation-specific construct, and the context for developing efficacy matters (Bandura, 1995). The mixed results of these studies highlight the need for scholars to examine the effect of teacher education program experiences (including field placements) and the impact that these experiences have on developing efficacious elementary science teachers.

Summary of Empirical Research Regarding Science Self-Efficacy

Palmer (2006) stated that pre-service elementary teachers become efficacious in teaching science through cognitive content and cognitive pedagogy mastery experiences. Courses in science teaching methods can positively impact pre-service elementary teachers' science self-efficacy (Bleicher, 2007; Bleicher & Lindgren, 2002; Cantrell et al., 2003; Jarrett, 1999; Settlage, 2000). Research about the experiences of pre-service elementary teachers in teacher education programs, including field placements, has led to conflicting results about the effects of these experiences on the development of self-

efficacy for teaching science (Cantrell et al., 2003; Ginns et al., 1995; Wingfield et al., 2000). When teachers have low science self-efficacy, they typically dislike teaching science and, in the worst case, try to avoid teaching it (Koballa & Crawley, 1985). The best way to support science self-efficacy among pre-service elementary teachers is to include science methods courses and productive field placement experiences within teacher education programs.

Synthesis of Current Empirical Findings Using Science as a Cultural Construct

Incorporating multicultural science education into teacher education programs provides unique opportunities for researchers to grapple with the discord between canonical and cultural knowledge. Respecting students' cultural wealth while maintaining science epistemology in the classroom can be tricky, even for experienced educators. In this next section, I will broadly discuss empirical work with multicultural education within teacher education coursework, field experiences for pre-service teachers, and community science events. Narrowing the focus, I will discuss the empirical research on field experiences with pre-service elementary science teachers, multicultural science education with pre-service elementary teachers, and equitable science education with early childhood pre-service teachers.

Empirical Research in Teacher Education Programs

Coursework

Pre-service teachers learn about multicultural education in their coursework and field placements (Gorski,2009). Including multicultural education courses in teacher preparation coursework often positively affects pre-service teachers' development of culturally responsive teaching practices (Daniel, 2016; Morales, 2000; Whitaker &

Valtierra, 2018). Morales (2000) studied multicultural knowledge growth among 23 university students in an early childhood education course on cultural diversity. Results showed that students learned about cultural diversity and acquired confidence in teaching culturally and linguistically diverse students. Whitaker and Valtierra (2018) examined how a teacher preparation program changed 22 pre-service teachers' motivation to teach culturally and linguistically diverse learners. Teaching candidates demonstrated statistically significant gains in their self-confidence related to teaching diverse learners in part because of their experiences in courses. Daniel (2016) conducted an in-depth case study of 16 pre-service candidates during their field placements and teacher preparation courses. Students demonstrated overall gains in conceptual understanding of culturally responsive pedagogy but had difficulty enacting these practices in the field. These case studies indicate the potential for pre-service teachers to acquire knowledge and confidence with concerningly responsive teaching. Daniel (2016) also highlights the difficulty of enacting these pedagogies in field placements without the support of strong mentors from the teacher education program.

Other studies have shown that limited exposure to multicultural coursework within teacher education programs can affect how pre-service teachers conceptualize personal diversity beliefs. Many teacher education programs do not provide opportunities for teaching candidates to learn about multicultural, culturally relevant, or culturally responsive education as a central focus (Villegas & Lucas, 2002). In programs that do address these topics, many offer only a single course within their total program (Gorski, 2009). Akiba (2011) surveyed 234 pre-service teachers to study the relationship between opportunities to take courses focused on diversity and changes in their beliefs about

diversity. Controlling individual background characteristics, the study examined the possible effects of teacher preparation coursework for diversity and pre-service teachers' beliefs about diversity in personal and professional contexts. The analysis showed that beliefs about diversity in personal contexts (specifically personal beliefs about interracial marriage, immigration, and stereotypical ideas about minoritized groups) did not change as a result of taking one diversity course or field experiences. In contrast, pre-service teachers' diversity belief scores in professional contexts did improve. For pre-service teachers to enact multicultural education, they need exposure to these topics across their teacher education programs instead of only focusing on them in one course (Daniel, 2016; Gorski, 2009).

Field Placements

Studies that have examined the effects of field experiences in diverse schools or communities on pre-service teachers' multicultural awareness and beliefs have produced mixed results (Daniel, 2016; Jacobs et al., 2015; Mason, 1999; Ramirez et al., 2016; Settlage et al., 2009). Some studies reported that field experiences in diverse settings helped teaching candidates develop positive attitudes about diversity or feel prepared to work with diverse students (Jacobs et al., 2015; Mason, 1999), while others did not find such impacts (Daniel, 2016; Settlage, 2009). The inconsistent findings could reflect differences in mentor support from participating schools during the field experiences.

Positive experiences have been reported when cooperating teachers support pre-service teachers in field placements. Mason (1999) identified the critical roles that cooperating teachers perform in supporting pre-service teachers in their field experiences. This result is consistent with Daniel (2016), who noted that positive mentor relationships supported pre-service teachers in their field placements. Jacobs et al. (2015) suggest that

fieldwork in urban schools can be sites of ‘unlearning’ and ‘relearning’ what it means to be a teacher of diverse students. In their study, several teacher candidates began their fieldwork with deficit-oriented perspectives of urban contexts but finished their field experiences reflecting on the possibilities of urban teaching. This understanding was developed through strong coaching and mentorship with cooperating teachers in the urban context. Strong mentorship and guidance in field placements from the teacher education program or cooperating teachers can positively affect the extent to which pre-service teachers feel confident using culturally responsive pedagogy and multicultural education.

Other studies have shown that lacking support can lead to negative field experiences for pre-service teachers. Settlage et al. (2009) examined the effects of diverse field placements on pre-service teachers’ self-efficacy concerning teaching science to diverse students. He reported no direct impact of the diverse field placements on teacher candidates’ understanding of culturally responsive pedagogy or multicultural education. Placing pre-service teachers in diverse settings without guidance and strong mentorship from cooperating teachers or mentors within teacher education programs did not increase their confidence in enacting multicultural education. Daniel (2016) reported similar results where candidates could not enact practices emphasized in multicultural coursework because of a lack of support. These studies highlight the need for solid mentoring from cooperating teachers or teacher education programs in field placements to help teachers enact multicultural education.

Community Science Events

Community science events can also help pre-service teachers learn to incorporate culturally relevant mathematics and science activities for their students (Ramirez et al., 2016). Ramirez et al. (2016) held family Math/Science Learning events as part of their required course activities; they were designed to inform pre-service teachers of the importance of interacting with Latinx families and affirming their culture in after-school settings. The researchers partnered with cooperating schools to support pre-service teachers during these events. The authors reported that several pre-service teachers changed their perceptions of Latinx parents through these events as they identified and reconstructed misconceptions and perceptions of family roles. Ramirez et al.'s findings support the strong community and mentoring connections in other field work and community studies (Daniel, 2016; Jacobs et al., 2015; Mason, 1999).

Empirical Research on Pre-Service Science Teachers

Research on how science educators prepare pre-service teachers to implement multicultural science education is a field with many research opportunities. This empirical review will examine studies using culturally responsive and relevant teaching. These are connected to multicultural science education since they emphasize culture within science education. Pre-service elementary and middle school science teachers reported gains in self-confidence concerning using multicultural science education after completing mathematics and science methodology coursework that emphasized these practices. Aguirre et al. (2012) studied a cohort of elementary and middle school pre-service teachers in their science and mathematics courses, including targeted interventions designed to cultivate cultural responsiveness. The pre-service teachers reported greater confidence in implementing culturally responsive teaching. Mark and Id-

Deen (2022) investigated how pre-service teachers planned implementing culturally relevant pedagogy in middle and secondary mathematics and science. Using action research, they examined the effect of science methods coursework designed to integrate culturally conscious pedagogy to disrupt historical power dynamics in science education. They concluded that teachers could enact culturally responsive practices when they emphasized cultural consciousness at the beginning of their lesson planning. These studies demonstrate that embedding culturally responsive pedagogy within science and math method coursework can help candidates develop confidence in enacting these practices in science and mathematics.

Narrowing the focus to just pre-service elementary teaching candidates, Mensah (2011) investigated the experiences of three elementary pre-service teachers in co-planning and co-teaching a science unit in 4th and 5th grade. The findings suggest that fostering collaborations and partnerships are valuable approaches to preparing teachers for diverse classroom settings (Ladson-Billings, 1995). Opportunities to model and practice culturally responsive teaching in field placements were key to candidates incorporating culturally responsive practices. Pre-service teachers could enact culturally relevant science in their planning, instruction, assessment, and reflections on teaching. Mensah reported that the three candidates increased their use of culturally relevant practices because of the solid mentoring relationship with the researcher in the school setting.

In another case study, Mensah (2022) explored the development of multicultural curricula by three pre-service elementary teachers in their science methodology course. The pre-service teachers were encouraged to focus on multicultural integration (i.e., the

social action approach from Bank's (2013) four tiers of multicultural education. The pre-service teachers in her study needed opportunities to experience and see science differently before attempting to integrate multicultural education practices. Their initial deficit perspectives about science impacted how they thought they could teach. Offering opportunities for candidates to experience science differently in methodology coursework empowered them to teach science in a new way. The science methodology courses seemed to impact how pre-service teachers viewed the importance of science education for themselves and their students. Mensah concluded that to develop a multicultural science curriculum, epistemological changes in how one teaches and learns science must be addressed (Atwater, 1996; Rodriguez, 1998). Once the pre-service teachers felt efficacious regarding the science content, they successfully created lessons incorporating all four multicultural education tiers (Banks, 2013). Mensah's research highlights the importance of incorporating multicultural education within science methodology coursework experiences to help candidates develop efficacy concerning science and multicultural education.

Empirical Research with Equity and Pre-service Early Childhood Teachers

Lee et al.(2022) completed a qualitative study examining how early childhood pre-service teachers conceptualized equity in science education. Using an open-ended survey to collect qualitative data, they received responses from 380 pre-service early childhood teachers enrolled in a teacher education program in Texas. Data were collected during a science methods course. Thematic analysis revealed that participants' conceptions about equity in science education included viewing equity as equality and providing appropriate access and support based on children's needs. Colorblindness was

pervasive in participants' responses. Most participants also believed that equity in science education was related to children's English proficiency. Although participants were knowledgeable about how to support English language learners, many were not confident in their ability to teach science to English language learners due to the students' insufficient English proficiency and their hesitancy to learn students' languages. One limitation of this work is that participants came from one teacher education program, and there is no discussion of validity to support qualitative data.

Summary of Empirical Research Centering Equity and Culture for Pre-Service Teachers.

When pre-service teachers complete coursework focused on multicultural science education, they gain confidence in using this method in their classrooms (Daniel, 2016; Morales, 2000; Whitaker & Valtierra, 2018). Teacher education programs should incorporate this training to help teachers understand what it means to be a multicultural educator (Akiba, 2011; Daniel, 2016; Gorski, 2009). Field placements and community events are also sites where pre-service teachers can learn to enact theory into practice. For field placements to have a positive effect, pre-service teachers need support from cooperating teachers and mentors (Daniel, 2016; Jacobs et al., 2015; Mason, 1999; Settlage, 2009).

Research supports incorporating multicultural science education (including culturally responsive and culturally relevant education) within science methods coursework for pre-service science educators (Aguirre et al., 2012; Mark & Id-Deen, 2022; Mensah, 2011; 2022). Mark and Id-Deen (2022) found that emphasizing cultural consciousness at the beginning of lesson planning was an effective strategy to help pre-

service teachers enact culturally responsive pedagogy. Mensah (2011) found that small action research partnerships with cooperating schools helped pre-service elementary teachers enact culturally relevant practices within their 4th and 5th-grade science classes. To feel confident about enacting multicultural education, teachers need positive experiences with science methods coursework (Mensah, 2022). When pre-service elementary teachers are supported, they can typically construct lessons for diverse students using all four tiers of Bank's (2013) multicultural typology.

Smaller quantitative and mixed methods studies have examined the impacts of science methods coursework and diverse field placements on pre-service elementary teachers' equitable science instruction (Cone, 2009; Settlage et al.,2009). These studies highlight potential small changes in pre-service elementary teachers' conceptualization of equitable science instruction associated with these experiences. Other qualitative studies (Lee et al., 2022) have examined large samples but with early childhood pre-service teachers, not elementary teachers. There are plenty of opportunities for expansion examining equity in science education.

Opportunities for Research

This literature review has highlighted scholarly research on science self-efficacy, multicultural science education, and conceptualizations of equity among pre-service elementary teachers. For pre-service elementary teachers to feel confident in teaching science to diverse students, they need opportunities to become efficacious and interwoven into teacher education programs. Research shows that incorporating science methods courses and providing opportunities for mastery and vicarious experiences through field placements increases pre-service teachers' science self-efficacy (Bleicher, 2007; Bleicher

& Lindgren, 2002; Cantrell et al., 2003; Jarrett, 1999; Settlage, 2000). Research also supports addressing multicultural science education with pre-service elementary science teachers so that they can learn to enact this vital pedagogy (Mensah, 2011; 2022).

Self-efficacy is an essential concept because efficacious science educators are likely to have a lasting interest in science, a desire to help students, and a willingness to improve science education (Bandura, 1997; Ramey-Gassert et al., 1996; Tschannen-Moran & Woolfolk Hoy, 2007). Bandura (1997) stated that science teaching efficacy "is of particular concern, given the increasing importance of scientific literacy and competency in the technological transformations occurring in society" (p. 242). Pre-service elementary science teachers need to develop personal self-efficacy and outcome expectancy to be successful in the classroom. Teacher education programs that provide mastery experiences, vicarious experiences, positive verbal persuasion, and limit physiological stress (Bandura, 1995) should be most successful in cultivating efficacious educators. According to Palmer (2006), cognitive content mastery and pedological mastery experiences should increase science self-efficacy with pre-service teachers. The empirical scholarship demonstrates that experiences in elementary science methods courses and opportunities to practice teaching in field and practicum placements all support the development of science self-efficacy among pre-service elementary teachers.

Plenty of research areas within this field are open for scholarly inquiry. For example, we need to expand what we know about the effect of field experiences on self-efficacy development. The conflicting research on the impact of field and practicum placements (Cantrell et al., 2003; Ginns et al., 1995; Wingfield et al., 2000) provides an opportunity for additional research to understand further how these mastery experiences

influence the development of science teaching self-efficacy. Also, little empirical work has been done across teacher education program experiences, specifically within science methods courses and teacher field experiences, to see how differences among programs might impact pre-service elementary teachers' science self-efficacy. This study, in part, seeks to fill this research opportunity gap.

There is also a need for research on how equity can be incorporated into teacher education programs for pre-service elementary science teachers. In terms of enacting equitable science instruction, there are a few examples of researchers examining equity with pre-service elementary teachers (Cone,2009; Lee et al., 2022; Settlage et al., 2009), but expansion with sample size and across programs would add knowledge to this research base. Additionally, studies have not applied a convergent mixed methods design to ask how pre-service teachers conceptualize equity in science education through surveys and in-depth interviews. This methodology would allow for a more comprehensive analysis of equitable practices through the lens of pre-service elementary science teachers.

Currently, minimal empirical work supports effective multicultural science practices with pre-service elementary science teachers within their science method coursework (Mensah, 2011; 2022; Mensah et al., 2018). More research could be done to support efficacious science teachers using the science methods course as a context. Specifically, research that incorporates the conceptualization of equity from the viewpoint of the science methods course instructors would add valuable insight into supporting pre-service elementary teachers in their development as equitable science educators.

In terms of field experiences, there is a need to investigate the demographics of field placements (in terms of racial and ethnic demographics, percentage of ELs, percentage of low-SES students) and how this might be associated with pre-service elementary teachers' self-efficacy related to teaching equitable science across different programs and schools; this would contribute to what we already understand about the importance of field placements for pre-service elementary teachers.

This work seeks to expand upon the prior scholarship in this field through a cross-case, convergent mixed-method design that examines pre-service elementary teachers' teacher education coursework and field placement experiences and the association of these experiences with their self-efficacy related to equitable science teaching. Utilizing a comprehensive approach through mixed methods will allow a holistic understanding of how to support pre-service elementary teachers in their work. The following section will delineate the methodology used to investigate this work.

CHAPTER 3: METHODOLOGY

The subsequent chapter presents a detailed examination of the convergent mixed methodology used to answer the research questions posited in Chapter 1. Following an overview of the research design, Figures 3 and 4 will illuminate the procedural steps executed for the analysis of data and the integration of findings. After that, the contextual backdrop and participants' demographics will be elucidated. An in-depth analysis of the quantitative methodology will highlight the characteristics of the SEBEST survey, as validated by Ritter et al. (2001), that was employed in the data collection process. This analysis will cover the survey's validity, the data collection strategies, and the analytical methods applied. Next, this chapter continues to the qualitative methodology, articulating the qualitative sampling strategies, interview protocols, data analysis techniques, and validity and reliability considerations. Conclusively, the final section will articulate the methodologies' synthesis and discuss the potential threats to validity inherent in the convergent mixed method design.

Methods

Research Design

The application of convergent mixed-method research has been instrumental in exploring pre-service teachers' self-efficacy concerning various instruction.

For instance, Tankiz and Uslu (2022) employed a convergent mixed methods approach to examine pre-service teachers' self-efficacy in teaching computational thinking. This inquiry utilized a quasi-experimental framework with pretest-posttest evaluations to generate quantitative data alongside thematic analysis to extract qualitative insights. The integration of these methodologies culminated in the discussion segment, offering a holistic understanding of pre-service teachers' self-efficacy in imparting computational skills. Similarly, Unal et al. (2017) employed a convergent mixed methods design to investigate the relationship between pre-service elementary teachers' self-efficacy in technology integration and their participation in a course designed to augment such integration capabilities. Given the precedence of research using this methodology to examine self-efficacy related to teaching, convergent mixed methods are appropriate for a comprehensive examination of pre-service elementary teachers' self-efficacy related to equitable science instruction.

This study employed a parallel convergent mixed methods design, consisting of qualitative and quantitative data collected and analyzed separately. Integration of methodologies in the concluding chapter of this work provides a comprehensive understanding of pre-service elementary teachers' conceptualization of equitable science teaching (Creswell & Plano Clark, 2018). There were four significant phases in the research design. First, quantitative and qualitative data were collected concurrently but kept separate for analysis. The quantitative data did not inform the qualitative data, and vice-versa. Data was separated to address distinct research questions that were not integrated. Second, data analysis occurred separately and independently from each other using quantitative (Chapter 4) and qualitative (Chapter 5) analytic procedures. Data was

merged in the final phase (Chapter 6), with a joint display followed by a discussion regarding the congruent or discrepant nature of the two types of results and the broader implications of this work. The rationale for this approach is to bring together the strengths and weaknesses of quantitative and qualitative methods and, in this study, to illustrate quantitative results with qualitative findings (Creswell & Plano Clark, 2018). Figures 3 and 4 are procedural diagrams that anchor the methods to the research questions and outline the procedures and products for each methodology component.

Figure 3: Procedural Diagram Research Questions and Data Collection

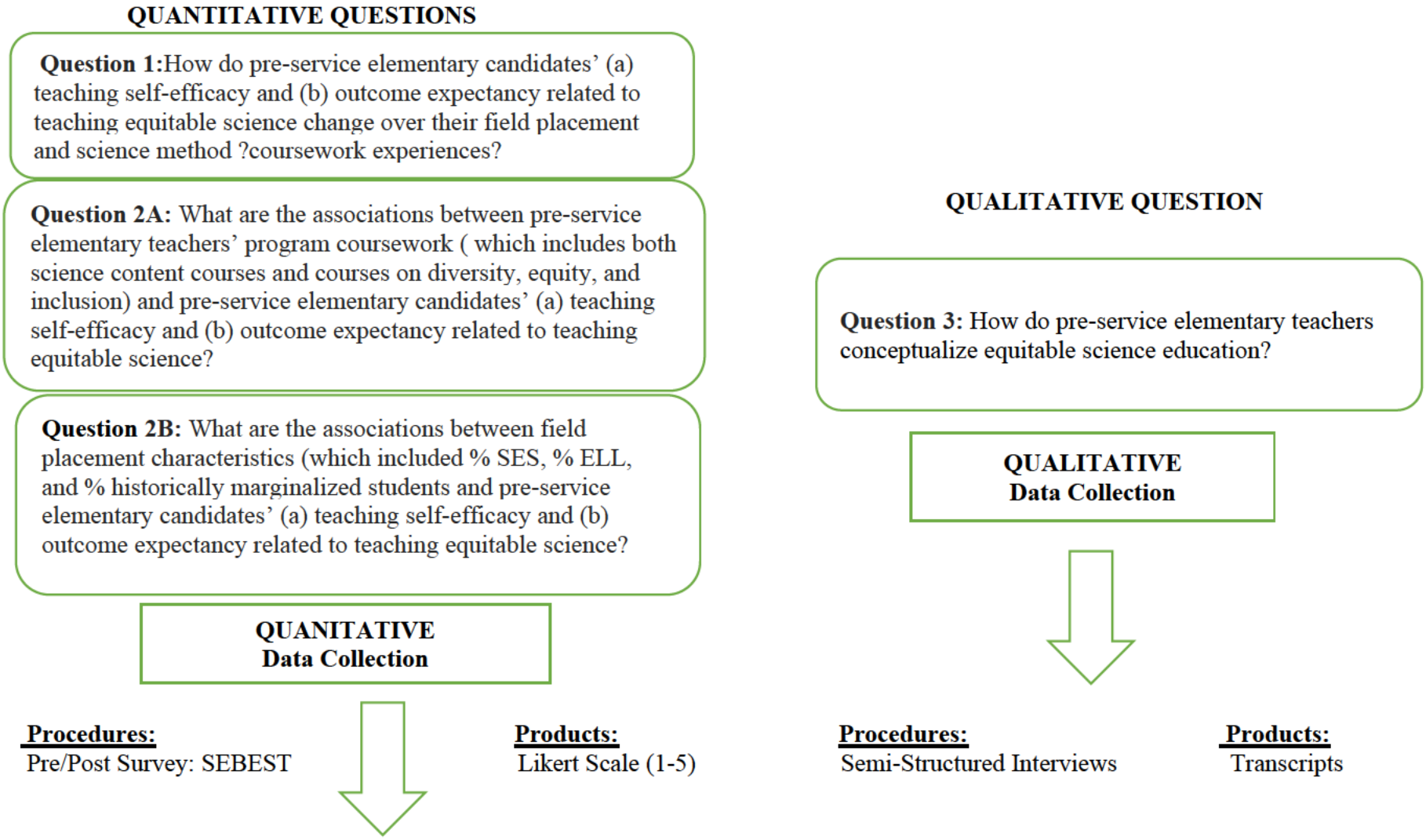
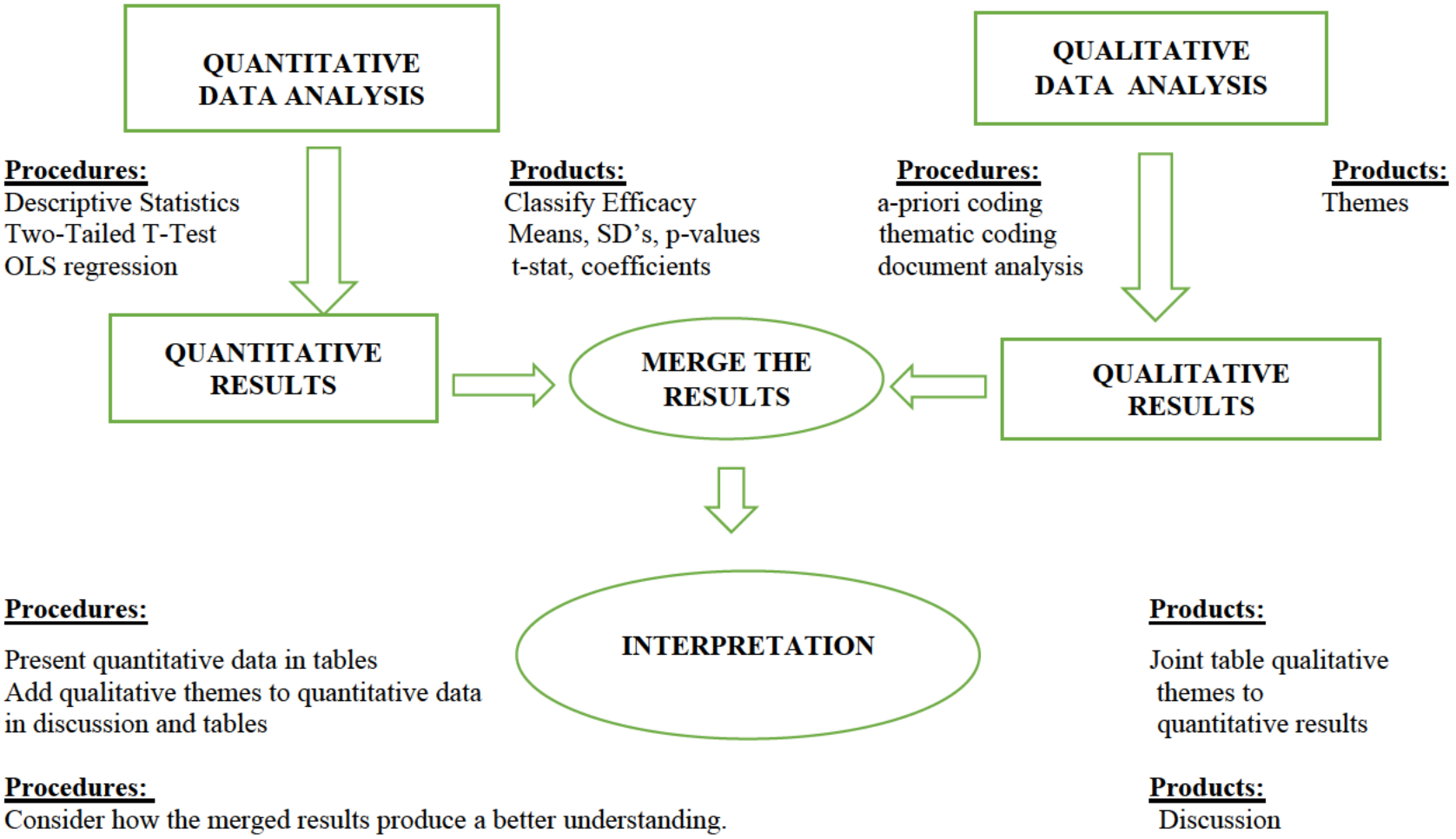


Figure 4: Data Analysis and Integration



Context and Participants

Participants were recruited in the summer of 2022. Initially, thirty-six different teacher education programs at higher education institutions were contacted in a Mid-Atlantic state to illicit participation. Five science methods course instructors and their institutions were incorporated into this work from these thirty-six. Program information from each participating institution, including the type of program (undergraduate, graduate, or both) and the number of participants from each institution, is included in Table 2. Three out of five institutions had graduate and undergraduate elementary education degrees. Pseudonyms are used to protect the institutions' identity. Additional demographic information from these institutions and the pre-service teaching candidates attending teacher education programs within these institutions can be found in Chapter 4.

Table 2 *Teacher Education Program Information*

Institution	Type of Program	# of participants
Oak	Undergraduate	13
	Graduate	8
Locust	Undergraduate	9
	Graduate	7
Sassafras	Undergraduate	44
Maple	Undergraduate	7
	Graduate	4
Hickory	Undergraduate	4

Participant demographic data are presented in Table 3 below. Ninety-seven participants completed the pre- and post-survey across the five institutions. Most of the participants were White (87%), female (91%), and from undergraduate programs (66%). The average age of pre-service elementary teachers was 21.4 years old.

Table 3: *Pre-Service Elementary Participant Demographics*

Characteristics	n	%
Gender		
Male	3	3
Female	88	91
Non-Binary	4	4
Not Listed	1	1
Race		
white	82	85
Black	9	10
Asian	7	7
Latinx	3	3
Multiracial	1	1
Program		
Undergraduate	64	66
Graduate	26	28

Note. N=97. Participants were, on average, 21.4 years old.

Quantitative Methods

Research questions one and two needed to be answered quantitatively. The first research question asked: How do pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science change over their field placement and science method coursework experiences? The second question contained two parts. First: What are the associations between pre-service elementary teachers' program coursework (which includes both science content courses and courses on diversity, equity, and inclusion) and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science? Second: What are the associations between field placement characteristics (which included % SES, % ELL, and % historically marginalized students and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science? This next section will discuss the survey used in this work, including the validity and reliability of the instrument. It continues with a discussion of the data collection processes for each question. In conclusion, this section will delineate the analytic process to address the quantitative research questions.

Survey

The Self-Efficacy Beliefs About Equitable Science Teaching (SEBEST) survey, developed by Ritter et al. (2001), originated from Bandura's seminal contributions to self-efficacy theory (1977, 1986) as well as the foundational work of Ashton and Webb (1986), which established a link between teachers' self-efficacy beliefs and their classroom behaviors. Survey development was inspired by the Science Teaching Efficacy Belief Instrument (STEBI) formulated by Riggs (1988) and the subsequent adaptation for

prospective teachers, the Science Teaching Efficacy Belief Instrument for Prospective Teachers (STEBI-B) by Enochs and Riggs (1990)

The SEBEST, as articulated by Ritter et al. (2001), evaluates both personal self-efficacy and outcome expectancy in delivering equitable science education to students of diverse demographic backgrounds, encompassing variations in race and ethnicity, gender, socio-economic status, and English language proficiency. The instrument delineates eight subscale scores to encapsulate these dimensions. Responses to the survey items are captured on a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), facilitating quantifying participants' beliefs and outcome expectations.

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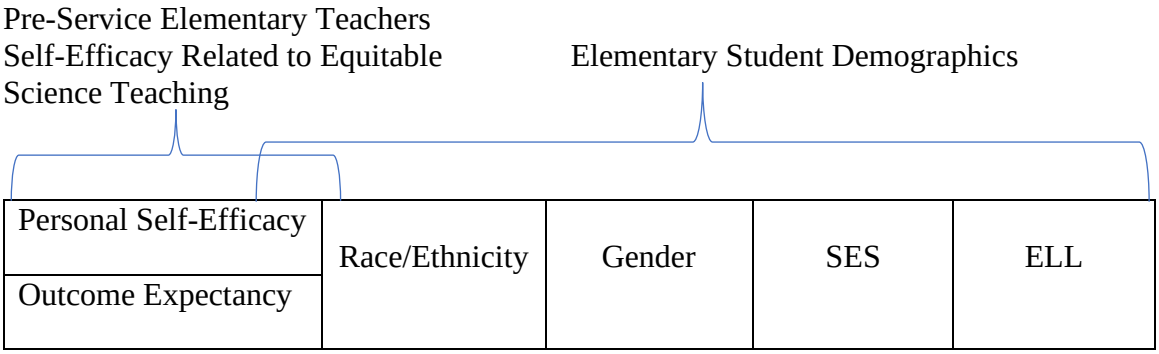
Figure 5 presents the content matrix for the SEBEST survey (Ritter et al.), providing an organizational framework for the survey items, detailed in Appendix A.

Figure 5: Content Matrix SEBEST (Ritter et al. 2001)



Validity of SEBEST instrument

The SEBEST was validated following a seven-step procedure. As part of the validation process, a panel of graduate students in science education at Pennsylvania State University reviewed the initial pool of nearly 200 items (Ritter et al., 2001). Out of 200, 80 surviving items were critiqued for content validity by eight faculty members from inside and outside Pennsylvania State University specializing in science education, multicultural education, and self-efficacy. The resulting 48 items were compiled into an instrument administered to 226 preservice elementary teachers as a "first draft" of the instrument. Factor analyses refined the survey to 34 items administered to another group of over two hundred pre-service elementary teachers.

Reliability of SEBEST instrument

The reliability of the published SEBEST survey was 0.87, with subscale reliability of 0.83 for personal self-efficacy and 0.78 for outcome expectancies, respectively. Remmers, Gage, and Rummel (1965) support a reliability coefficient of .80 or higher for school use and .70 or higher for research instruments. The reliability coefficient of .87 on the 34-item SEBEST and .83 and .78 on the subscales are also interpreted within the acceptable reliability range for a research instrument.

To ensure the instrument's validity, all of the items on the SEBEST survey were kept the same for this work. Content validity for this specific research was ensured by discussing the 34 items with two science education colleagues from the Ph.D. program in Curriculum and Instruction at the University of Virginia. I added demographic questions to the original survey (e.g., age, race, gender), and I asked two open-ended questions about working with diverse students and types of teaching experiences. I also solicited interviews and asked students to provide an email address if they were interested in participating further in individual interviews after the survey. The following section will discuss data collection techniques.

Data Collection

The administration of the Self-Efficacy Beliefs About Equitable Science Teaching (SEBEST) survey via the Qualtrics© platform was executed in the summer of 2022, with subsequent data collection phases occurring in the fall of 2022 and the spring of 2023. The researcher personally visited the respective institutions for four teacher education programs to distribute the surveys during science methods courses, appearing at the semester's commencement and conclusion. These visits were solely for survey distribution; no observational data were recorded during these sessions. To recruit participants, the researcher introduced herself and provided a succinct overview of their dissertation project to the prospective participants. Instructors of the science methods courses facilitated the distribution process by providing the pre-service elementary teachers with a QR code to access the survey, allocating approximately fifteen minutes of class time for its completion. To incentivize participation, stickers crafted by a local

artist, valued at roughly $2.50 each, were distributed and made available to all pre-service elementary teachers, irrespective of their participation in the survey.

In the spring of 2023, for the fifth teacher education program, the science methods course instructor was furnished with a web link to the survey, which they then disseminated among their students. Data collection mirrored the previous semesters, with sessions scheduled at the beginning and end of the semester. As a means of encouragement, participating pre-service elementary teachers were offered a $10 gift card, with the option of choosing between Amazon and Starbucks. Unlike the previous approach, only those who participated in the survey could receive this incentive.

Question 2A: Teacher Education Program Coursework Experiences

Inquiries were made to collect data on teacher education coursework experiences through institutional websites or by contacting program coordinators to compare coursework experiences across contexts. Additionally, science methods course instructors shared their syllabi for document analysis. Information was gained from program coordinators or science methods course instructors for the total number of pre-service teaching candidates within each teacher education program. Chapter 4 contains data tables outlining the results of this data collection.

Question 2B: Field Placement Demographics

For each participating pre-service elementary teacher, requests were made to the teacher education programs to furnish details about the schools where these individuals were placed for their field experiences. Upon acquiring all pertinent school-level information, the researcher utilized the Mid-Atlantic state's educational website to collate demographic data related to the schools identified. This data included school-level

demographic information about the racial and ethnic composition of the student body, the percentage of students eligible for free and reduced lunch (as an indicator of socio-economic status), the percentage of students classified as English language learners, and the percentage of females and males. This demographic data was meticulously documented within an Excel spreadsheet. After collecting this information, all personally identifying details concerning the participants and their field placement schools were expunged from the dataset to uphold confidentiality measures. Data tables demonstrating field placement demographics are in Chapter 4.

Data Analysis

Question 1: Descriptive Statistics

The analytical process commenced with the requisite reverse coding of all Likert items on the Self-Efficacy Beliefs About Equitable Science Teaching (SEBEST) survey. Within the Qualtrics© platform, modifications were made to reassign the value of items initially coded as strongly agree from a nominal value of 1 to the more conventional Likert scale value of 5. Additional adjustments with the coding of limited survey items were necessitated by the original design of the SEBEST items, which were deliberately reverse-coded to moderate the pace at which participants completed the survey.

After re-coding, pre and post-survey responses were extracted from Qualtrics© and systematically compiled into a singular Excel© spreadsheet, amalgamating responses from all five science methods courses into a unified dataset. This process ensured the alignment of participant responses between the pre-survey and post-survey phases. Initially, 101 surveys were gathered as a pre-measurement, with 103 collected for the

post-measurement phase. Upon consolidation, 97 survey responses were identified as having pre- and post-measurements and were used in this work.

Following the collation of responses, the dataset was imported into STATA© for further analysis. Within STATA ©, subscale responses were averaged, and the dataset was subjected to a t-test comparing post-survey scores against pre-survey scores to generate descriptive statistics. This analysis employed a two-tailed t-test methodology, as Babbie (2013) recommended, to rigorously compare the scores from pre- and post-survey administrations.

Questions 2A and 2B: Regression Analysis

I created correlation tables of all predictor and outcome variables to build regression models. Details of this analysis are in Chapter 4. None of the significant variables correlated>.6. Hence, the analysis continued without considering multicollinearity(Flora, 2017). To analyze the association of teacher education coursework experiences (predictor variable) and field placement demographics (predictor variable) on pre-service elementary teachers' SEBEST survey responses (outcome variable), I used Ordinary Least Squares Fit (OLS) regression analysis in STATA©. OLS regression provides a straightforward way to model the relationship between the outcome variables and one or more predictor variables. The coefficients derived from OLS regression are easily interpretable, indicating the average change in the dependent variable for a one-unit change in an independent variable, holding other variables constant (Flora).

To begin the regression model-building process, I modeled the post-survey score as a function of the pre-survey score and other variables of interest. There are some

statistical issues in analyzing change scores, requiring many assumptions to be met (Vickers, 2001). Therefore, I ran my analysis on post-survey scores. Using the following equation:

$$Y = bo + b1X1 + ei \quad (1)$$

I ran all the regression models with the outcome variable being post-SEBEST scores (Y) and the predictor variables being pre-SEBEST scores (X). I then added in the predictors of school-level demographics of field placement schools and compared coursework experiences.

For the association of teacher education program coursework experiences, specifically explicit DEI courses, I ran a regression analysis on the differences among programs. I used Maple as the comparison program for this analysis because it offered no explicit Diversity, Equity, and Inclusion courses. In this equation, bo is the intercept, b1 is the slope, Y=post-SEBEST score, X1=pre-SEBEST score, X2=Oak, X3=Locust, X4=Hickory, X5=Sassafras. The multiple linear regression equation looked like this:

$$Y = bo + b1X1 + b2X2 + b3X3 + b3X4 + b3X4 + ei \quad (2)$$

To investigate the relationship between school-level demographic characteristics (including the percentage of historically underserved students, socioeconomic status (SES), English Language Learners (ELL), and female students) and post-SEBEST survey scores, a regression analysis was conducted for each demographic variable as an independent predictor. Furthermore, the variable Race_Wh, denoting pre-service elementary teachers who identified as white, was incorporated into the analysis as an additional predictor. To mitigate the potential impact of school-level clustering, where pre-service elementary teachers were grouped within the same schools, robust standard

errors were employed (Bell et al., 2008). All predictor variables were grand mean-centered to facilitate the interpretation of a one-unit increase in terms of the variable's mean (Flora, 2017).

A comprehensive set of eight multiple regression analyses was performed to assess the correlation between program experiences and several outcomes related to personal self-efficacy, specifically equitable science instruction for students from low-SES backgrounds, ELLs, students of diverse racial and ethnic backgrounds, and students of different genders, as detailed in Chapter 4, Tables 12 and 13. The multiple linear regression equation is below (3). In this equation, bo is the intercept, b1 is the slope, Y=post-SEBEST score, X1=pre-SEBEST score, X2=school level student demographic(grand mean centered), X3=Race_Wh (pre-service elementary teachers who identified as white). For interpretation, a one percent increase in the demographic characteristics of the school-level student group (for example, % ELL students) above the mean in that school would be associated with white pre-service elementary teachers' responses on the post-survey, controlling for average pre-SEBEST survey score.

$$Y= bo +b1X1+ b1X2+ b1X3 ei \quad (3)$$

Validity of Quantitative Results

For each regression model, an R2 value was reported for model fit. According to Flora (2017), an R2 of >.20 indicates that over 20% of the variability in the data is represented in the model, and thus, the regression model is an acceptable fit. I included these fit statistics within all the data tables for the regression models in Chapter 4.

The outcomes of the regression analyses underwent rigorous peer review by scholars in education and statistics. These results were disseminated among colleagues

within the Ph.D. program for further scrutiny. The construction of statistical models benefited from the expertise available at the Statistics Lab at the University of Virginia, introducing an additional layer of peer review to authenticate the findings. Ultimately, all quantitative outcomes were shared with instructors of science methods courses, thereby extending the validation process through academic scrutiny.

Qualitative Methods

Qualitative methodologies addressed the third research question, which seeks to understand how pre-service elementary teachers conceptualize equitable science education. The investigation involved conducting semi-structured interviews with eight pre-service elementary teachers spanning four of the five teacher education programs. The purpose of integrating the interview component was manifold, aimed at eliciting participants' perceptions, interpretations, confirmations, and anticipations regarding the phenomenon under study (Lincoln & Guba, 1985). This section dedicated to qualitative methods will elucidate the data collection approaches, encompassing the sampling strategy, development of the interview protocol, execution of the interview process, analysis of documents, techniques for analyzing data, and measures to ensure validity.

Data Collection

Semi-Structured Interviews Pre-service Elementary Teachers

Interview participants were chosen based on their demonstrated willingness to partake in an interview, as evidenced by their responses to a survey administered at the commencement of their science methods course. I contacted the pre-service elementary teachers, inviting them to schedule the interview at a convenient time. Eight pre-service elementary teachers from across four teacher education programs participated in hour-

long semi-structured interviews during the fall of 2022 and spring of 2023. As a token of appreciation for their participation, the pre-service elementary teachers were offered incentives in either $5 Starbucks gift cards or $5 Amazon gift cards**.**

Interview Protocols

The formulation of the semi-structured interview protocol for pre-service elementary teachers was informed by an extensive literature review undertaken as part of the preparatory work for this research. This review focused on critical areas, including science self-efficacy, diversity, and equity within educational contexts. To ensure construct validity, the initial version of the protocol underwent field testing with a peer enrolled in the Ph.D. program during the fall of 2022. Feedback from this preliminary interview led to refinements in the phrasing of questions to enhance specificity.

The study utilized two distinct versions of the interview protocol when engaging with pre-service elementary teachers, detailed within Appendices B and C of the research document. In both iterations, the interviews commenced with inquiries into the participants' prior experiences with science education before their enrollment in the teacher education program. This initial line of questioning aimed to elicit insights into their underlying motivations for pursuing a career in elementary education and to assess their baseline comfort with science as an academic discipline. Subsequent questions explored how the teachers' preparatory programs, field experiences, and coursework bolstered their science teaching self-efficacy.

The original version of the protocol (Appendix B) examined participants' perceptions of diversity within classroom settings and queried whether they anticipated adapting their teaching approaches in response to varying student demographics.

Following a consultative session with Dr. Chiu in February 2022, the protocol was revised (Appendix C) to incorporate explicit inquiries regarding equity in science education. This adjusted version aligns closely with the survey instrument, directing questions specifically toward the teaching of science to students of diverse racial or ethnic backgrounds, those from lower socioeconomic statuses, and English language learners, and considering gender differences.

Interview Process

Comprehensive semi-structured interviews were conducted with eight pre-service elementary teachers via Zoom©, each lasting approximately 45 to 60 during the fall of 2022. Each interview was audio-recorded and subsequently transcribed to facilitate detailed analysis. The semi-structured nature of these interviews was designed to optimize time efficiency while simultaneously providing the flexibility to explore emergent topics through follow-up questions as necessary.

Following each interview, a structured analytic memo was written following the framework proposed by Miles et al. (2014). These memos document the alignment of participants' responses with the research questions, assess the congruence between interview and survey responses, identify emerging patterns, categories, themes, concepts, and assertions, and record preliminary thoughts on potential coding schemes.

Data Analysis

Interviews

Interview transcriptions were performed using Otter.ai© and uploaded to Dedoose© (Version 7.0.23, 2016) for coding and analysis. To ensure the security of the

data, the original audio and video recordings from the Zoom© meetings were deleted following the transcription process. All transcripts have been blinded and are securely stored on my personal computer.

In the initial coding phase, holistic coding techniques were employed to grasp the narrative data's overarching content and identify emerging categories, following the approach outlined by Miles et al. (2014). Subsequent coding involved the application of deductive codes derived from the conceptual framework presented in Chapter 2 and inductive pattern codes developed through the analysis of analytic memos. The deductive codebook is included in Appendix E.

To enhance the validity of the findings and ensure the reliability of the coding process, a colleague from the Curriculum and Instruction Ph.D. program was engaged to review and apply the deductive codes. This collaboration validated the researcher's assertions and facilitated the reporting of inter-rater reliability scores, further bolstering the study's validity.

After the coding process, data matrices were employed as an analytical tool to scrutinize the results, which was in line with the methodology described by Miles et al. (2014). These matrices facilitated cross-case comparisons within individual participants, enabling an examination of the consistency or lack thereof in thematic emergence. Furthermore, using data matrices provided a mechanism to explore the divergence or convergence of themes, particularly concerning self-efficacy concerning equitable science instruction. The application of these data displays played a pivotal role in formulating qualitative assertions about the perceptions of pre-service elementary

teachers towards equitable science instruction. Examples of these data matrices can be found in Appendix F.

Validity of Qualitative Work

The qualitative component of this work was validated through a multifaceted approach. Initially, member checking was employed as a primary method. Upon transcription of each interview, transcripts were returned to the respective participants to verify accuracy. This procedure not only facilitated validation directly with participants but also allowed them to contribute additional remarks, thereby enhancing the integrity of the data (Leavy, 2017). Furthermore, the finalized qualitative findings were disseminated among the interview participants and instructors of science methods courses for further member checking, extending the validation scope.

Applying multiple methodologies for inter-rater validation introduced an additional layer of validity. A peer within the Ph.D. program was engaged to code the interview transcripts using a deductive codebook, thereby incorporating investigator triangulation (Leavy, 2017). The coding process, which included both holistic and deductive codes, is detailed in Appendix E. Collaboration with this colleague yielded an inter-rater agreement Kappa k= of .60, indicative of moderate inter-rater agreement (Cohen, 1960).

Innovatively, a novel validation methodology was employed utilizing a Large Language Model (LLM) to assess the validity of deductive codes (Tai et al., 2023). This process entailed the analysis of deductive codes alongside anonymized interview excerpts to verify the coding accuracy. An exemplar of this methodology is documented in Appendix F. Following forty iterations of this process with the ChatGPT 3.5 ©, the

results for each deductive code were compiled, with a representative outcome for a specific interview excerpt illustrated in Appendix G. Through this technique, the LLM provided validation for the deductive codes, evidencing the robustness of the qualitative analysis.

The utilization of triangulation in this study is further enhanced by adopting principles from multiple case study designs (Yin, 2009). The participants, pre-service elementary teachers, were in diverse teacher education programs. Their perceptions and responses concerning equitable science education spanned a spectrum of awareness levels. To fortify the triangulation process, disconfirming evidence was systematically integrated to cross-verify the data derived from the interview analyses. This approach enriched the findings' depth and reliability and ensured a comprehensive examination of the varied perspectives on equitable science education, thereby adhering to rigorous methodological standards.

Researchers Positionality

The significance of acknowledging my positionality within this scholarly work cannot be overstated, as it can influence the interpretation and conclusions drawn from my research. Originating from Quito, Ecuador, and relocating to the United States at eight, I have navigated the complexities of existing outside predominant cultural norms. This journey entailed a struggle to assimilate into a monolingual society, culminating in losing my native language, Spanish. Furthermore, my decade on the Big Island of Hawaii introduced me to the sensation of being "othered," further molding my identity and perspectives. These personal narratives are integral to understanding my research

approach, particularly in my roles as a Ph.D. candidate and as a graduate assistant within a science methods course for pre-service elementary educators.

In science education, the prevailing stereotype of a scientist as an elderly, white male cloistered within a laboratory setting persists. This image starkly contrasts the demographic profile of many pre-service elementary educators, predominantly white middle-class women with limited science backgrounds. My objective has been to dismantle the notion that science is an esoteric discipline, demonstrating through various lesson models that science education can be both accessible and captivating. Given the homogeneity of the teaching candidates, emphasizing cultural responsiveness and equity in pedagogy was paramount. By integrating students' cultural backgrounds and interests into science lessons, I aimed to challenge pre-service educators to confront their implicit biases and perceive their students as valuable contributors to the learning environment.

Thus, another form of validation for this work was keeping a methodological log during data collection and analysis. This introspection permeates my research, and I endeavor to remain reflective and cognizant of how my positionality might skew the data. This positionality underscores a commitment to conducting research grounded in principles of equity. I welcome critical feedback and embrace the opportunity for growth in the pursuit of equitable scholarly practices.

Integration of Quantitative and Qualitative Data

The convergent mixed methods paradigm, characterized by the concurrent collection, separate analysis, and subsequent integration of qualitative and quantitative data, embodies a holistic research strategy that leverages the distinct advantages of both

methodological approaches. This methodological synergy facilitates a comprehensive exploration of research inquiries, surpassing the capabilities of singular methodological frameworks. The process of method integration is elaborated upon in Chapter 6, wherein findings are cohesively presented within a unified table. This presentation not only delineates methodological convergence and divergence points but also elucidates the nuanced insights derived from the amalgamation of data collection methods (Creswell & Plano-Clark, 2018). The discourse presented here will examine the potential validity threats inherent to the convergent design, with an expansive discussion on the methodological convergence detailed in Chapter 6.

Potential Validity Threats with Convergent Design

Convergent design research methodology identifies four primary threats to validity, as delineated by Creswell & Plano-Clark (2018). The first concern arises from the need for parallelism in conceptualizing and operationalizing data collection across quantitative and qualitative datasets. To mitigate this issue within my study, I have meticulously developed interview questions for pre-service elementary teachers that correspond with the survey questions, ensuring conceptual congruence across data collection instruments.

A second threat to validity stems from discrepancies in the sample sizes between quantitative and qualitative datasets. Although acknowledging the presence of differing sample sizes within my study's quantitative and qualitative components, I propose a methodological adjustment by correlating group means derived from the quantitative dataset with individual narratives from the qualitative dataset. This approach is intended to diminish the impact of this validity threat.

The third validity concern involves the segregation of results obtained from distinct databases. To address this, my analysis will incorporate a joint display to integrate findings related to the broader research problem. A cohesive synthesis of these findings will be presented in the discussion section of Chapter 6. This strategy is aimed at curtailing the potential compartmentalization of data.

Lastly, the inability to reconcile disconfirming findings significantly threatens validity. To overcome this challenge, I will employ analytical strategies and utilize the joint display mechanism to thoroughly examine and interpret disconfirming evidence within the context of my research. This comprehensive approach is designed to enhance the robustness and integrity of the study's findings.

Ethical Issues

I have followed various procedures to ensure the ethical treatment of my participants in conducting this work. To begin with, this work has been approved by the UVA IRB board, protocol #5337. Each participating institution has received a copy of the approved protocol, and I have been given dean-level approval from all five teacher education programs. All participants received study consent forms either electronically or through a Word© document. I have respectfully entered the research sites to hand out survey QR codes and to solicit participation. All participant information has been kept confidential and only stored on my computer. Standardized procedures for data collection have been followed. No risks or benefits are associated with using this mixed methods design for the participants, the institutions, or myself.

Conclusion

This study used a convergent mixed methods design to comprehensively examine how pre-service elementary educators conceptualized equitable science instruction. Chapter 4 will delineate the quantitative results for the first two questions of this work. The qualitative findings will be presented in Chapter 5. The integration of research methodologies will add nuances to this work and will be presented in Chapter 6, along with a more extensive discussion of its implications.

CHAPTER 4: QUANTITATIVE RESULTS

This chapter details and summarizes the results of the analytical process used to answer research questions one and two outlined in Chapter 1. It begins with a review of the descriptive data used to answer the first research question: How do pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science change over their field placement and science method coursework experiences? For this analysis, I paired pre- and post-survey scores for a two-tailed t-test analysis. I present the results in Tables 5 and 6 and discuss their significance.

The second research question contains two parts. The first part asks: What are the associations between pre-service elementary teachers' program coursework (which includes both science content courses and courses on diversity, equity, and inclusion) and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science? The second part asks: What are the associations between field placement characteristics (which included % low socioeconomic status [SES], % English language learners (ELLs), and % historically minoritized students and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science? I outlined the descriptive data for the five teacher education programs included in this study (Table 7), followed by school-level demographic information from the field placement schools where the pre-service elementary teachers worked in the fall of 2022 (Table 8). I also included the urbanicity of each field placement school as defined by the National Center for Education

Statistics (NCES, 2022). These include cities, suburban environments, and rural environments. In the final table for the descriptive statistics (Table 9), the demographics of the pre-service elementary teachers are compared across teacher education programs. I included this detailed descriptive analysis to provide the reader with a comprehensive overview of the characteristics of the teacher education programs.

Following the descriptive analysis for questions one and two, my regression analysis of the association between field placement demographics and coursework experiences and the outcome of post-SEBEST survey scores related to personal self-efficacy and outcome expectancy for teaching equitable science are presented. To begin this work, I created a correlation table to examine the associations between my predictor and outcome variables. Correlation tables results appear in Table 8. Next, the results from a series of ordinary least squares (OLS) regression models are displayed, starting with the predictors of coursework experiences embedded within the teacher education program experiences. This enabled me to examine whether there was an association between coursework experiences and the outcome of personal self-efficacy and outcome expectancy related to equitable science education. Since all the programs required science content courses, I compared the program with the least Diversity, Equity, and Inclusion (DEI) explicit and separate coursework credit hours to the other programs.

The second set of regressions examined associations between the predictors of school-level demographics (historically minoritized students, percent ELL learners, percent females, and percent low SES students), pre-SEBEST survey scores, and the self-identified race of pre-service elementary teachers (white) and the outcome variables of post-SEBEST scores regarding personal self-efficacy and outcome expectancy related to

equitable science education. This chapter concludes with an overarching discussion of these results and describes the findings of the first two research questions.

Descriptive Statistics

Changes in Self-Efficacy Related to Equitable Science Instruction

For the first research question, I was interested in how pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science change over their field placement and science method coursework experiences. I completed a two-tailed t-test analysis of the pre- and post-survey scores to answer this. Results are displayed in Tables 4 and 5.

Table 4:

Personal Self-Efficacy Related to Equitable Science Instruction

Personal Self-Efficacy	Pre-Survey Mean	SD pre	Post Survey Mean	SD post	*t*	*p*
Ethnicity/race	4.68	.40	4.82	.39	3.28	0.0007***
Language	4.16	.40	4.55	.48	7.74	0.0000***
Gender	4.78	.35	4.83	.35	1.32	0.0958
SES	4.5	.53	4.83	.37	6.37	.0000***

Note: $p<0.05$, ** for $p<0.01$, and *** for $p<0.001$.

Table 5:

Outcome Expectancy Related to Equitable Science Instruction

Outcome Expectancy	Pre-Survey Mean	SD pre	Post Survey Mean	SD post	*t*	*p*
Ethnicity/race	4.72	.36	4.77	.33	1.51	0.0665
Language	4.75	.42	4.90	.30	3.44	0.0004 *
Gender	4.88	.27	4.78	.36	-2.25	0.0134**
SES	4.73	.34	4.65	.44	-2.24	.013**

Note: $p<0.05$, ** for $p<0.01$, and *** for $p<0.001$.

Personal Self-Efficacy

Regarding personal self-efficacy, pre-service elementary teachers had positive increases in their self-efficacy related to teaching equitable science to students from all demographic groups, including students with different racial and ethnic identities, ELL learners, students with different binary genders, and students from low SES backgrounds. Results indicate that pre-service elementary teachers started their science methods coursework experiences already feeling relatively confident in their personal self-efficacy to teach students from all demographic backgrounds, with the highest mean personal self-efficacy for teaching students across binary genders at M=4.73[iii], SD =.35 and the lowest mean personal self-efficacy for teaching students who are ELL at M =4.16, SD=.40. Mean pre-survey self-efficacy scores were similar for teaching students from different racial and ethnic backgrounds (M=4.68, SD=*.40*) and for teaching students from low socio-economic backgrounds (M=4.54, SD=.53).

There were positive changes in pre-service elementary teachers' personal self-efficacy related to teaching equitable science to students from all demographic categories, and some of these positive differences were statistically significant. The largest positive increase was in the area of self-efficacy related to teaching equitable science to students who are English language learners. Pre-service elementary teachers' self-efficacy increased by .4 points for this demographic category, t=7.74, p=0.00. Pre-service elementary teachers also had relatively significant positive changes in their self-efficacy related to teaching students from low SES backgrounds, with a survey change of .32, t=6.37, p=0.000. However, there were more minor changes (.15) in their self-efficacy concerning teaching students from different racial and ethnic groups, with t= 3.28 and

p=0.0007. The most minor changes occurred in pre-service elementary teachers' personal self-efficacy concerning teaching students from different binary genders, specifically females. Pre-service elementary teachers did not experience a statistically significant change for this demographic group at $p < .05$, t=1.3150, and p=0.0958.

Overall, results indicate that pre-service elementary teachers started their science methods coursework experiences already feeling efficacious concerning teaching science to students from various demographic backgrounds. There were statistically significant positive changes in their personal self-efficacy concerning teaching students from different racial and ethnic identities, ELL students, and students from low SES backgrounds when comparing pre-and post-survey measures during a science methods course. Pre-service elementary teachers had the largest significant gains in their personal self-efficacy survey responses about teaching ELL students and students from low SES backgrounds. More minor changes occurred in the area of self-efficacy with regard to teaching students from different racial and ethnic backgrounds. However, pre-service elementary teachers had relatively high self-efficacy on mean pre-survey scores for this demographic category (M=4.68, SD=40). This means that pre-service elementary teachers did not report similar gains in confidence (compared with their confidence in teaching ELL students and students from low SES backgrounds). However, during the pre-survey, they self-reported feeling efficacious about teaching science to students from different racial and ethnic backgrounds. The most minor changes occurred in the survey responses for pre-service elementary teachers' personal self-efficacy concerning teaching female students, and these changes were not statistically significant.

Outcome Expectancy

Regarding outcome expectancy (Table 6), pre-service elementary teachers began their science methods coursework with mean values larger than M=4.7 for their outcome expectancy for all demographic categories of students on their pre-survey responses. The results indicate that pre-service elementary teachers held strong beliefs about the effectiveness of their science teaching actions in achieving desired results or outcomes across all demographic categories of students. The most considerable mean pre-survey outcome expectancy was related to teaching females M=4.88, SD=.27, and the smallest mean outcome expectancy was regarding students from different racial and ethnic groups was almost at the same level: M=4.72, SD=.36. Pre-service elementary teachers reported similar mean pre-survey outcome expectancy values for teaching ELL students M=4.75, SD=.42, and students from low SES backgrounds M=4.73, SD=.34.

There were differences in changes in pre-service elementary teachers' mean outcome expectancy beliefs across demographic categories of students when comparing pre-and post-survey responses. Pre-service elementary teachers experienced positive changes in their outcome expectancy related to teaching ELL students, with an increase of .15, t= 3.43, and p=.0004. However, pre-service elementary teachers' outcome expectancy related to teaching female students and students from low SES backgrounds decreased, and this decrease was statistically significant. Regarding gender, the mean outcome expectancy concerning teaching females decreased by .11 points, t= -2.25 and p= 0.0134, and the mean outcome expectancy about teaching students from low SES backgrounds decreased by .09, t=- 2.24, and p=.013. Pre-service elementary teachers reported minimal positive changes in their outcome expectancy for teaching students

from different racial and ethnic groups (.06). However, these changes were not statistically significant t=1.52, p=0.0665.

In summary, pre-service elementary teachers reported strong mean outcome expectancy beliefs related to all student demographic groups in their pre-survey responses at the beginning of their science methods coursework experiences. Comparing the mean values on their pre- and post-survey responses, pre-service elementary teachers had positive gains in their mean outcome expectancy beliefs about ELL students, and these positive changes were statistically significant. This means pre-service elementary teachers felt that their actions in the classroom produced favorable outcomes for ELL students. However, there were small statistically significant decreases in outcome expectancy beliefs related to teaching females and students from low SES backgrounds. Even though there was a statistically significant decrease in pre-service elementary teachers' outcome expectancy pertaining to females and students from low SES backgrounds, post-survey values for these demographic categories were still relatively high (>4.5). This means that despite the slight statistically significant decrease in mean outcome expectancy concerning these demographic groups of students, pre-service elementary teachers still self-reported strong beliefs that their actions in the classrooms would produce positive outcomes for females and students from low SES backgrounds.

The slight drop in the mean change in outcome expectancy values for teaching females and teaching students from low SES backgrounds reflects a moment of hesitation, where pre-service elementary teachers might be considering how outcomes for these groups would be different because of their science teaching. Since the values are minimal (.11 for females and .09 for SES), it is hard to infer what caused the difference.

The most minor positive changes occurred with pre-service elementary teachers' self-reported outcome expectancy beliefs related to teaching students from different racial and ethnic backgrounds. However, these changes were not statistically significant. Overall, since all mean survey values (pre and post) for outcome expectancy were above 4.7, I conclude that the pre-service elementary teachers in this sample were confident that their science teaching in their classrooms would produce desired equitable outcomes for all their students across racial and ethnic demographics, for ELL students, female students, and students from low SES backgrounds.

Teacher Education Programs

To examine the second research question, I summarized the characteristics of the five teacher education programs (Table 6). Teacher education program experiences varied by the length of the program, student enrollment in both the Bachelor of Arts (BA) and Master of Arts (MA) programs, required science content courses, required ELL courses, required coursework with DEI (explicit in course title), evidence of a focus on equity from the science methods coursework syllabi, and total hours in field placement settings during the fall of 2022.

Table 6: *Cross Program Comparison Table*

School	Locust	Locust Masters	Maple Undergrad	Maple Masters	Oak Undergrad	Oak Masters	Sassafras Undergrad	Hickory
Length of Program	4 years	1.5 years	4 years	1 year + summer	4 years	1year+ summer	4 years	4 years
Number of Students in Elementary Program	70 *Juniors and seniors	75	72	20	19* Juniors and Seniors	8	487	113
Approximate Required Science Content Credits	14 credits	14 credits	6 credits	6 credits	6 credits	6 credits	9 credits	3 credits
Required ELL credits	2 credits	2 credits				3 credits		
Required and Separate Equity, Diversity, and Inclusion class	6 credits total 3 Diversity, Democracy, and Ethics 3Assessment in Diverse Settings	6 credits total 3 Diversity, Democracy, and Ethics 3Assessment in Diverse Settings	Embedded throughout	Embedded throughout	Embedded throughout	Embedded throughout	3- credits total 3 Diversity in Elementary Education course	3-credits total 3 Teaching Culturally and Linguistically Diverse Students Embedded throughout
TOTAL DEI+ ELL	8 credits	8 credits				3 credits	3 credits	3 credits
Explicit Focus on Equitable Science in Syllabus	InTASC Standards **	InTASC Standards **			Textbook* InTASC Standards **	Textbook* InTASC Standards **	Textbook* Uses InTASC Standards **	Textbook* Mentions CRT InTASC Standards **
Length of placement experience in Fall 2022	76 hours	76 hours	160 hours total	160 hours total	70 hours	60 hours	80 hours	40 hours

Looking across program experiences, undergraduates in fall 2022/spring 2023 were finishing teaching degrees in four years, whereas a master's degree in education took one and a half years. Sassafras had the most pre-service elementary teachers, with 487 undergraduates, and Oak had the least, with 27 undergraduates and graduates enrolled. All programs required pre-service elementary teachers to take at least three credits in a science content course. Locust and Hickory required ELL coursework. Locust, Sassafras, and Hickory required explicit Diversity, Equity, and Inclusion coursework, whereas Maple and Oak did not. Locust required eight credit hours in DEI and teaching ELLs through their coursework experiences. Examining the science methods course syllabi, I found that the syllabi from Maple did not explicitly include the Interstate Teacher Assessment and Support Consortium (InTASC) equity standards. The InTASC standards offer resources that both define and support ongoing teacher effectiveness. The goal is to ensure students reach college and career standards (Council of Chief State School Officers, 2011). All accredited teacher education programs in this study follow these standards, which include a focus on equitable instruction. Finally, pre-service elementary teachers averaged 60 hours per semester in field placement classrooms across all five programs.

Across all five programs, pre-service elementary teachers gained experience in science content by taking at least three required science credits. They also gained experience with equity standards through InTASC requirements. In every program, pre-service elementary teachers worked an average of 60 hours per semester in elementary classrooms during their field placement experiences. However, across these five programs, the experiences of pre-service elementary teachers varied in the number of

credit hours required in DEI and ELL coursework. Pre-service elementary teachers who attended Maple and Oak did not have to take explicit and separate DEI coursework. In contrast, pre-service elementary teachers in Locust, Sassafras, and Hickory took at least three credit hours in separate Diversity, Equity, and Inclusion coursework.

Field Placement School Level Student Demographics

For the field placement schools, I examined school-level demographics in terms of percentages for students who identified as being from a historically minoritized race, ELL students, students from low-SES backgrounds, and the percentage of females in the classroom. Data were drawn from the Mid-Atlantic state school report card. To calculate the percentage of historically minoritized students, I averaged all racial categories that were not White into one group (Hispanic, Black, Native American, Multiple Races). The Virginia report card defined economically disadvantaged students as "A student who is a member of a household that meets the income eligibility guidelines for free or reduced-price school meals (less than or equal to 185% of Federal Poverty Guidelines)"(NCES, 2022). I renamed this category low SES background for consistency in terminology within this dissertation.

In considering urbanicity, The National Center for Education Statistics (NCES) identifies 13 different types of urban areas that can be collapsed into three distinct regions: rural, suburban, and city. Using the (NCES) locale framework, I categorized the school community into three basic types: city, suburban, and rural (NCES, 2022). These categories rely on standard urban and rural definitions developed by the U.S. Census Bureau. Rural environments are at least 5 miles outside of cities. Suburban environments have between 100,000 and 250,000 people, and cities have more than 250,000 people.

I have aggregated all field placement school-level demographic information and displayed the information by teacher education program (Table 7). This provides context to better understand pre-service elementary teachers' experiences through their field placement school-level environments and compare them across teacher education programs. For the descriptive statistics, I have also included urbanicity to understand the population density in the communities where the field placement schools are located.

Table 7: Average School level Field Placement Demographics across Five Teacher Education Programs

Teacher Education Program	Average Percent Historically Minoritized Students	Average percent ELL	Average percent low SES	Average percent numbers of Females in the Classroom	Average School Size
Maple	50.8	13.6	43.5	48.16	431.32
Oak	59.2	9.3	41.8	48.57	538.58
Sassafras	30.9	8.2	53.1	49.28	420.5
Locust	77.7	19.9	57.1	49.53	468.75
Hickory	72.8	30.2	54.9	49.58	661
Average Across Sample	50.16	12.43	49.39	48.96	508.23

Field placement school-level demographics varied by teacher education program (Table 8). Hickory had the largest schools, with an average of 661 students across city and suburban settings. About 73 percent (*M*=72.8%) of the students identified as a historically minoritized race or ethnicity, and about 31 percent (*M*=30.9%) identified as ELL students—a little over half the students (*M*=54.5%) identified as coming from low-SES backgrounds. By comparison, Sassafras has the smallest schools, with an average of 420.5 students, mostly in rural settings (*M*=68.89%). Sassafras also had the smallest percentage of historically-minoritized students (M=30.9%) and ELL students (*M*=8.9%). Locust, with an average school size of 468.75 students, had the highest percentage of historically-minoritized students (*M*=77.7 %) in suburban settings (*M*=72.73%) and the highest percentage of students from low-SES backgrounds (*M*=57.1%). The schools in Locust also had high numbers of ELL students, with almost 20 percent (*M*=19.9) of the students identifying as ELL. Overall, the number of females across all program school settings (*M*= 48.96%) did not vary widely.

Pre-service elementary teachers enrolled in different teacher education programs had various experiences with different students based on the demographics of their field placement schools. Those enrolled in Hickory and Locust taught in settings with large numbers of historically minoritized students (*M* >70%), across suburban and city communities, with large numbers of ELL students (*M* >19%), and with more than 50 percent of the students coming from families with low-SES backgrounds. The pre-service elementary teachers enrolled in Oak and Maple taught in similar school contexts and thus might have had similar experiences based on school-level student demographics. These school settings: More than 50% of the students in these schools were from historically

minoritized racial and ethnic backgrounds, between 9% and 13% were ELL students, and over 40% were from low-SES backgrounds. However, pre-service elementary teachers enrolled at Maple taught in suburban and city communities, compared with the mostly rural (*M*=42.86%) and suburban (*M*=47.62%) communities of Oak. Pre-service elementary teachers enrolled in Sassafras had the most experiences in rural settings (*M*=68.89%), and these contexts had a smaller percentage of historically-minoritized students (*M*=30.9%) and the smallest percentage of ELL students (*M*=8.9%). In summary, these teacher education programs were located within different demographic communities, reflected in the school-level student demographic data for each field placement context.

Pre-Service Elementary Teachers' Demographics

Table 8 presents the demographics of the pre-service elementary teachers who participated in this study across their teacher education programs. The demographics of this sample (N=97) mirror the demographics of the teaching workforce nationally. Seventy-nine percent of pre-service elementary teachers in this study self-reported as White, compared with a national average of 80% (NCES, 2021). Ninety-two percent reported as female, compared to a national average of 89% females in elementary classrooms (NCES).

Table 8:

Pre-Service Elementary Teachers' Demographics by Teacher Education Program

Teacher Education Program	Race White	Race Black	Race Asian	Race LatinX	Race Multiple	Gender (% Female)	Mean Age	Total Participants
Maple	16	1	3		1	100	21.33	21`
Oak	13	2		1		81.25	21.56	16
Sassafras	37	5	1		2	91.11	20.75	45
Locust	8	1		1	1	90.90	22.63	11
Hickory	3		1			100	21.25	7
Total Across Sample	77	9	6	3	2	91.75	21.50	97

Summary of Descriptive Statistics

The ninety-seven pre-service elementary teachers in this study were primarily White (79%), young (*M*=21.50), and female (92%). These racial and gender statistics mirror national demographic trends in elementary classrooms (NCES, 2024). On average, the pre-service elementary teachers in my sample began their science methods coursework experiences with high personal efficacy (*M*=>4.0) and outcome expectancy (*M*=>4.5) that they could teach equitable science to students from different racial and ethnic backgrounds to ELLs, to students who were from low-SES backgrounds, and to females. They had statistically significant positive changes (pre- and post-measures during science methods coursework) in their personal self-efficacy related to teaching ELLs, students from low-SES backgrounds, and students from different racial and ethnic backgrounds. They also experienced statistically significant positive changes in their outcome expectancy concerning the learning outcomes of ELL students. However, statistically significant decreases in their outcome expectancy were related to females and students from low-SES backgrounds. This suggests that pre-service elementary teachers lose some confidence in producing equitable outcomes for females and students from low-SES backgrounds at the end of their science method course experiences.

Not all teacher education program experiences are the same. Pre-service elementary teachers in Locust, Hickory, and Sassafras took explicit and separate credit hours in coursework centering on DEI. Oak and Maple did not require explicit credit hours in coursework on these topics. Instead, these topics were embedded throughout all curricula. Considering field placement school settings, pre-service elementary teachers enrolled in Hickory and Locust taught in the most diverse settings (related to % historically minoritized students, % ELL students, and % low-SES background) compared to pre-service elementary teachers enrolled in

Sassafras who experienced the minor diverse settings. Pre-service elementary teachers in Oak and Maple had similar experiences in their field placement schools when considering school-level student demographics. However, Oak included a rural context, and Maple had only suburban and city placements.

Building Models of Personal Self-Efficacy and Outcome Expectancy Predictors

The second research question asked about associations between pre-service elementary teachers' program coursework (which includes both science content courses and courses on diversity, equity, and inclusion) and field placement characteristics (which included school level demographics of % SES, % ELL, % historically-minoritized students, and % females) and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science? To answer this, I first created correlation tables with all predictor and outcome variables for the two main measures of self-efficacy: personal self-efficacy and outcome expectancy (Tables 9 and 10). Since none of my outcomes of interest (post-survey scores) had high correlations with my predictors of interest (pre-survey scores and demographics of field placement settings), I did not complete additional analysis for multicollinearity (Flora, 2018). I continued my analysis with a series of regression equations.

Table 9:

Correlation Table Personal Self-Efficacy

	Post-race	Post-gender	Post-Lan.	Post-SES	Pre-race	Pre-gender	Pre-Lan.	Pre-SES	%min.	%female	% ELL	% Low SES	Race_wh
Post-race	1.00												
Post-gender	0.83***	1.00											
Post- Lan.	0.47***	0.39***	1.00										
Post- SES	0.69***	0.59***	0.53***	1.00									
Pre-race	0.41***	0.36**	0.26***	0.41***	1.00								
Pre-gender	0.33***	0.27**	0.21*	0.35**	0.71***	1.00							
Pre-Lan.	0.19	0.22**	0.36**	0.16	0.336**	0.30**	1.00						
Pre-SES	0.35**	0.40***	0.26**	0.40***	0.63***	0.43***	0.40**	1.00					
%min.	-0.03	0.07	-0.24 *	-0.12	-0.05	-0.11	0.02	0.11	1.00				
%female	-0.01	-0.06	0.17	0.00	0.01	0.15	0.12	0.07	-0.02	1.00			
% ELL	0.12	0.12	-0.10	0.06	0.04	-0.06	-0.05	0.06	0.67***	-0.04	1.00		
% low SES	-0.03	-0.13	0.15	0.10	0.01	-0.03	-0.06	0.03	0.40***	.16	0.29**	1.00	
Race_wh	0.51***	0.42***	0.24*	0.36**	0.06	0.13	-0.02	0.10	-0.13	0.05	-0.22*	-0.12	1.00

Note: ***p<.001, **p<.01, *p<.05

Outcome Variables: Post Survey Means for SEBEST scores: Post-Race, Post-Gender, Post-Lan.=Post-teaching to ELL learners, Post-SES=teaching to students from low SES backgrounds. Predictor variables: Pre-survey Means for SEBEST scores: Pre-Race, Pre-Gender, Pre-Lan.=Pre-teaching to ELL learners, Pre-SES=teaching to students from low SES backgrounds, and % demographics of students all mean centered: % min. =% minoritized, % female, %ELL, % low SES) all mean centered. Race_Wh= Self-Identified race of Pre-service teacher.

Table 10:

Correlation tables Outcome Expectancy

	Post-race	Post-gender	Post-Lan.	Post-SES	Pre-race	Pre-gender	Pre-Lan.	Pre-SES	%min.	%female	% ELL	% Low SES	Race_wh
Post-race	1.00												
Post--gender	0.65***	1.00											
Post Lan.	0.72***	0.73***	1.00										
Post-SES	0.69***	0.62***	0.58***	1.00									
Pre-race	0.42***	0.22*	0.25**	0.47***	1.00								
Pre-gender	0.18	0.08	0.07	0.25**	0.53***	1.00							
Pre-Lan.	0.30 *	0.32**	0.31*	0.44***	0.50***	0.54***	1.00						
Pre-SES	0.33**	0.27**	0.21*	0.60***	0.58***	0.45***	0.51***	1.00					
%min.	0.07	0.31*	0.10	0.14	0.05	-0.03	0.11	0.05	1.00				
%female	-0.16	-0.18	-0.28**	-0.06	0.17	0.03	0.08	0.04	-0.0242	1.00			
% ELL	0.08	0.20*	.07	-0.03	0.01	-0.01	0.09	0.02	0.67 ***	-0.04	1.00		
% low SES	-0.11	-0.07	0.02	-0.07	-0.07	-0.07	0.05	-0.06	0.40***	0.16	.30*	1.00	
Race_wh	0.33**	0.16	0.25**	0.26**	.25*	0.14	0.16	0.20*	-0.13	0.05	-0.22*	-0.1202	1.00

Note: ***p<.001, **p<.01, *p<.05

Outcome Variables: Post Survey Means for SEBEST scores: Post-Race, Post-Gender, Post-Lan.=Post-teaching to ELL learners, Post-SES=teaching to students from low SES backgrounds. Predictor variables: Pre-survey Means for SEBEST scores: Pre-Race, Pre-Gender, Pre-Lan.=Pre-teaching to ELL learners, Pre-SES=teaching to students from low SES backgrounds, and % demographics of students all mean centered: % min. =% minoritized, % female, %ELL, % low SES) all mean centered. Race_Wh= Self-identified race of pre-service teacher.

Regression Analysis

Data were analyzed using Ordinary Least Squares (OLS) regression to examine the association between various predictor variables (pre-SEBEST survey score, demographics of school level setting, programs, and race of pre-service teachers) and post-SEBEST survey scores. I decided to model the post-score as a function of the pre-score and other variables of interest. There are some statistical issues in analyzing change scores, requiring many assumptions to be met (Vickers, 2001). I do not focus the discussion of the results on the associations between pre-survey scores and post-survey scores because this is outside the scope of my research questions. However, I present the results of this analysis in the regression data tables.

Using the following equation:

$$Y = bo + b1X1 + ei \quad (1)$$

I first ran regression models with the outcome variable being post-SEBEST scores (Y) and the predictor variables being pre-SEBEST scores (X). I then added in the predictors of school-level demographics of field placement schools and compared coursework experiences.

Associations of Teacher Education Coursework Experiences and SEBEST Scores

I ran a regression analysis on the differences among programs in explicit Diversity, Equity, and Inclusion coursework. Since all programs required science content, I compared the programs with explicit Diversity, Equity, and Inclusion coursework to those that did not require such coursework. I used Maple as the comparison program for

this analysis because it offered no explicit Diversity, Equity, and Inclusion courses. The multiple linear regression equation looked like this:

$$Y= bo +b1X1+b2X2+b3X3+ b3X4+ b3X5+ b3X6+ ei \quad (2)$$

In this equation, X2=Oak, X3=Locust, X4=Hickory, X5=Sassafras.

For the regression analysis on school-level demographics, I used robust standard errors to account for any school-level clustering where pre-service elementary teachers were nested in the same school (Bell, 2007). I grand mean centered all of the predictor variables so that a one-unit increase can be interpreted based on the mean for that variable. I ran a series of eight multiple regressions to measure the association between program experiences and the outcomes of personal self-efficacy related to each of the outcomes: equitable science instruction for students from low-SES backgrounds, ELLs, students from different racial and ethnic groups, and gender (Tables 11 and 12). I will first present the results from this regression analysis and then discuss the implications of the associations.

Table 11

Associations between Teacher Education Programs and Personal Self-Efficacy

	B	SE	*t*	*p*	CI
		SES			
Intercept	4.77	.07	65.00	0.000 ***	[4.62 - 4.91]
Pre-SES	.29	.07	4.39	0.000 ***	[.157 - .416]
Hickory	.16	.18	0.89	0.38	[-.201- .527]
Locust	.02	.13	0.16	0.87	[-.228- .269]
Sassafras	.14	.09	1.57	0.120	[-.037- .316]
Oak	-.06	.11	-0.50	0.169	[-.277- .166]
R2	0.40				
		ELL			
Intercept	4.40	.08	52.42	0.000***	[4.23 - 4.56]
Pre-ELL	.44	.10	4.46	0.000 ***	[.245 - .639]
Hickory	.12	.21	0.58	0.562	[-.295- .539]
Locust	.26	.14	1.80	0.076	[-.027- .541]
Sassafras	.36	.10	3.59	0.001**	[.163 - .566]
Oak	-.30	.13	-2.34	0.022*	[-.552 - .045]
R2	0.40				
		RACE			
Intercept	4.84	.08	61.17	0.000***	[4.69 - 5.01]
Pre-RACE	.41	.09	4.38	0.000***	[.224 - .596]
Hickory	.08	.21	0.42	0.675	[-.310 - .476]
Locust	-.04	.13	-0.29	0.772	[-.307 - .229]
Sassafras	-.07	.10	-0.68	0.500	[-.256 - .126]
Oak	.02	.12	0.14	0.887	[-.222 - .257]
R2	0.18				
		GENDER			
Intercept	4.92	.07	67.67	0.000***	[4.77 - 5.060]
Pre-GENDER	.31	.10	3.13	0.002**	[.112 - .503]
Hickory	.09	.18	0.50	0.615	[-.269 - .452]
Locust	-.01	.12	0.10	0.917	[-.234 - .260]
Sassafras	- .20	.11	-2.26	0.026*	[-.374 - -.024]
Oak	.10	.13	.09	0.929	[-.210 - .230]
R2	0.17				

Note: p<.001**, p<.01 **, p<.05 *; N=97

Pre-SES, Pre-ELL, Pre-RACE, Pre-GENDER: All pre-survey scores are grand mean centered. Maple is the comparison group.

Table 12

Associations between Teacher Education Programs and Outcome Expectancy

	B	SE	*t*	*p*	CI
		SES			
Intercept	4.81	.07	64.47	0.000*	[4.66 - 4.95]
Pre-SES	.75	.10	7.17	0.000*	[.542 - .957]
Hickory	-.01	.19	-0.03	.976	[-.381 - .370]
Locust	-.17	.13	-1.30	.197	[-.417 - .087]
Sassafras	-.28	.09	-3.05	.003*	[-.454- -.096]
Oak	-.05	.1	-0.43	0.670	[-.275- .178]
R2	0.43				
		ELL			
Intercept	4.89	.06	78.80	0.000***	[4.77 - 5.01]
Pre-ELL	.21	.07	3.01	0.003 **	[.072 - .351]
Hickory	.05	.16	.35	0.724	[-.254 - .364]
Locust	.13	.11	1.18	0.240	[-.085 - .336]
Sassafras	-.05	.08	-0.68	0.499	[-.201 - .099]
Oak	.08	.09	0.83	0.408	[-.109- .265]
R2	.14				
		RACE			
Intercept	4.89	.06	75.27	0.000***	[4.76- 5.02]
Pre-RACE	.38	.09	4.42	0.000***	[.208 - .548]
Hickory	.08	.16	.48	0.631	[-.245 - .401]
Locust	-.10	.11	-.91	0.368	[-.321 - .120]
Sassafras	-.19	.08	-2.45	0.016 *	[-.349 - .037]
Oak	-.10	.10	-0.99	0.325	[-.296 - .099]
R2	0.24				
		GENDER			
Intercept	4.94	.07	71.73	0.000***	[4.801 -5.076]
Pre-GENDER	.11	.12	.85	0.399	[-.142 - .354]
Hickory	.05	.17	.31	0.757	[-.288 - .395]
Locust	-.01	.12	- .08	0.933	[-.250 - .229]
Sassafras	-.36	.08	- 4.34	0.000***	[-.527- -.196]
Oak	.06	.10	- .52	0.981	[-.153 - .262]
R2	0.29				

Note: p<.001**, p<.01 **, p<.05 *; N=97

Pre-SES, Pre-ELL, Pre-RACE, Pre-GENDER: All pre-survey scores are grand mean centered. Maple is the comparison group.

Associations between Teacher Education Programs and Self-Efficacy.

There are statistically significant associations between pre-service elementary teachers' teacher education coursework experiences (related to explicit DEI courses) and their personal self-efficacy for teaching ELL students. Compared with Maple, pre-service elementary teachers enrolled in Sassafras had a .36-unit increase in their personal self-efficacy related to teaching ELL students (t=3.59, p=.001). In contrast, compared with Maple, pre-service elementary teachers enrolled in Oak decreased .30 points in their personal self-efficacy concerning teaching ELL students (t=-2.34, p=.002). The model measured about 40% of the variance (R2=.40), which indicates a strong fit for the data (Flora, 2008).

One potential explanation for the difference between Sassafras and Oak related to personal self-efficacy concerning teaching ELL students could be that Sassafras requires explicit DEI coursework. This coursework might explain the association between Sassafras and candidates' increased personal self-efficacy pertaining to teaching ELL students. On the other hand, Oak does not require explicit DEI coursework, and the negative association could reflect this lack of explicit coursework. Since this analysis did not include an in-depth review of all course syllabi (concerning how courses might be embedding DEI), it is difficult to infer the total coursework experience. These results indicate a potential area for further research into the association between explicit ELL coursework and pre-service elementary teachers' self-efficacy related to teaching science to ELL students.

There was also a decrease in personal self-efficacy related to teaching science to females for pre-service elementary teachers enrolled in Sassafras. For pre-service

elementary teachers enrolled in Sassafras, compared to Maple, their personal self-efficacy related to teaching equitable science for females decreased by .20 points, *t*=-2.26, *p*=.026, R2=.17. Since no other programs had changes concerning gender, it is challenging to infer meaning from this result. This result warrants further investigation of potential gender stereotypes that might be perpetuated in teacher education programs concerning females in science.

There were also statistically significant associations involving candidates' outcome expectancy related to teaching equitable science when comparing teacher education program experiences (Table 13). Concerning teaching students from low-SES backgrounds, pre-service elementary teachers enrolled in Sassafras had a .28 drop in outcome expectancy compared with other programs, *t*=-3.05, *p*=.003, R2=.43. Regarding outcome expectancy related to teaching students from different racial and ethnic backgrounds, pre-service elementary teachers in Sassafras dropped .19 points in their outcome expectancy compared with pre-service elementary teachers enrolled in Maple (*t*=-2.45, *p*=.016, R2=.24). Concerning teaching females, the outcome expectancy for teaching females of pre-service elementary teachers in Sassafras decreased by .36 points, compared to Maple (*t*=-4.34, *p*=0.000, R2=.29).

Compared with Maple, pre-service elementary teachers enrolled in Sassafras had negative outcome expectancy changes related to teaching equitable science to students from low-SES backgrounds, students from different racial and ethnic backgrounds, and females. This negative change in outcome expectancy indicates that pre-service elementary teachers in Sassafras had less confidence that the specific teaching strategies or actions they learned would achieve the desired results for these specific groups of

students. Pre-service elementary teachers from Sassafras might need additional support to increase their outcome expectancy for students from low-SES backgrounds, students from different racial and ethnic backgrounds, and females.

In addition, pre-service elementary teachers from Sassafras had negative changes in their personal self-efficacy with regard to teaching females. A deeper look at the nuances of this result is beyond this study. However, additional research could highlight why these changes are occurring, especially given that personal self-efficacy and outcome expectancy for teaching equitable science to females decreased for pre-service teachers enrolled at Sassafras. More research is needed to investigate programmatic differences regarding self-efficacy related to equitable science teaching. The associations presented here highlight the need for additional study. The implications are limited since the changes in self-efficacy (personal and outcome expectancy) are minimal (*M*=.28), and further evaluations of coursework experiences are necessary to draw more robust conclusions.

Associations of School-Level Student Demographics and SEBEST Scores

I ran a regression analysis on the association of school-level student demographics and pre-service elementary teachers' personal self-efficacy and outcome expectancy related to teaching equitable science to students from different racial and ethnic backgrounds, low-SES backgrounds, ELL students, and females. The multiple linear regression equation looked like this:

$$Y= bo +b1X1+b2X2+b3X3+ b3X4+ b3X5+ b3X6+ ei \quad (3)$$

In this equation, X1=pre-survey score, X2=% of school level demographics, X3=race of preservice teacher (white teachers). Once again, I used robust standard errors to account for any school-level clustering where pre-service elementary teachers were nested in the same school (Bell, XXXX). I also grand mean-centered all predictor variables so that a one-unit increase can be interpreted based on the mean for that variable. I ran a series of four multiple regressions to measure the association between field placement school demographics and the outcomes of personal self-efficacy related to teaching equitable science to students from low-SES backgrounds, ELL students, students from different racial and ethnic groups, and gender (Table 13). I ran an additional set of similar regressions with outcome expectancy for teaching equitable science to students from low-SES backgrounds, ELL students, students from different racial and ethnic groups, and gender differences across the five teacher education programs (Table 14). I will present the results and then discuss the findings.

Table 13

Associations between School Level Demographics and Personal Self-Efficacy

	B	SE	*t*	*p*	CI
		SES			
Intercept	4.57	.12	38.63	0.000 ***	[4.34- 4.813]
Pre-SES	.25	.07	3.50	0.001 **	[.109- .396]
% SES	.003	.002	1.31	.192	[-.001 - .007]
Race_Wh	.30	.12	2.53	0.013*	[.065 - .543]
R2	0.28				
		ELL			
Intercept	4.29	.17	25.94	0.000***	[3.969 - 4.616]
Pre-ELL	.44	.10	4.48	0.000 ***	[.247 - .641]
%ELL	-.001	.004	-0.26	0.798	[-.009 - .007]
Race_Wh	.29	.12	2.39	0.02*	[.049 - .527]
R2	0.14				
		RACE			
Intercept	4.442537	.12	36.54	0.000***	[4.201 - 4.684]
Pre-RACE	.38	.10	3.73	0.000***	[.176 - .577]
% minoritized	.001	.001	0.68	.500	[-.002 - .003]
Race_Wh	.48	.12	3.87	0.000***	[.232- .721]
R2	0.4112				
		GENDER			
Intercept	4.62	.12	40.07	0.000***	[4.389 - 4.845]
Pre-GENDER	.24	.09	2.62	0.01**	[.059 - .426]
% female	-.01	.16	-.88	0.382	[-.046 - .018]
Race_Wh	.35	.13	2.65	0.009 *	[.087 - .606]
R2	0.24				

Note: p<.001**, p<.01 **, p<.05 *; N=97

Pre-SES, Pre-ELL, Pre-RACE, Pre-GENDER, % SES, %ELL, % minoritized, %female: values are grand mean centered.

Table 14:
Associations between School Level Demographics and Outcome Expectancy

	B	SE	*t*	*p*	CI
		SES			
Intercept	4.53	.11	39.54	0.000 ***	[4.300 - 4.754]
Pre-SES	.73	.13	5.82	0.001 **	[.483 - .982]
% SES	-.0004361	.002	-.19	0.850	[-.005 - .004]
Race_Wh	.16	.12	1.36	0.178	[-.074 - .393]
R2	0.38				
		ELL			
Intercept	4.84	.08	57.44	0.000***	[4.675 - 5.010]
Pre-ELL	.19	.08	2.25	0.027 *	[.021 - .351]
%ELL	.0024607	.002	1.40	0.166	[-.001 - .006]
Race_Wh	.17	.10	1.68	.096	[-.031 - .371]
R2	0.15				
		RACE			
Intercept	4.44	.10	45.00	0.000***	[4.407 - 4.814]
Pre-RACE	.32	.08	4.10	0.000***	[.165 - .477]
% minoritized	.001	.001	1.06	.294	[-.003 - .423]
Race_Wh	.21	.11	1.95	0.054 *	[.232 - .721]
R2	0.24				
		GENDER			
Intercept	4.78	.09	51.36	0.000***	[4.596 - 4.965]
Pre-GENDER	.09	.11	0.409	.83	[-.123 - .301]
% female	-.03	.19	-1.34	.185	[-.063 - .012]
Race_Wh	.14	.12	1.16	0.247	[-.099 - .380]
R2	0.06				

Note: p<.001**, p<.01 **, p<.05 *; N=97
Pre-SES, Pre-ELL, Pre-RACE, Pre-GENDER, % SES, %ELL, % minoritized, %female: values are grand mean centered.

Associations between School-Level Demographics and Self-Efficacy

There were statistically significant associations between pre-service elementary teachers who self-identified as White and changes in their personal self-efficacy concerning teaching equitable science for all school-level demographic groups (Table 13). In these regression models, the comparison group includes pre-service elementary teachers who self-identified as a race other than White, and all other predictor variables

are grand mean-centered. For interpretation, the intercept equals classrooms with average demographic characteristics and average pre-survey scores.

In the first model, regarding teaching equitable science to students from low-SES backgrounds, pre-service elementary teachers who self-identified as White increased their personal self-efficacy related to teaching these students by .30 points, *t*=2.53, *p*=.013, R2=.28. These results indicate that in classrooms with average numbers of students from low-SES backgrounds, controlling for average pre-survey scores and the race of pre-service elementary teachers, candidates who self-identified as white demonstrated a positive association of .30 points with their post-survey outcomes regarding their personal self-efficacy. To teach equitable science to students from low SES backgrounds. However, when controlling for average numbers of students from low-SES backgrounds, average pre-survey scores, and race of pre-service elementary teachers, pre-service elementary teachers in classrooms with a one percent increase in students from low-SES environments did not experience a significant change in their personal self-efficacy related to teaching these students (B=.003, *t*=1.31, *p*=.192).

The second model produced similar results regarding teaching equitable science to ELL students. In classrooms with average numbers of ELL students, controlling for average pre-survey scores and the race of pre-service elementary teachers, candidates who self-identified as white showed a positive association of .29 points in their post-survey outcomes about their personal self-efficacy to teach equitable science to ELL students(*t*=2.29, *p*=.02, R2=.14). In addition, when controlling for average numbers of ELL students, average pre-survey scores, and the race of pre-service elementary teachers, candidates in classrooms with a one-percent increase in ELL students did not experience

a significant change in their personal self-efficacy related to teaching these students (B=-.001, *t*=-.26, *p*=.798).

The third model ran a series of regressions on personal self-efficacy related to teaching equitable science to students from different racial and ethnic backgrounds. In this model, in classrooms with average numbers of historically minoritized students, controlling for average pre-survey scores and the race of pre-service elementary teachers, candidates who self-identified as white exhibited a positive association of .48 points in their post-survey responses concerning their personal self-efficacy. To teach equitable science to historically minoritized students (*t*=3.87, *p*=.0000, R2=.41). A one-percent increase in the number of students from historically minoritized backgrounds, when controlling for average numbers of historically-minoritized students, average pre-survey scores, and the race of pre-service elementary teachers, was not significantly associated with a change in personal self-efficacy related to teaching these students (B=.001, *t*=.68, *p*=.500).

The final model analyzed pre-service elementary teachers' personal self-efficacy related to teaching equitable science to females. In classrooms with average numbers of females, controlling for average pre-survey scores and the race of pre-service elementary teachers, candidates who self-identified as white displayed a positive association of .35 points with their post-survey measurements regarding their personal self-efficacy to teach equitable science to historically minoritized students (*t*=2.65, *p*=.0009, R2=.24). However, a one-percent increase in the number of females in a classroom, when controlling for average numbers of females, average pre-survey scores, and the race of

pre-service elementary teachers, was not significantly associated with a change in personal self-efficacy related to teaching females (B=-.01, *t*=-.88, *p*=.382).

Regarding outcome expectancy (Table 14), the only model that produced statistically significant results was the one that looked at outcome expectancy related to teaching students from different racial and ethnic groups. In this model, controlling for the average number of historically minoritized students, average pre-survey score, and the race of pre-service elementary teachers, candidates who self-reported as white showed a positive association of .21 points in their outcome expectancy for teaching historically minoritized students (t=1.95, p=.054, R2=.24) historically. In addition, a one-percent increase in the number of students from historically-minoritized backgrounds, when controlling for average numbers of historically-minoritized students, average pre-survey scores, and the race of pre-service elementary teachers, was not significantly associated with a change in outcome expectancy related to teaching science to these students (B=.001, *t*=1.06, *p*=.294).

Overall, the demographics of the field placement settings (in terms of school level % students from historically-minoritized backgrounds, % students from low-SES backgrounds, % ELL students, and % females) did not have significant associations with pre-service elementary teachers' personal self-efficacy or outcome expectancy related to teaching equitable science to these students. Simply placing pre-service elementary teachers in different diverse environments did not significantly increase their personal self-efficacy or outcome expectancy. However, for pre-service elementary teachers who self-identified as White, these contexts made a difference in their personal self-efficacy. The strongest associations (controlling for the average number of historically minoritized

students, average pre-survey score, and the pre-service elementary teacher's race) were for pre-service elementary teachers who self-identified as White; these contexts were significantly associated with their personal self-efficacy and outcome expectancy related to teaching students from historically minoritized racial and ethnic backgrounds. For pre-service elementary students, results indicate an association between field placement demographics and their self-efficacy regarding teaching equitable science to these groups of students.

Regarding personal self-efficacy, there were statistically significant associations for pre-service elementary teachers who self-identified as white; these associations were between their race and their personal self-efficacy related to teaching students from low-SES backgrounds, ELL students and females when controlling for average school-level demographics, and average pre-survey scores. However, these associations did not produce statistically significant results concerning outcome expectancy. Pre-service elementary teachers who self-identified as White experienced an increase in how confident they felt teaching diverse students because of their field placement experiences with diverse students. However, except for historically minoritized students, pre-service elementary teachers do not experience a change in how confident they feel about attaining learning goals and outcomes because of their field placement experiences with diverse students.

Summary

First Research Question

My first research question asked: How do pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to equitable science change

over their field placement and science method coursework experiences? Results from a two-tailed t-test analysis indicate that pre-service elementary teachers had statistically significant positive changes (pre- and post-measure during science methods coursework) in their personal self-efficacy with regard to teaching ELL students, students from low-SES backgrounds, and students from different racial and ethnic backgrounds. However, there were no statistically significant changes in pre-service elementary teachers' self-efficacy related to teaching equitable science to females.

Regarding outcome expectancy, pre-service elementary teachers reported mixed changes in their outcome expectancy as a possible result of science methods coursework and field placement experiences. Pre-service elementary teachers had significant positive changes in their beliefs that they could create equitable learning outcomes for ELL students. However, there were statistically significant decreases in their outcome expectancy for females and students from low-SES backgrounds.

The conflicting results are similar to other empirical research on pre-service elementary teachers and their self-efficacy related to teaching science (Cantrell et al., 2003; Ginns et al.,1995). Cantrell et al. (2003) found significant positive changes in personal self-efficacy compared to outcome expectancy. Their study showed no significant differences in outcome expectancy beliefs, but personal self-efficacy scores increased significantly. On the other hand, Ginns et al. (1995) found the opposite to be true. In their study, outcome expectancy increased, but personal self-efficacy decreased.

Self-efficacy changes throughout a teacher's education experiences (Webb & Ashton, 1986), and negative efficacy reflects confidence cycles with pre-service elementary teachers. My results indicate that pre-service elementary teachers experienced

statistically significant gains in their confidence concerning teaching students from different racial and ethnic backgrounds, ELL students, and students from low-SES backgrounds; these gains seem associated with their preparation experiences. They also believed they could create equitable outcomes (outcome expectancy) for ELL students. However, they experienced decreases in efficacy with regard to creating equitable learning outcomes for students from low-SES backgrounds and females.

Second Research Question

My second research question contained two parts. First: What are the associations between pre-service elementary teachers' program coursework (which includes both science content courses and courses on diversity, equity, and inclusion) and their (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science? Results from my regression analysis, which compared coursework experiences among programs, suggest that courses in DEI have a positive association with pre-service elementary teachers' personal self-efficacy with regard to teaching ELL students (when controlling for explicit DEI coursework and pre-survey score). However, regarding outcome expectancy, when comparing programs, Sassafras candidates had negative outcome expectancy changes related to teaching equitable science to students from low-SES backgrounds and different racial and ethnic backgrounds. Sassafras candidates also had negative personal self-efficacy and outcome expectancy related to equitable science instruction for females.

The mixed results from this work align with some findings from Akiba (2011). In this large-scale survey study, the author concluded that pre-service teachers' beliefs about supporting diverse learners did not change due to taking one diversity course or field

experience. In my work, there are changes, but it is difficult to infer a strong reason for the changes based on coursework experience. Like other research, my study's five teacher education programs did not centralize multicultural, culturally relevant, or culturally responsive education as a primary focus (Villegas & Lucas, 2002). Three programs offered explicit DEI coursework; two stated that they embedded this content in their curricula. It is difficult to tease apart what embedded Diversity, Equity, and Inclusion coursework means without completing a document analysis of every course syllabus and interviewing every course instructor. This work was beyond the boundaries of this dissertation but leaves opportunities for further analysis.

When comparing these five programs, one inference that can be drawn from the findings is the need for more research. Suppose pre-service elementary teachers enrolled in Sassafras had less confidence in creating equitable learning outcomes for students from low-SES backgrounds, students from different racial and ethnic backgrounds, and females when comparing the program to Maple. In that case, more work must be completed to determine what could be causing the difference. It was beyond the scope of this work to provide a complete program evaluation, but the results warrant further inquiry.

The second part of question two asks: What are the associations between field placement characteristics (which included % SES, % ELL, and % historically marginalized students and pre-service elementary candidates' (a) teaching self-efficacy and (b) outcome expectancy related to teaching equitable science? Regarding personal self-efficacy, when controlling for mean pre-survey score, mean school-level student demographics in the classroom, and pre-service elementary teachers' race, there were

statistically significant positive associations for candidates who self-identified as White between their field experiences and their personal self-efficacy related to teaching students from low-SES backgrounds, ELL students, students from historically minoritized races and ethnicities, and females. There were additional statistically significant results in outcome expectancy when controlling for mean pre-survey score, mean school-level student demographics in the classroom, and pre-service elementary teachers' race. In these models, there were statistically significant positive associations for pre-service elementary teachers who self-identified as White between their field experiences and their outcome expectancy for teaching students from historically-minoritized backgrounds. However, there were no changes in pre-service elementary teachers' personal self-efficacy or outcome expectancy related to the percentages of different demographic groups of students in schools.

This work extends similar research with pre-service elementary teachers and their self-efficacy related to equitable science teaching. Settlage et al. (2009) found that placing pre-service elementary teachers in diverse field placement settings produced marginal changes over time, and additional qualitative interviews revealed no discernible changes in teacher identity that could be attributed to the demographics of their field placements. Placing pre-service elementary teachers in diverse settings did not increase their self-efficacy with regard to working with diverse students. Cone (2009) concluded that the community-based service-learning experience (compared to traditional university-based course experience) increased outcome expectancy but not personal self-efficacy for pre-service teachers related to teaching diverse students. The results from my analysis indicate that for pre-service elementary teachers who self-identify as White,

diverse field placement settings make a difference in their self-efficacy concerning teaching equitable science.

Limitations

My regression analysis for question two used a relatively small convenience sample (N=97). The participants self-reported outcomes on a coarse scale (1 to 5). There is likely some measurement error in the data given this scale. I provided an extensive descriptive analysis to provide context for this work. I have been intentionally modest in my conclusions because while there are some notable associations, they truly lead to more questions. In furthering this work, I now turn to the qualitative results to further understand how pre-service elementary teachers conceptualize equitable science instruction.

CHAPTER 5: QUALITATIVE FINDINGS AND DISCUSSION.

The following chapter will outline the qualitative results to answer research question 3: How do pre-service elementary teachers conceptualize equitable science education?

This section commences with a concise, descriptive synthesis of the eight participants, encompassing their motivations for pursuing a teaching career and their overarching perspectives on learning and instruction. Such an overview establishes a contextual framework for the ensuing analysis.

Subsequently, the chapter will elaborate on the discoveries derived from the thematic analysis, complemented by a visual illustration (Figure 3) that delineates the emergent themes and their association with the pre-service elementary educators' conceptualization of equitable science instruction. Emphasis will be placed on the recounting of an Asian American participant's experiences as a counternarrative within the theme of advocacy, aimed at challenging the normativity of whiteness within the qualitative findings. In summation, the chapter will integrate the thematic analysis with the conceptual framework to illuminate how pre-service elementary educators conceptualized equitable science education.

Descriptive Findings

The eight pre-service elementary teachers who participated in the qualitative interview portion of this work all had varied experiences coming into education. Table 15 describes each participant’s age, gender, race/ethnicity, educational degree, and teacher

education program. Participants were primarily female and 21 years old (on average); seven were white, and one was Asian American. Three pre-service elementary educators were enrolled at Oak, two were attending Locust, and three were from Maple. Four participants were pursuing their B.A. in elementary education, and the other four were pursuing their M.A. in elementary education.

Table 15:

Interview Participant Demographics

Participant	Age	Gender	Race	Program	B.A. or M.A.
Jennifer	20	Female	white	Oak	B.A.
Charity	23	Not Listed	white	Oak	M.A.
Agnes	20	Female	white	Oak	B.A.
Emily	22	Female	white	Locust	M.A.
Katie	22	Female	white	Locust	M.A.
Elenor	20	Female	white	Maple	B.A.
Kristina	23	Female	Asian American	Maple	M.A.
Carry	N/A	Female	white	Maple	B.A.

Note: Gender options on the survey were female, male, binary, and not listed. Carry did not share her age.

Why Teaching?

In an inquiry into the motivations behind pursuing a career in teaching, half of the respondents disclosed that they were influenced by familial ties to the profession, with their mothers serving as educators. Among these individuals, three out of four initially pursued academic pursuits in disparate fields such as business, accounting, and dentistry. However, they felt a compelling pull towards education, attributing their shift to a latent desire to teach. Other pre-service elementary teachers cited diverse sources of inspiration for their career choice, ranging from participating in programs like Teachers for Tomorrow and the America Reads Program to engaging in local community college career development initiatives. The influence of educators from various disciplines, including English, history, and geology, was also highlighted as a significant motivational factor. One individual recounted a personal struggle with anxiety during their educational journey, which motivated them to pursue teaching to advocate for students requiring assistance with social-emotional health.

Reflections on Learning and Teaching

The participants considered the different ways individuals prefer to receive and process information. Some pre-service elementary teachers centered learning on their own experiences. Others thought about learning through the lens of their students. Additionally, one participant observed that learning is intrinsically linked to teaching, highlighting the teacher as a role model for learning. Each perspective adds a distinct layer to the complexities of learning within classroom settings and shapes the foundational concepts of learning and teaching for the candidates included in this study.

While the concept of learning styles is appealing and widely recognized, it lacks robust empirical evidence to support its effectiveness in improving learning outcomes. Still, some pre-service elementary teachers reflected on learning styles and expressed affinities for certain types of lesson delivery. From her lived experiences, Jennifer reflected on her learning preference and generalized her experience when conceptualizing learning. She stated,

> " I think people learn differently. I know that the learning styles things are controversial. However, I think that, and I don't think that anyone is restricted to one learning style. Still, I think I understand better by engaging in discussion and being like, lectured in a way, um, I have friends who, like, are better with just reading their textbook. They can't focus on lectures, and I do well when I can take notes, and I know people who record their lectures to listen to them."(*Jennifer, fall, 2022*)

Agnes echoed similar thoughts on learning. Through her experiences, she noticed that how she processes information might differ from that of her peers. When asked how people learn, she explained:

> "I think that people have different strengths when it comes to learning and like different methods that work best for them. Like, for me, I a note taker. I need to do every page of reading and take notes on it. Otherwise, the material doesn't go on my mind. But like, I know, some people that can just sit there and absorb material when they listen or like prefer to do hands on activities and stuff. So, I've definitely seen that within my friends. (*Agnes, fall, 2022*)

Chrissy reflected on differentiation. When I asked her about learning, she thought about her students. Instead of focusing the conversation on learning styles, she talked about differentiation:

> " I think about how I am going to make this lesson so that all the students understand what's going on, and how they can all explain to me like, you know, how they understand the material. Differentiation is important. And I think that's also true in every single subject, because not all students learn the same way."(*Chrissy, fall, 2022)*

Kristina acknowledged that not all students would learn science the same way. She focused her reflections on learning within the context of student demographics:

> "I feel like there's so many different factors you have to take into consideration like, race, and if they're an English language learner, if they're a student with, like a disability and need accommodations, and I feel like in science, especially since it is so like, male dominant, gender is also a factor."*(Kristina, fall, 2022)*

Finally, when asked about learning, Cary reflected on learning as connected to good teaching, shifting the importance of learning to delivering instruction instead of centralizing the learner. She highlighted the teachers' role as a model for learning.

> "If you see someone who is passionate about something, see someone you admire, you will want to strive to be like that person, or at least have the same drive. And probably try to emulate them in whatever way you can. I think that's probably the biggest motivating factor, especially for young kids, I would say like role models are just such a huge part of learning and growing up." *(Cary, fall, 2022)*

The dissemination of these initial findings presented descriptively, lays the groundwork for understanding the conceptions held by pre-service elementary educators regarding their roles within the classroom context. The individuals interviewed embarked on their teaching careers motivated by various factors, including parental influence, inspirational educators, a commitment to mental health advocacy, or engagement in specific pipeline programs designed to facilitate entry into the teaching profession. Notably, an explicit dedication to advocating for social justice did not emerge as a primary motivator for these pre-service elementary teachers' entry into the profession. Instead, influences such as familial backgrounds, educational experiences, and structured support programs have contributed to the cultural replication of the teaching profession's demographic composition, predominantly young white women in this study.

The constructivist schemas underpinning these pre-service teachers' approaches to learning are predominantly shaped by their personal experiences, reflecting a spectrum of individual preferences, competencies, and capacities. Given their novice stage in the profession, these educators are concurrently navigating their roles in the learning process and their identities as exemplars for their pupils. This aspect warrants emphasis considering the inquiry into their conceptualizations of equitable science education. They are recalibrating their instructional focus towards student-centeredness, a shift that necessitates moving beyond a self-centric pedagogical orientation.

Building upon the preceding discussion, the subsequent section is dedicated to delineating the thematic outcomes of the qualitative interviews. This portion will accentuate the diversity of participants' perspectives, categorizing them across a continuum within each domain of meaning construction. The conclusion of the thematic analysis will be marked by emphasizing the counter-narrative provided by Kristina, the sole Asian American participant in the sample, to de-emphasize whiteness within the findings. Kristina's narrative, wherein the theme of advocacy is recurrently echoed in various facets, will be positioned at the forefront of the discussion on advocacy, thereby centralizing her experiences within this thematic context.

Thematic Findings

Continuum of Understanding

Figure 6 delineates the five central themes that surfaced from analyzing participants' responses regarding their conceptualization of equitable science instruction. These emergent themes are science self-efficacy, recognition of different worlds, facilitation of students’ participation in science, cultivation of critical consciousness, and

advocacy. Each theme encompasses a range of understandings, indicative of the spectrum of interpretations among participants. The identified constructs demonstrate interconnectivity, with the pre-service elementary teachers' perceptions of equitable science education oscillating among the various layers of comprehension.

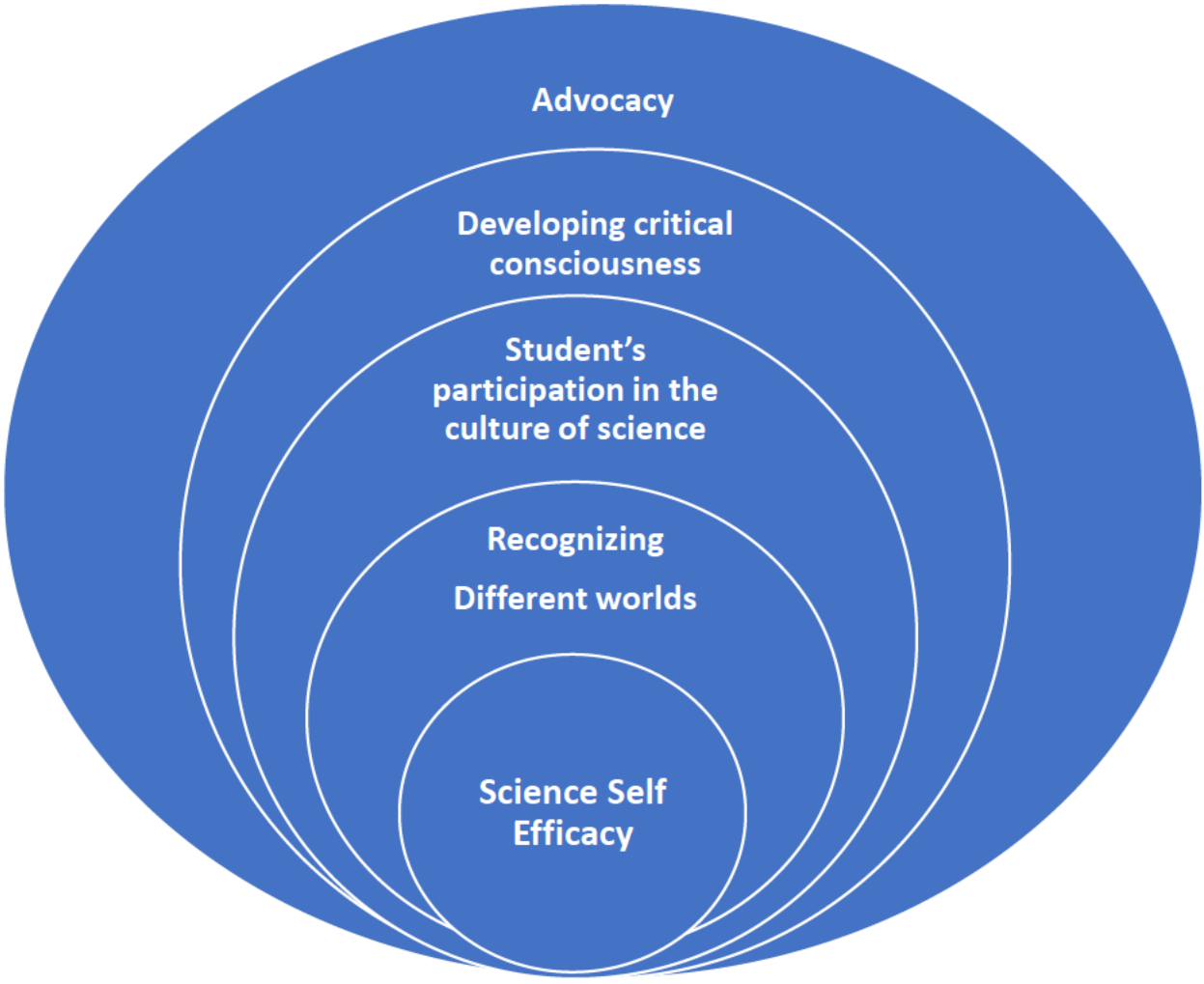


Figure 6: *Pre-Service Elementary Teachers' Conceptualization of Equitable Science Instruction*

Science Self Efficacy

To conceptualize equitable science teaching, pre-service elementary teachers must first develop confidence to teach science. Participants shared mixed experiences with science, discussing the challenges of teaching different content, thinking about state curricula, and reflecting on their experiences with learning science. Most participants had lower self-efficacy related to teaching science, although some felt excited about learning specific content.

Reflecting on their self-efficacy with science, these pre-service elementary teachers indicated that their confidence depended on the grade level and science content matter they were teaching. Jennifer noted she felt less confident teaching grade levels that might have more detailed science content. She reflects on the science content in layers of specificity instead of distinct units:

> "It depends on the grade level. Because, you know, fourth grade is more specific, many more details go into it versus, like if you teach second and below. But also, I think there is room for growth for me to teach these materials" (*Jennifer, fall, 2022*).

Elementary teachers are expected to teach Biology, Astronomy, Earth Science, Chemistry, Physics, and Engineering, all addressed in their science curricula frameworks. Elenor explained that the broad range of content required at the elementary level would be challenging to master:

> "I've always struggled in Biology. I can look over paper before I teach it, and, you know, memorize the facts. But I might have struggled with that, because I don't honestly remember everything that I learned in elementary school. I might have a hard time with teaching genetic makeup and stuff like that especially if I was to teach an older elementary grade " (*Elenor, fall, 2022).*

Charity felt that bridging the connection between having a rigid set of state standards and then being able to explore what students were interested in would be challenging. Her efficacy was related to having autonomy over curricula rather than focusing on explicit science content:

> "The Standards of Learning (SOLs) aren't necessarily everything that students need to know or should know. You know, there's other forms of knowledge that are just as important. So I feel like that's the hardest part is just kind of like building a bridge between here's what I need to teach, and whatever other tools and things that my administration expects me to teach in the classroom, bridging that with okay, like, here are some other things that maybe are written on paper that are just again, just as important to teach."(*Charity, fall, 2022*)

Participants also reflected on their experiences with science learning and how that was connected to their self-efficacy related to teaching science. For Kristina, she did not enjoy her science classes at her university, which had over 500 students housed in a lecture hall. She had difficulty when the science content was more abstract:

> "Everything in chemistry is so small on like the molecular level. I could not visualize what this was all. It didn't feel relevant to me, very abstract." (*Kristina, fall, 2022*)

Others reported that they liked the hands-on component of science, but when it came to understanding the science content, they felt less confident. For example, in Katie's words,

> "I'm not very scientific, just because it is not something that has interested in me. To be honest. I think I really enjoyed my physics class, my freshman year of high school, it was a lot of experiments. I think when I started to dislike it was when it came to the exam. And I had to know the equations" *(Katie, fall, 2022).*

Finally, some pre-service elementary teachers do not enjoy science. According to Carry,

> "There definitely were science teachers that I had that I enjoyed, and I thought that they were very enthused. They did a really good job of teaching us the information in a fun and engaging way, but I just, personally, never ever really liked science. I want to be the kind of teacher who puts forth the energy that like oh, I love this. Like I love what I'm

> teaching you guys. But yeah, I can't say that. It was ever my favorite subject." (*Carry, Fall, 2022*)

Additionally, Emily expressed similar reflections on science:

> "I just don't consider myself a science person. Because I feel like it really challenges me in a way that I've found that I don't like." (*Emily, fall, 2022)*

In summary, self-efficacy related to science teaching was generally low across the interview participants, although there were nuances in experiences. These pre-service elementary teachers highlighted different elements of the curricula that they felt would be challenging. These reflections were on content-specific topics, grade-level specificity, and enactment issues. The participants also highlighted how they had experienced science and reflected that these experiences defined their self-efficacy. Finally, a few pre-service elementary teachers reflected a lack of affinity toward science. Whether this stemmed from personal habits of mind or the challenges of understanding science, they didn't enjoy the content.

Recognizing Different Worlds

The participants recognized the importance of building relationships with their students to bridge experiences between curricula and the students' worlds. Upon inquiry regarding the presence of diversity within their science classrooms, they offered numerous reflections on its definition and importance. On one side of the spectrum are pre-service elementary teachers who never really thought that diversity mattered in science. Others treated diversity as a checklist, enumerating categories without making meaningful connections to their students' experiences. Progressing towards a deeper level of acknowledgment, a subset of participants recognized the diverse backgrounds from which students originate yet remained detached from these experiences due to language

barriers. At the opposite end of the spectrum, some pre-service teachers perceived diversity through the lens of students' perspectives, advocating for integrating students' experiences as valuable assets within the classroom environment. This group was attentive to the dynamics of inclusion and exclusion, actively considering both the presence and absence of students in the classroom discourse.

Elenor was taken aback when I asked about diversity in science class. To her, science should be devoid of culture, so she never considered it. She was focused on the science content and was not worried about connecting it to students' experiences. She stated,

> "I've never really thought about it just because I'd never really thought it made much of a difference. Like the background they come from, like, in my experience from student teaching, like when I've done my science lesson plans, it's never really like, jumped out at me the diversity, right? Students are just in science. I never really thought about it." (*Elenor, fall, 2022*)

When I asked about considering diversity in science classrooms, a few other pre-service elementary teachers rattled off a checklist of the term's meaning. They included different categories, such as students with various (dis)abilities and students with different religious beliefs. For example, Katie noted,

> We have students of many different races and ethnicities. We have a few kids with Individual Education Plans(IEP's). We have three ELL learners. We have a student who I think is in the process of getting tested for like neuro divergence and things like that. So like, a very different, like group of students."*(Katie, fall, 2022)*

Katie can recognize that different students will need different support in her classroom, but she does not mention how to support these students. Students are listed as "*a very different*" group, but there is no connection to what this might mean for their learning.

Agnes has had a different experience in her field placement. When I asked Agnes about diversity, she related a story about a new immigrant student from Mexico. Her new student does not speak English and has been relying on another student in the classroom who speaks Spanish to help navigate and adapt to school in the United States. She reflects,

> "Just even like the past month that I've been in there, just see how he (the new student) has started to figure out the flow of the classroom, and stuff. And I can't even imagine, like, I can't understand anything that's, you know, being said. But I think it's, I mean, teaching science versus teaching anything. It's just good to be aware of like, where these kids are coming from in terms of their home life, family life. Their cultures, obviously, can be completely diverse and different. So if I, personally, I would just always want to, like, really get to know my students and be aware of you know, where they are coming from, so that I can either add things to my lessons or, you know, take things away, whatever needs to be done to make sure that they are comfortable in the classroom." (*Anges, fall, 2022*)

When I asked Agnes if she could speak Spanish, she stated,

> "I wish I could talk to him fluently. Like, I tried to look up a little bit of Spanish because I used to take Spanish, but I'm not fluent. I didn't do it all through high school or anything. I don't really have even like conversational level. I need to, like get back up on it. Yeah, it's so cute. And I just feel I feel for him. I'm like, oh my gosh, I wish I could really communicate with you." (*Agnes, fall, 2022)*

Agnes has empathy for her ELL student; she wants to be able to communicate with him. She separates her lived experiences from his by not prioritizing her Spanish learning. She does not mention using any translating software or any other communication tool. Thus, she recognizes the student and the student's needs but isolates herself from bridging the gap between her world and her student's lived experience. This leaves the student isolated in class, relying on his classmate for translation.

Charity had a different reflection on diversity. When I asked her what diversity in science meant, she explained,

> "I think diversity to me, means recognize recognizing, I think, who is in your classroom, and then who is not in your classroom? And really thinking about the perspectives that are in your classroom and saying, okay, like, what perspectives are here? What perspectives are missing? And how can I accommodate for that, and I think the other part of diversity is, again, is, as I said, before, equality is not giving everyone the same thing. It is giving everyone what they need. I think that's the other part of diversity is understanding your students, understanding where they come from, what their interests are, what their languages, their culture. And from that background knowledge thinking, okay, like, how is my how is this student going to learn best? And it might not be the same way another student learns." (*Charity, fall, 2022*)

Charity's response reflects a deeper understanding of diversity. She recognizes students as humans with perspectives and includes those not in the classroom. She thinks about students' understanding and notes that diversity is knowing who your students are, their cultures, and their backgrounds. She reflects on these experiences as assets. Recognizing multiple perspectives in the classroom is rich and vital when conceptualizing equity.

In summary, when pre-service elementary teachers conceptualize equity, they begin by recognizing diversity in science learning. To do this, they must acknowledge different perspectives and different world views. There are a range of reflections when it comes to diversity in science. Some participants never considered diversity in science teaching. Science was separate from culture. For other pre-service elementary teachers, diversity is a list of student demographics or accommodations you must adhere to, including students with (dis)abilities and ELL students. Moving towards a richer understanding, Agnes reflected on an ELL student who recently immigrated to the United States. Although Agnes empathized with her student, she kept her world separate from his and maintained the language barrier despite different technologies that could have bridged the two worlds. Finally, Charity recognized diversity in terms of students'

perspectives. She acknowledged that students have multiple ways of understanding and advocated supporting students' diverse classroom knowledge. She also acknowledged the perspectives that are not present in the classroom.

Students' Participation in Science

Another theme from the interview data was pre-service elementary teachers' reflections on students' participation in science. Participants reflected that with the right resources, all students should be able to succeed. There were also reflections about differentiation in the classroom. Some pre-service elementary teachers highlighted forming connections between science learning and the students' lived experiences, fostering diverse sensemaking with their students. Other participants highlighted using culturally responsive practices to support students' participation in science. Within this theme were a range of reflections, but all pre-service elementary teachers included supporting students in their conceptualization of equitable science.

Kristina shared that she had low self-efficacy to support the participation of all students in science. She mentioned that with the proper resources, every student should be able to succeed, but she questioned whether she was prepared to deliver differentiated instruction. She stated,

> "I guess because I haven't seen a lot of instruction in science. I don't know what different differentiating necessarily looks like. And I feel like it's because science is a field with a lot of like tier three vocabulary, very technical language, especially for English language learners. I'm not sure how I would be able to scaffold instruction."(*Kristina, fall,2022*)

Kristina's focus on vocabulary probably came from her field placement experiences. She noted that she was placed in a classroom with many ELL learners, which might have influenced her focus on vocabulary instruction. Kristina also mentioned differentiation,

which was the focus of other pre-service elementary teachers in the study. For example, Emily explained,

> " I think it's important for them to be able to apply it to understand it. I definitely think that there's a lot of differentiation that needs to happen in science."(*Emily, fall, 2022)*

Regarding how they would differentiate the curriculum, some pre-service elementary teachers stated that creating connections with students and highlighting students' diverse sensemaking was part of differentiation. For example, Jennifer reflected on making connections with students:

> "I mean, I guess the ones that are going to succeed are probably students who are able to make connections between the classroom and their own lives, like make it relevant. If you can make your teaching relevant to your students, they're more likely to succeed." (*Jennifer, fall, 2022*)

Emily expressed similar thoughts about students' sensemaking. For Emily, differentiation is a process through which teachers can support students' diverse sensemaking. In her words,

> " I can work from what I know. And what I know will be different from what other people know. But that's okay. It's essential to build that diverse sense-making and the efficacy of that with students so that they know that it's okay to have different perspectives and learn other things. And that's encouraged."(*Emily, fall, 2022)*

Finally, Katie talked about differentiation with explicit tools. She envisioned enacting science curricula with different groups of students. What was different in her response was a leaning towards supporting culturally responsive teaching as part of differentiation. She noted,

> "I try to not simplify my vocabulary but make it a little more like I could explain it easier. For the kids with IEP s, I try to make very kid friendly notes, so that it was easy for them to take notes and things like that. I really want to understand and research more about culturally responsive

> pedagogy. That's something I'm really interested in. I think it's important." (*Katie, fall, 2022*)

In summary, when the pre-service elementary teachers in my sample thought about creating equitable science spaces, they conceptualized supporting all students' participation in science. For example, Kristina's self-efficacy related to using vocabulary instruction in science was still growing. She felt unprepared to support all learners in science with this tool, and she reflected that she needed more support in differentiation. When I asked about supporting diverse students, many participants discussed differentiation as part of equitable science instruction. Their definitions of differentiation included creating connections with students, helping students with diverse sensemaking, and using culturally responsive pedagogy.

Developing Critical Consciousness

Another theme that emerged from the data was the development of critical consciousness. When thinking about creating equitable spaces, some pre-service elementary teachers were able to reflect upon the systemic structures that limited learning opportunities for some students. In congruence with other findings, this theme emerged with participants placed along a continuum of understanding.

Emily stated that one of her field placement experiences was at a school with many ELL students. When I asked about the additional school-level support for these students, she noted,

> "It was difficult because they didn't have anybody to translate for them. Because most of the teachers didn't speak a second language. And that was difficult to see. Because they were like, asking fellow practicum students who could speak two languages to translate, and to talk on the phone to the parents. I thought that was hard. Because, you know, as a school, you should have those resources. It's sad to see that you don't have those resources. And for all students, it makes it difficult." (*Emily, fall, 2022*)

Emily's reflection on her field placement setting exemplifies her pushing back and developing critical consciousness. When she states that the school "*should have those resources*" for the ELL population, she critically reflects on the situation. However, she does not move beyond this critical reflection into advocacy. She does not mention if she played a role as a translator or helped with translating. She shares the scene as an observer, not an actor.

When I asked Cary about creating equitable spaces, she described a self-reflection about a science lesson she taught. She noticed different cultural norms around behavior and developed critical self-awareness about her responses to students' behavior. After her science lesson, she explained,

> *"*I reflected afterward because I had students who are jumping out of their seats and raising their hands, but I'd ignore them in favor of someone who was sitting quietly, and I reflected after my lesson about how they were showing me their interest in a different way. It's something I try to do a lot." (*Carry, fall, 2022*)

Continuing to be aware of your position in the classroom is a crucial step toward developing critical consciousness in those spaces. Carry's thoughts about behavioral "norms" and noticing who is getting attention and who is not are vital to becoming a culturally responsive educator. She can reflect on behavior "norms" but does not name where these structures of "normal" behavior come from. She does not acknowledge the presence of whiteness and white behavioral "norms" in that space.

Charity had a high level of critical awareness. When I asked her about creating equitable spaces, she shared her critical reflections on what it means to be good at science. According to her,

> "I think that when we say good at science, I feel like the wording there is very important to consider, and I believe that some students are going to

> come with an advantage, right? If you come from a higher socio-economic status, you're going to have more books at home, you're going to have more resources available. And you might have more time to, or you might have a tutor or something like that, to help you with your understanding of science. I feel like some students, depending on their socio-economic background, race and gender, I feel like looking at the intersectionality of those, if you're a white student from like, a wealthy middle class, upper middle class background, and you're coming to science, you might have a little bit more of an advantage of information, you know, of having more access to book resources."(*Charity, fall, 2022)*

Charity acknowledged that systemic inequities in access might prevent some students from being "good" at science. She is aware of the racial, gender, and SES inequities that prevent sure students from accessing the same resources. She is also critically aware of whiteness and how privileged white middle-class students are in our institutional settings.

In summary, when I asked the pre-service elementary teachers in my interviews about creating equitable spaces in science, there was a range of responses. The theme that emerged was the development of critical consciousness. Some participants were able to reflect on the inequity in the institutional structures that support ELL students. Others could be reflexive about their practice, utilizing culturally responsive reflexiveness in their work. Still, others were able to critically push back on the idea of being a "good" science student and highlight the opportunity gap that is created because of SES status, race, and gender. Despite all these reflections, none of the pre-service elementary teachers could position themselves as participants in systemic injustices. They were not yet able to tackle their whiteness in the system of inequity. They conceptualized equitable science as something that deals with systemic oppressive systems but did not critically reflect on their whiteness in classroom spaces.

Advocacy

The last theme that emerged was advocacy. To explicate this finding, I will highlight Kristina's counter-narrative. Kristina was the only pre-service elementary teacher I interviewed who self-reported her race as Asian American. Her reflections are highlighted here for two reasons. One is to try to de-center whiteness in the findings from my sample by applying Critical Whiteness and highlighting a counter-narrative on advocacy. Second, her thoughts on equitable science instruction are distinct because, in several instances, she reflects on different ways to advocate for educational equity. She mainly frames her advocacy around her own experiences (instead of directly supporting her students). However, she has experienced different forms of marginalization that have pushed her to self-advocate. These experiences were distinct in my sample.

Kristina first experienced feeling marginalized while still in high school. When I asked about her experiences as a learner, she related a story about her mathematics teacher.

> "I went to a really small high school. So all the departments were really small. And it was really it was really likely that you would have the same teacher for multiple years. And so I had a math teacher that I did not particularly get along with. And she was the only calculus teacher in the building. So I had her for precalc calculus and AP Calc, which was not not so great. And I was supposed to have the opportunity to take a college level math course, my senior year, instead of instead of taking a class at the high school, and since I was a high school student, the division was going to pay for it. So that would have been super nice. But she told me that she didn't feel like I was prepared to do it. And would not let me continue. And that was super frustrating, because the next year, there were students that were also in that like, accelerated program that were supposed to take the college course. And she told them, no. But her parents were doctors and very involved in her education. So they went to, you know, the principal, the school board, everything to complain, and they got her into the classes. So it's, I mean, it's a lot of like, issues of equity and all that with that situation." (*Kristina, fall, 2022*)

I asked Kristina whether this result was because of discrimination. Did the mathematics teacher dislike Kristina because of her race, gender, or SES status? Kristina explained,

> “I don't think it was like a personal thing, because like, she had also told the students that she didn't want her continuing as well. I think it's more of like a socioeconomic status. Like, I had a pretty abusive childhood. Like, I did not have parents that were present to advocate for my education, whereas the other students did.” (*Kristina, fall, 2022*)

Kristina’s reflections on advocacy are critical to fighting for equity in education. In her story about the math teacher, if she had parents who could have advocated on her behalf, she would have been able to take the college math class. Reflecting on the situation and pushing forward beyond barriers for the learner's needs is vital when conceptualizing equitable instruction.

Kristina also discussed times when she had to self-advocate in her field placement setting. When I asked if she had taught a science lesson, she said she had just switched placement classrooms. In her previous field placement classroom, more than half of the students were ELL students. When I asked Kristina why she switched, she explained.

> “ I switched because she (the mentor teacher) just didn't; it was a lot of racial inequalities in the classroom like these students were not provided with what they needed to succeed. I had a student who could not write his name (second grade) And he was not given any additional support. He would just like sit there during instruction time and like play and when it came to, like, work time. Like, I mean, there's two of us and like, 20 kids, so I couldn't sit there and like, work with him the whole time. But it'd be like, a good thing if we could get him to write his name. Yeah, just like trace what I wrote. That seems like a really important life skill to have. I know, it sounds kind of bad, but I truly do not think that she cared. Like, she was always saying, like, Oh, I'm so close to retirement, and I just want to be done. And I don't want to do this anymore. So I think she was just kind of getting through until she could be done and do the bare minimum.” (*Kristina, fall, 2022*)

Kristina knew this situation was terrible and advocated for a different field placement setting. She described what was happening in the classroom with these students through advocacy. Thus, tangentially, she also advocated for them. Kristina was aware of the

inequitable situation, reflected on it, and pushed against it. In this way, Kristina is conceptualizing equitable instruction by including advocacy.

I asked Kristina about additional support she might need to enact equitable science instruction. In her words,

> "I think we need an entire class just on, like, equity in the classroom and social justice issues and stuff like that. I think that would be beneficial. And then also having people in our cohort that are not all, like, white cis-gendered females, like we need a more diversified group and bring in people of different backgrounds to be able to, like have these kinds of important discussions like not that we cannot have them, but like the entire cohorts pretty homogeneous." (*Kristina, Fall, 2022)*

In her reflection, Kristina pushes back on the homogenization of the teaching workforce, which is powerful. She is advocating for more support in creating equitable science spaces and including diverse perspectives in our conversations about equity. In this way, she is fighting against centering whiteness and using her critical voice to advocate for change.

Kristina's narrative is given precedence within the advocacy theme due to the pivotal nature of her experiences in conceptualizing equitable science instruction. Teachers must be emboldened to validate their students' experiences and advocate on their behalf, thereby fostering equitable educational environments. Kristina's experiences serve as exemplars of this theme in various aspects. Her experiences and perspectives are accentuated through her counter-narrative, which shifts the focus away from the predominantly white voices within the sample.

Discussion

The pre-service elementary teachers in this study conceptualize equitable science instruction in various ways. Their experiences are nuanced and layered

within a continuum of understanding. I presented my findings as a set of five interlocking themes (Figure 3), and participants fluctuated between these different layers of understanding. For the discussion, I will connect these findings to my conceptual framework (Figure 4).

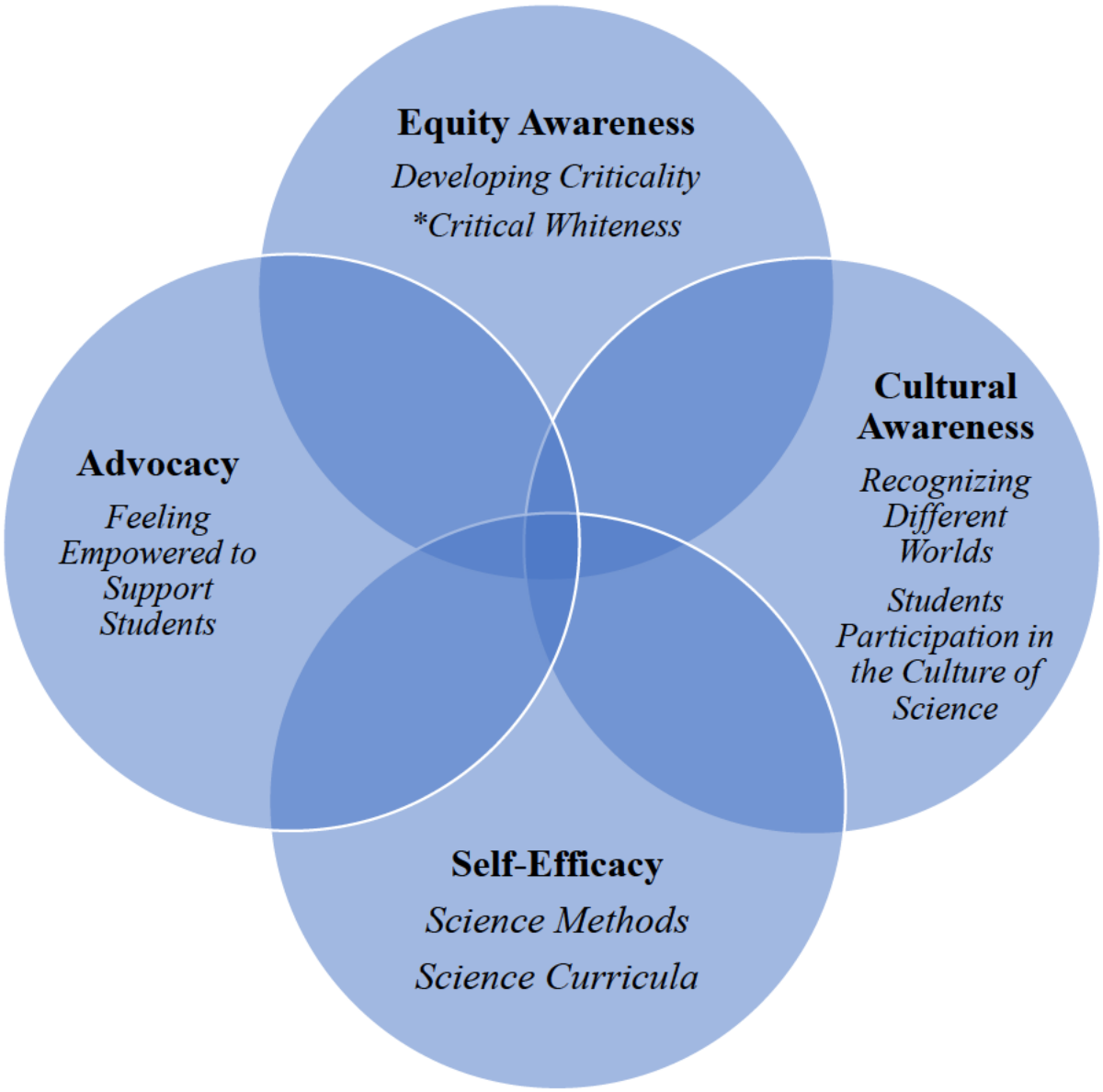


Figure 7: Conceptualization of Equitable Science Instruction

Self-Efficacy

The pre-service elementary teachers participating in this study contemplated their relationship with science in the context of equitable science education. The qualitative analysis unearthed subtleties in the participants' self-perceptions of efficacy in science instruction, with a predominant sentiment of hesitancy toward teaching science. The teacher candidates within the interview cohort articulated apprehensions regarding their command of scientific knowledge and the breadth of content they were expected to master. Additionally, they voiced reservations concerning their science identities and expressed trepidation about exercising independence in curriculum content decision-making while adhering to strict state-mandated curriculum frameworks.

Research has demonstrated that there is a strong association between pre-service elementary teacher's self-efficacy related to teaching science and their science methods coursework (Bleicher, 2007; Bleicher & Lindgren, 2002; Cantrell et al., 2003; Jarrett, 1999; Settlage, 2000). This follows Bandura's (1995) self-efficacy theory and Palmer's (2006) assertions that the cognitive pedagogical mastery experiences embedded in science content courses support self-efficacy related to science teaching. Thus, science methods courses generally support pre-service elementary teachers' science self-efficacy. My findings indicate that additional support from science methods coursework could help increase pre-service elementary teachers' self-efficacy to teach all science content and should aim to support their identity development as science teachers.

From my findings, a novel reflection about having autonomy over curricula provided new questions about the role of standards in supporting pre-service elementary teachers. Learning standards are essential to ensure that all students receive the same

curricula, but grappling with centering students' life experiences while adhering to standard curricula can be challenging. It makes me wonder how we can create spaces for pre-service elementary teachers to envision creating authentic learning experiences crafted by students wondering about science and help them connect these lessons to the standards of learning that must be followed. Elementary teaching candidates might need more opportunities to enact these lessons in their field placements or through their science methods courses. My findings indicate that self-efficacy related to equitable science teaching is integral to how pre-service elementary teachers think about equitable instruction. Additional support to feel confident to teach science should come from their science methods coursework experiences and opportunities to enact science curricula.

Cultural Awareness

Pre-service elementary teachers shared that equitable science instruction was based on being able to recognize different worlds and that it was necessary to support students' participation in science. I framed these findings under cultural awareness (Figure 4). When pre-service elementary teachers are given explicit scaffolds to enact culturally relevant pedagogy, they can recognize different worlds and support students' participation in science (Aguirre et al., 2012; Mark & Id-Deen, 2022; Mensah, 2009; 2011; 2022).

In my findings, a spectrum of responses reflected participants' conceptualization of culture in science. Without the proper scaffolding, some pre-service elementary teachers do not see culture in science, and this finding is also reflected in Mensah's (2022) work with pre-service elementary teachers. Others shared deficit perspectives (Milner, 2010), reflecting on students' languages as a deficit in the classroom instead of

framing language as an asset. In contrast, some pre-service elementary teachers viewed students' perspectives as assets, pushing against Milner's (2010) assertion of deficit perspectives.

The findings from my interviews demonstrate a range of cultural awareness. One implication from this work is that pre-service elementary teachers need explicit support to enact cultural awareness in their science lessons. Mark and Id-Deen (2022) found that when pre-service elementary teachers frame their lessons concerning students' culture, they can enact those lessons with their students. Another implication is that pre-service elementary teachers are growing in their awareness and understanding of culturally responsive pedagogy, and many of Milner's (2010) assertations are being challenged by this new generation of teachers.

Equity Awareness

The participants were developing a critical consciousness necessary for equitable science instruction. I aligned this finding under equity awareness (Figure 4). Unlike Milner's (2010) work with pre-service teachers, which stated that pre-service teachers in his sample demonstrated cultural conflicts, the pre-service elementary teachers I interviewed could reflect on their positionality in the classroom, thus attempting to address issues with different cultures in classrooms. In contrast to Milner's (2010) assertation of the myth of mediocrity, some participants in this work held their students to high standards and framed students' perspectives as assets.

The range of themes under equity awareness adds a novel finding to the field of science education. Although much research on equitable instruction has been done in science classrooms (Carlone et al., 2011; Haverly & Davis, 2023), we must explore how

we support pre-service elementary teachers in creating spaces for equitable science instruction. This work highlights that pre-service elementary teachers notice inequities in institutional spaces. They also practice reflexively in these spaces, especially concerning classroom behavioral "norms." They are critically pushing back on definitions of a "good" science student, thus acknowledging opportunity gaps within our institutions. We must keep these critical conversations going in a reflective and supportive environment to continue supporting them in this work. These interviews have great potential, and I hope these pre-service elementary teachers continue to grow in their critical awareness.

One theme not apparent in my analysis was a critical self-reflection of the pre-service elementary teachers' whiteness in their classroom spaces. Although the participants could discuss systemic injustices and notice their students' lived experiences, they did not share critical reflections about their position in their relationships with their students. They were starting to become self-aware of their reactions (especially in the case of classroom norms), but no one talked about white supremacy or the over-representation of white females in those classroom spaces. Thus, I re-imagined the conceptual framework and added Critical Whiteness under equity awareness (Figure 4) as a sub-category.

In continuing this work, we need to support pre-service elementary teachers in noticing their power and privilege in classroom spaces. One area of support for this can come from the teacher education programs. Teacher education programs must continue actively recruiting teachers of Color to be role models in classroom spaces. It is critically important to change the racial dynamics in our classrooms to fight against

white supremacy. Decentering the white narrative and highlighting people of color in classrooms and learning spaces are crucial next steps to creating equitable learning spaces. I look forward to exploring ways to help pre-service teachers develop their critical lens in my future work.

Advocacy

Advocacy became part of my re-imagined conceptual framework (Figure 4). Kristinia helped me to think about advocacy as a central finding within this work. Researchers highlight empowering students with science knowledge to create equitable science spaces (Kolonich et al., 2018), but what about empowering teachers?

There is a need to create learning spaces with pre-service elementary teachers to teach them how to advocate for their students. Kristina could reflect on advocacy naturally because of her early experiences with a lack of advocacy and her mathematics teacher. Could there be other examples of this across participants' experiences? How can pre-service elementary teacher educators build self-efficacy regarding equitable science instruction and empower pre-service elementary teachers to become advocates for their students? What role does advocacy play in equitable science instruction? These questions add new lines of novel inquiry to this work. I am grateful that Kristinia was willing to share her experiences and that I could add her voice to this work. Her reflections are central to the way pre-service elementary teachers should think about equity in science education.

In conclusion, the qualitative analysis underscores the understanding that pre-service elementary teachers conceptualized equitable science education along a comprehension continuum, as depicted in Figure 3. The emergent themes are

multidimensional, illustrating that participants perceived equitable science education through various and multiple perspectives. Embedded within these themes are intricate nuances in how elementary teaching candidates envisioned equity in science education.

Limitations

This qualitative work is limited by the number of participants willing and able to converse with me about equitable science instruction. I interviewed each participant once, and their understanding of equitable science might have changed throughout their teacher education program experiences. An interview study is limited to what the participant shares, and thus, there might be different nuances I missed because I did not ask the right questions. A more thorough ethnographic study might uncover different understandings.

Additionally, qualitative findings can be limited by subjectivity and generalizability. These are also two limitations I have outlined in Chapter 3 within the methodology section of this work. I have attempted to alleviate bias with my interpretations by keeping analytic memos and reflections during data analysis in a methodological journal. I have also shared my findings with the participants and the elementary science method instructors to conduct member checking. Finally, these findings represent the voices of eight participants, and I acknowledge that the themes may not be generalizable because of the sample size.

I have conducted my analysis with due diligence within the constraints of the allotted timeframe. To bridge the gap between the quantitative outcomes and the qualitative insights, I will proceed to integrate the analyses in Chapter 6, where I will also explore the broader implications of this work.

CHAPTER 6: DISCUSSION AND IMPLICATIONS

The overarching objective of this scholarly endeavor was to examine how the pre-service elementary teachers in my sample conceptualized equitable science education. Anchored in Bandura's theoretical self-efficacy framework (1995), this investigation probes the extent of the participant's confidence in imparting equitable science education in classrooms that include students from different races, ethnicities, gender identities, socio-economic statuses, and linguistic backgrounds. Self-efficacy consists of two distinct constructs: personal self-efficacy and outcome expectancy (Bandura, 1995). The critical difference lies in the focus of the belief. Personal self-efficacy is centered on the teacher's confidence in their abilities. Outcome expectancy is the teacher's belief in the effectiveness of specific teaching strategies or actions in achieving desired results. Both are crucial for teacher performance and student outcomes, but they address different aspects of the teaching experience. A teacher might have high self-efficacy (believing they can deliver a lesson effectively) but low outcome expectancy if they doubt the lesson will significantly impact student learning, or vice versa.

To explore this work's broader conclusions and implications, this chapter will merge the quantitative and qualitative work to comprehensively discuss pre-service elementary teachers' self-efficacy related to equitable science instruction. This discussion will examine the entire sample instead of comparing the sample across teacher education programs. I will discuss personal self-efficacy and outcome expectancy related to

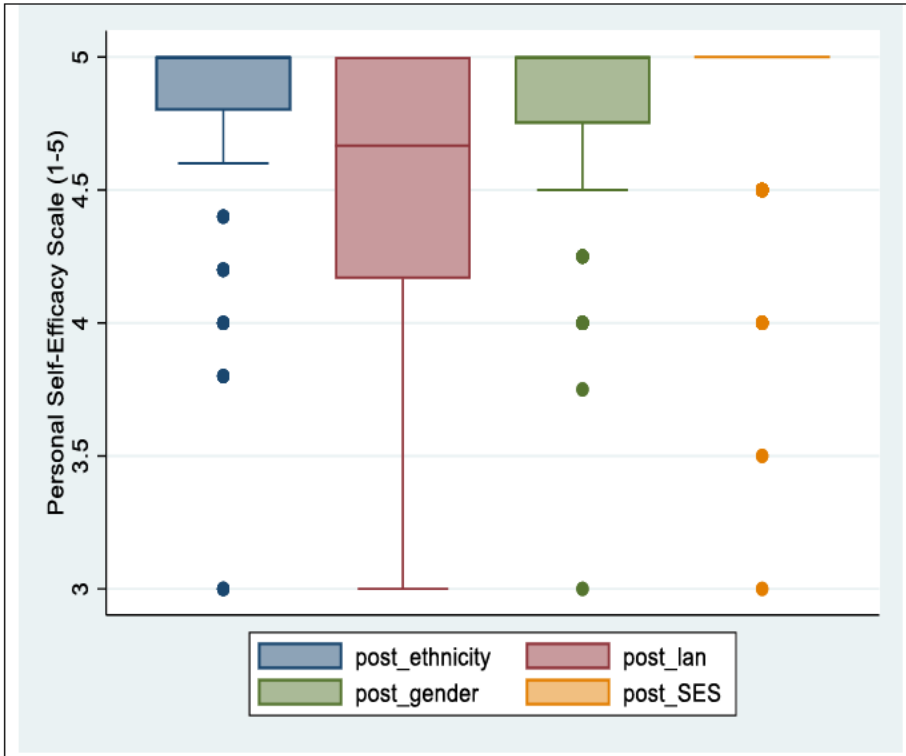
equitable science instruction separately and compare the quantitative and qualitative pieces. In this discussion, I will analyze how some of the findings from the two methods are congruent or discrepant. I will also discuss the implications of this work for pre-service elementary teachers and elementary teacher educators. Further, the limitations of this work as a mixed methods study will be addressed. I will conclude with a summary of this work and highlight potential next steps.

Personal Self-Efficacy Related to Equitable Science Instruction

A box plot was constructed to synthesize the post-survey data, facilitating a comparative analysis between the quantitative and qualitative datasets. This visual representation encapsulated the post-survey results across four distinct sub-scales—namely, post-ethnicity (post_ethnicity), post-language (post_lan), post-gender (post_gender), and post-ELL (post_lan)—derived from the Self-Efficacy Beliefs about Equitable Science Teaching (SEBEST) survey (refer to Figure 8). The post-survey scores were employed as indicators of pre-service elementary teachers' self-efficacy beliefs after their participation in a science methods course. To augment the comparative analysis, excerpts from the qualitative data that resonated with themes pertinent to each sub-scale were juxtaposed with the quantitative findings.

The timing of the interviews, conducted amidst the pre-service elementary teachers' engagement with the science methods course, presents a minor temporal misalignment with the post-survey measurements, amounting to a disparity of mere weeks rather than an entire academic term. The ensuing discourse will elucidate select subtleties discerned within each sub-scale of the SEBEST survey vis-à-vis the interview data, intending to illuminate the broader implications of this study.

Figure 8: *Joint Display Personal Self-Efficacy Related to Equitable Science Instruction*

Quantitative post-SEBEST scores	Qualitative Interview Transcripts
	Ethnicity: "*We had a very multi-cultural classroom, with many different types of students from different ethnic and socio-economic status backgrounds. That was interesting and cool to see. Because, you know, they were all very respectful of one another. It was a very collectively supportive classroom.*"(*Emily, fall, 2022*) *M*=5 Language: Reflecting on an online reading program, *"In a lot of books, when they're (the program) reading it to them, they're highlighting the word and moving along. It's not just reading it, like an audiobook; it's highlighting the word for them. If you click on the word, most will tell you what the word is out loud. I feel like that's beneficial for multilingual students."*(*Charity, fall, 2022)M*=4.2 Gender: "*Girls are getting more into STEM and more science roles. Because it used to be, and even now, a male-dominated career. And I think that a lot of places are trying to keep track of that and put more emphasis on trying to have more women or girls empowered with science. With first grade, I don't feel like it's probably as noticeable, I guess because they are still so young.*" (*Jennifer, fall, 2022)M*=3 SES: *Reflecting on providing lunch during a field trip, "As a low-income student myself, and I'm first generation, I've had to advocate for low-income students because, you know, from my experiences, I am aware that these students may not have a lunch, so we have to provide that one."*(*Agnes, fall, 2022)M*=4.5

Note: M=Average post-SEBEST score

Race and Ethnicity

The pre-service elementary teachers in this study reported a solid confidence in teaching equitable science to students from different races or ethnicities(> 4.5[iv]). A few responses were outliers from this range, but all values were above a neutral response of 3.0. However, the qualitative quote represents a more subtle understanding that is discrepant from this strong sense of personal self-efficacy.

Emily (Figure 5) reflects on the "collectively supportive classroom" she has been a part of through student teaching. However, she does not describe any strategies that might help mitigate potential bias in those spaces. Her self-efficacy score was strong (*M*=5) regarding her self-efficacy related to teaching equitable science to students of different races or ethnicities. Still, she did not reflect any critical consciousness in her interview response. Her reflection aligns with Milner's (2010) descriptions of colorblindness among pre-service teachers. The quote lacks a critical understanding of the role of race or ethnicity in institutional spaces or a reflection of the teaching strategies that helped create that equitable environment.

The socio-political climate related to conversations about race might influence the pre-service elementary teachers' reflections on how race and ethnicity function in classroom spaces. Although the classroom environment must be collectively supportive, how does this support equitable science instruction? It suggests that teacher educators, teacher education programs, and mentors might need to be more intentional in uncovering colorblind rhetoric to create spaces where critical reflection can foster the creation of equitable and supportive classrooms.

The two data types (quantitative and qualitative) regarding pre-service elementary teachers' conceptualization of equitable science instruction for students from different races and ethnicities led to significant findings in this study but also pointed to a need for further research. If pre-service elementary teachers report solid confidence in supporting students from diverse racial and ethnic backgrounds, what do they think about equitable science curricula enactment? What do they think about creating these spaces for their students? Do the quantitative results reflect a solid personal self-efficacy result because of colorblindness, or do these pre-service elementary teachers firmly believe they can enact socially just science curricula?

My qualitative findings in Chapter 5 point to a continuum of understanding regarding equitable science education. Some pre-service elementary teachers could reflect on race and ethnicity as factors that might limit students' opportunities because of systemic oppression. They were able to think about these students with critical consciousness. Other participants can recognize different worlds but do not challenge or bridge their positionalities with students' worlds. In the case of Emily, the convergence of the data highlights indicates that her reflections might be developing on the continuum of understanding equity.

An extension of this work would be examining pre-service elementary teachers' classroom methods for enacting equitable science instruction. How are they trying to mitigate bias within themselves, between their students, and within the structure of the school as an institution that may or may not support social justice and equity education? What are some of the nuances of their experiences? How can we support their development as equitable educators? Regarding race, how can we (teacher educators and

researchers) support the mostly white pre-service elementary teachers to examine their positions in their classroom spaces critically? The results with race and ethnicity center the need for more work in this space.

Language

According to the quantitative data, the pre-service elementary teachers in my sample believe they can teach equitable science to ELL students (> 4.0). The qualitative data is congruent with this result. In the interviews, participants focused on supporting vocabulary development when discussing ELLs. This aligns with the heavy emphasis in elementary classrooms on literacy and vocabulary instruction. From the quote in Figure 5," *It's not just reading it, like an audiobook; it's highlighting the word for them. Moreover, even if it is not like a read-to-me book, even the ones that are not read to me, if you click on the word, most will tell you what the word is out loud*. "

Charity envisions using the online reading program to integrate science vocabulary learning into their reading curriculum. She has shared a tangible tool that will support her science instruction, and from her self-efficacy score (*M*=4.2), she firmly believes that she can create equitable science lessons for ELL students. In this case, the quantitative and qualitative data are congruent. Charity feels confident that she can teach ELL students using the tools she has in her field placement setting and the vocabulary strategies learned in her literacy courses.

One critical missing piece not enumerated within the qualitative data in Chapter 5 or analyzed within the qualitative work in Chapter 4 is framing the elementary students' languages as assets in the science content. Charity does not mention using the reading program with the students' different languages to reinforce content understanding with

pluralism. Re-enforcing English language development is essential, but affirming students' own cultures and languages in science is also important. Equitable learning experiences should engage students' cultural and linguistic backgrounds to be involved as resources for science instruction. According to Aikenhead (2006), this support helps to ease the border crossing between the dominant cultural practices of mainstream schooling and those practiced at home. Charity seemed confident in supporting vocabulary development but did not reflect on using students' culture and language as science resources.

The qualitative and quantitative findings demonstrate that pre-service elementary teachers believe they can support equitable science instruction with ELL students. Still, there are finer details within their personal self-efficacy that warrant further study. From my interviews, Charity envisions supporting ELL students with English language development instead of creating spaces for language and cultural pluralism in their classrooms. These results reflect a developing understanding of recognizing different worlds (Chapter 5) instead of a critical consciousness that would allow for linguistic and cultural pluralism. Culturally sustaining practices (Paris & Alim, 2014) require a deeper understanding of students' cultural wealth and the linguistic assets children bring into classrooms. An extension of this work would examine the opportunities pre-service elementary teachers have to enact linguistically and culturally pluralistic science curricula. What would that look like, and how could teacher educators support their work?

Gender

My quantitative and qualitative findings indicate that pre-service elementary teachers believe they have the skills to enact an equitable science curriculum for all students regardless of gender. Survey data ranged >4.5, with four outliers in the sample, all self-reporting high levels of personal self-efficacy related to teaching science to girls (specifically as compared to boys) above 3.0, which represents a neutral category. The qualitative data also supported the idea that participants know gender differences in sciences and believe that girls are being empowered to learn and participate in STEM. The data are congruent, but the two have a minor discrepant nuance.

In my interview with Jennifer (Figure 5), she acknowledges that the messaging about empowering girls in science is not as prevalent as it might be in other places. In her words, "*a lot of places are trying to keep track of that* (male-dominated science*) and emphasize trying to have more women or girls empowered with science. With first grade, I don't feel like it's probably as noticeable, I guess because they are still so young*." At first, I thought Jennifer noted that the messaging around empowering girls in science is not as prevalent in her setting as it might be in other places. However, when I looked at her SEBEST score (*M*=3), I noticed she is neutral about creating equitable opportunities for girls. I infer she does not think empowering girls in science is essential, at least not in first grade.

What Jennifer probably does not realize is the strong potential for stereotype threat that occurs in elementary settings around gender roles. A stereotype threat is a concern or anxiety that one's performance or actions can be seen through the lens of a negative stereotype (Steele et al., 2002). This concern disrupts and undermines

performance in negatively stereotyped domains. For example, women who feel they cannot compete in science or mathematics achieve less because of stereotype threat (Beilock et al., 2010; Spencer et al., 2014). Despite Jennifer's assumptions that empowerment and messaging about gender roles should not matter for first graders, research shows that stereotype threat affects girls and their feelings about science in elementary classrooms (Regner et al.,2014). Gunderson et al. (2011) detail that parents' and teachers' gender-related mathematics attitudes—including their stereotypes and anxieties—can transfer to girls in elementary school, and these gender-related mathematics messages play a critical role in girls' development of mathematics attitudes and interests. Shapiro and Williams (2012) considered the role of teachers and parents in replicating stereotype threats about mathematics performance and found that these influences undermined girls' interest and performance in STEM domains.

There is a slight discrepancy between the quantitative range of data, which contains personal self-efficacy scores related to teaching equitable science to girls (>4.5), and Jennifer's outlier data (*M*=3). Jennifer reported feeling neutral about equitable science instruction for girls, perhaps because she did not see a need to worry about focusing on it. She did not talk about advocating for girls in science. She merely stated that there was less empowerment messaging in first grade. There is a need to examine how elementary children perceive the messaging about girls in STEM. When does gender messaging begin, and how can we support pre-service elementary teachers so they see the importance of advocating for girls in science?

Socio-Economic Status

Pre-service elementary teachers felt the most confident about their abilities to teach equitable science to students from different SES backgrounds. This was a congruent finding between the quantitative and qualitative work (Figure 5). The range of post-survey responses was above 4.5, with four outliers, none of which was below 3.0. Agnes could advocate for her low-income students because she had experienced poverty. She felt confident that she could help support equitable science instruction to students from low SES backgrounds (M=5).

This confidence to support students from economically disadvantaged backgrounds might come from the additional school-level support to help needy children. For example, Title One programming provides meals to many low-income students, and frequently, community programs will provide additional support to help struggling families. An extension of this research might look at the structures of poverty and why it might be easier for pre-service elementary teachers to envision supporting students from low-income households instead of the hidden nuances that create a lack of opportunities for other students based on race, gender, or language.

Additionally, there is an intersectionality between and among these various demographic factors (i.e., race and ethnicity, gender, language, SES status) that was not explored in this work but is essential to highlight. Building on this work, new research should explore how pre-service elementary teachers conceptualize the intersectionality of student demographics and how this might impact their self-efficacy related to teaching equitable science instruction to students within multiple spheres of identity.

Summary for Personal Self-Efficacy

The pre-service elementary educators in this study demonstrated a pronounced conviction in their personal self-efficacy concerning being able to teach equitable science to students of diverse racial and ethnic backgrounds, across the gender spectrum, from socio-economically disadvantaged environments, and to students who are English language learners. The investigation revealed congruence and divergence between the qualitative and quantitative data sets, underscoring intricate domains warranting further scholarly exploration.

One such domain necessitates that teacher educators engage in critical dialogues with pre-service teachers to deconstruct and challenge the prevalence of colorblind ideology, which may obfuscate the systemic mechanisms that engender educational disparities along racial and ethnic lines. There is an imperative for teacher educators to cultivate an ethos of pluralism within classroom environments that cater to English language learners, ensuring that these students' cultural and linguistic identities are not only accommodated but also revered and integrated within the educational context, in tandem with the advancement of their English language proficiency.

Moreover, it is essential to instill a sense of empowerment within female students in mathematics and science at every educational tier, cognizant of the potential implications of stereotype threats. Pre-service teachers must be equipped with an understanding of these dynamics to counteract them effectively.

Notably, the data indicated that these pre-service teachers exhibited the most substantial personal self-efficacy in teaching equitable science to students from economically challenged backgrounds. This phenomenon prompts questions regarding the underpinnings of this confidence: What factors contribute to this heightened sense of

self-efficacy? How do the intersecting demographics of students interplay to influence their educational experiences?

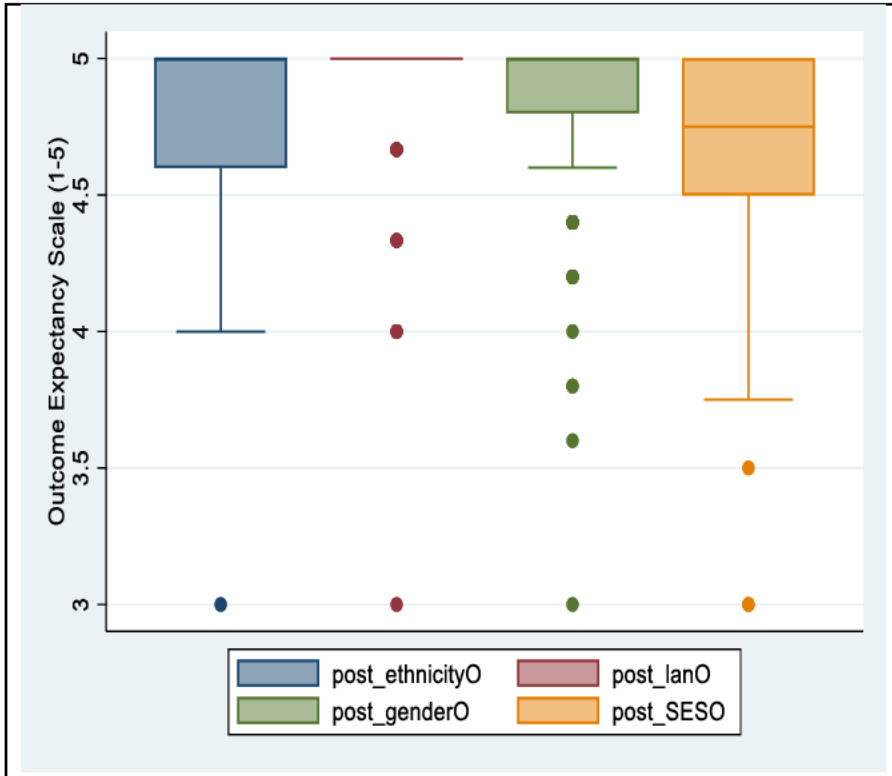
The findings suggest that future research should delve into the intersectionality of race, socioeconomic status, gender, and language within the educational landscape. Such research should aim to elucidate how these complex demographic interrelations shape pre-service teachers' perceptions and approaches to equitable science education.

Outcome Expectancy

Figure 6 is a joint display of the post-survey SEBEST results regarding outcome expectancy and two teachers' reflections on how they would mitigate bias as actionable steps to achieve equity in science instruction. The four sub-scales (post_ethnicityO, post-lanO, post-genderO, post-SESO) from the SEBEST survey are included. Post-survey scores were used to measure pre-service elementary teachers' outcome expectancy after their science methods course. To juxtapose these quantitative findings with qualitative insights, targeted inquiries through interviews were collected from Emily and Charity regarding their strategies for ameliorating potential biases within the classroom environment. Emily and Charity's insights were chosen because their subtle differences in viewpoints add a novel complexity to the work.

The following comparative examination of the qualitative and quantitative data sets will elucidate a more nuanced and integrated understanding of the interplay between the data, illuminating how they collectively contribute to a holistic comprehension of the dynamics at play in fostering equitable science learning outcomes. The discussion will center on mitigating bias, highlighting how the quantitative and qualitative data are congruent in their results.

Figure 9: *Joint Display Outcome Expectancy Related to Equitable Science Instruction*

Quantitative post-SEBEST scores	Qualitative Interview Transcripts
	*"I want to foster, a supportive environment in the school, in the classroom, if nothing else, you know, so that students don't feel isolated or different because of socio-economic status, gender or race."(Emily, fall, 2022)* *"I try to reflect like, if I asked her (my student) a question, and later I am thinking about it, like, well, maybe I shouldn't have asked it like that, you know? I try to reflect and see what I could do better the next time and what further opportunities I could provide to that kid? Or, like, how can I connect with them in a way that this subject that maybe they're not like, having the most fun? I know the kids love Pokémon. And so do I. And so we connect in that way. I found some sight words, I put them on pokey balls, and, you know, tried to connect with students in that way and try to see like, what they're passionate about. I definitely would say I reflect and try to have the feedback that people give me not be like a personal, you know? Yeah, like, not take it personal, but just try to take it as constructive. "(Charity, fall, 2022)*

Mitigating Bias

The pre-service elementary teachers in my sample had robust outcome expectancy beliefs pertinent to realizing equitable science education objectives for students of diverse racial or ethnic backgrounds, females, ELL students, and students from low socio-economic backgrounds. Notwithstanding a few anomalous data points of 3.0, the preponderance of responses was above 4.0. The qualitative data emphasizes the importance of fostering an inclusive environment, engaging in reflective practices, and developing connections with students.

Creating Supporting Environments

Regarding Emily's insights concerning concrete measures to attenuate bias within educational milieus, she articulated an aspiration towards cultivating an ambiance of inclusivity for her pupils. Emily harbored apprehensions regarding the potential alienation her students might experience, emanating from disparities in ethnicity, race, socio-economic status, or gender. While she did not delineate specific tactics for the materialization of such inclusive spaces, her contemplations were primarily rooted in the desire to obviate bias by fostering an environment that supports collective engagement among students. Her approach appears to be focused more on the establishment of a supportive communal framework for student interaction rather than introspective self-analysis of her teaching methodologies.

In terms of empirical measures, Emily's scores on the outcome expectancy scales were uniformly high, with a mean (M) value of 5 across all subscales. This statistic mirrors her self-assured stance regarding her capability to facilitate

equitable educational outcomes, In particular, it demonstrate her confidence in her role as an educator to effectively support a diverse student body—encompassing individuals of varying races and ethnicities, ELL students, those hailing from socio-economically challenged circumstances, and female students.

Connection and Reflection

Charity's reflections reveal her commitment to ameliorating classroom biases through student engagement strategies that are aligned with their personal interests, such as the integration of Pokémon-themed activities to facilitate the learning of sight words. This individualized approach to education augments overall student engagement and serves as a conduit for ELL students, potentially diminishing linguistic barriers and elevating their self-efficacy, irrespective of their linguistic provenance. Additionally, Charity contemplates mitigating bias by pursuing her professional development and applying reflective practices within her instructional milieu.

When evaluating her outcome expectancy scores, particularly in the context of fostering equitable learning outcomes for female students and ELLs, Charity reported a neutral position (M=3). While the granular reasons behind her neutral stance toward these demographics remain unexplored, it is plausible to infer that her emphasis on continuous professional development may correlate with her neutral expectancy beliefs for these student groups. Conversely, regarding students from low-income households and those of diverse racial and ethnic backgrounds, Charity expressed a robust conviction, with scores exceeding 4.0, in her capacity to deliver equitable science education.

Summary for Outcome Expectancy

Most pre-service elementary teachers had robust outcomes on post-survey measures for outcome expectancy (>4.0). The qualitative work provides a nuanced understanding of teachers' strategies to create supportive and inclusive learning environments and their reflective practices for personal and professional growth. A limitation of this work is that I did not frame more questions in my interviews around how the pre-service elementary teachers would enact equitable science instruction to meet the learning outcomes for all children. Thus, I present my analysis through what they shared about mitigating bias, rather than drawing direct parallels between the qualitative interviews and the SEBEST scores.

Extending this work, quantitative research could explore the relationship between teacher reflective practices (measured through self-assessment scales or frequency of reflective activities) and student outcomes. The qualitative data provides a foundation for understanding the content and focus of these reflective practices, and further quantitative work could explore how they affect student learning. The qualitative insights could help define what types of feedback are constructive and how teachers integrate them into their practices.

Limitations

Convergent mixed methods design, where qualitative and quantitative data are collected simultaneously and then integrated or merged, offers a comprehensive approach to research by combining the strengths of both qualitative and quantitative methods. However, this approach also presents several limitations. Some limitations include the integration of methodologies and sampling issues.

In the present study, I have endeavored to amalgamate methodological approaches, presenting a discourse that furnishes a holistic perspective on how pre-service elementary educators construe equitable science education, as delineated in Chapter 6. The granular exposition of discrete quantitative outcomes, as elaborated in Chapter 4, combined with the qualitative insights presented in Chapter 5, culminates in a more substantive synthesis pertinent to the research questions. Integrating research queries within the analytical framework would have fortified the study, facilitating a robust juxtaposition of the methodological paradigms. Moreover, achieving an equilibrium between the quantitative and qualitative methodologies, ensuring neither eclipses the other, posed a notable complexity. A significant interpretative challenge lies in articulating results that coalesce coherently, honoring the findings' veracity and methodological integrity.

There were also limitations within the sample sizes. The quantitative data had 97 participants, whereas the qualitative data had a sample of 8. Aligning the generalizations from the quantitative work with the smaller, more focused sample in the qualitative work was a limitation. Converging findings between the two data sets proved to be limiting because of the sense of scale.

Conclusion

This dissertation has investigated the self-efficacy of pre-service elementary teachers concerning equitable science instruction, employing a mixed methods approach to offer a comprehensive understanding of this critical issue. Through integrating quantitative data on self-efficacy levels and qualitative insights into the experiences and perceptions of these future educators, this study has illuminated the complex interplay

between teacher education programs, personal self-efficacy beliefs, outcome expectancy beliefs, and the anticipated challenges of delivering equitable science education.

The quantitative results (Chapter 4) reported that across five teacher education programs, pre-service elementary teachers reported changes in their self-efficacy related to teaching equitable science because of their teacher education program experiences. Regarding personal self-efficacy for teaching equitable science, pre-service elementary teachers reported feeling confident about teaching equitable science to students from different racial and ethnic backgrounds, students from low socioeconomic backgrounds, English language learners, and females. However, outcome expectancy related to equitable science instruction increased for ELL students and decreased for females and students from low SES backgrounds.

Additional regression analysis highlighted that for pre-service elementary teachers who self-reported their race as white, there was a positive association between their field placement experiences and their personal self-efficacy related to teaching science to students from different racial and ethnic backgrounds, students from low SES backgrounds, ELL students and females students (when controlling for average pre-survey score, average percentage of demographic group, and race of pre-service elementary teacher). There were also increases in participants outcome expectancy for teaching students from different racial and ethnic backgrounds (when controlling for average pre-survey score, average percentage of demographic group, and race of pre-service elementary teacher).

However, the qualitative data (Chapter 5) unearthed a more nuanced picture, highlighting that pre-service elementary teachers conceptualize equitable science

instruction on a continuum of understanding. The continuum was based on factors such as confidence in science, recognizing different worlds, being able to support students' participation in science, developing a critical consciousness, and advocacy. Within this continuum was a spectrum of meaning-making experiences, and pre-service elementary teachers demonstrated a multifaceted understanding of equitable science instruction.

The convergent discussions in Chapter 6 highlight another layer of complexity in this work. The quantitative findings revealed moderate personal self-efficacy and outcome expectancy among pre-service elementary teachers regarding their ability to provide equitable science instruction. The qualitative data provided a harmonious and sometimes discrepant nuance to the quantitative work. These findings underscore the need for targeted interventions within teacher education programs and more scholarship around supporting pre-service elementary teachers to enhance their self-efficacy with equitable science instruction.

Implications

This research contributes to the academic discourse on pre-service elementary educators and equitable science education, aligning with and diverging from existing studies in meaningful ways. Consistent with the findings of Cone (2009), this study observed positive shifts in participants' self-efficacy regarding equitable science teaching attributed to experiences within their methods courses. Contrary to Settlage et al. (2009), however, it was found that elementary teacher candidates, particularly those identifying as white, exhibited positive associations between the demographic characteristics of their field placement schools (e.g., percentage of students from historically underserved racial or ethnic groups, percentage of English Language Learner (ELL) students, percentage

from low socio-economic status (SES) backgrounds, percentage of female students) and their personal self-efficacy in teaching students from these demographic groups. Investigation into the intersectionality of student demographics and its association with increased complexity may unveil new insights into how pre-service elementary teachers conceptualize equitable science education. Moreover, revising the SEBEST (2001) survey instrument to reflect broader conceptualizations of gender represents a further avenue for research.

Participants in this study understood equitable science education through fluctuating frameworks that support student sensemaking, a finding in agreement with Haverly et al. (2020). This ability enables them to adeptly employ culturally responsive teaching strategies, as demonstrated in the work of Mensah et al. (2018) and Yoon and Martin (2019). Cross-case comparisons across programs underscored the significance of Diversity, Equity, and Inclusion (DEI) coursework in fostering culturally responsive teaching. Extending this research into program evaluations of diverse coursework experiences could deepen understanding of DEI initiatives' role in cultivating more inclusive classroom environments. Engaging with coursework focused on multicultural science education boosts pre-service teachers' confidence in applying these methodologies in their classrooms, as evidenced by Daniel (2016), Morales (2000), and Whitaker & Valtierra (2018), suggesting the incorporation of such training in teacher education programs to enrich their multicultural educational practices.

Furthermore, this study enriches the dialogue regarding field placements and their influence on developing self-efficacy in science teaching amidst conflicting empirical results (Cantrell et al., 2003; Ginns et al., 1995; Wingfield et al., 2000). Notably, the

demographics of field placement schools were significant for white pre-service elementary teachers. Yet, this research did not explore other pivotal aspects of field placements, such as mentor teacher roles, engagement duration, or the intersection of field placement experiences with DEI coursework. Future research could incorporate these elements to enhance our understanding of pre-service elementary teachers' field placement experiences.

Additionally, this research extends the discourse on how pre-service teachers conceptualize equity in science education, diverging from Lee (2022) by not finding a pervasive trend of colorblindness among participants. While nuances regarding ELL learners were noted, participants did not solely associate equity in science education with English proficiency. There was some congruence with Lee, where some participants from this work expressed a lack of confidence in teaching science to ELLs due to language barriers and their own reluctance to learn students' languages, which paralleled Lee's findings. This underscores the need for support mechanisms enabling pre-service teachers to advocate for linguistic plurality in their classrooms, highlighting a gap in research on balancing English literacy with multiple languages in elementary education settings.

Significantly, this research has shown that while pre-service elementary candidates are generally committed to equity in education, many feel underprepared to implement this in practice. The gap between their beliefs and their perceived ability to enact those beliefs in the classroom points to a critical area for development in teacher education. Specifically, the data suggests that more comprehensive training on culturally responsive pedagogy, inclusive curriculum design, and strategies for engaging diverse learners is required.

Implications of this study extend beyond the immediate context of teacher education, offering insights for policymakers, curriculum developers, and educational leaders. Systemic changes are needed to foster an educational environment where equity in science instruction is not just an ideal but a reality. These include revising curriculum standards to embed equity principles, enhancing teacher support systems, and creating accountability measures for equitable practices.

For future research, this dissertation opens several avenues. Longitudinal studies could examine how pre-service teachers' self-efficacy evolves throughout their early teaching years and the impact of continuous professional development on their equitable teaching practices. Additionally, more extensive comparative studies across different regions or educational systems could offer broader insights into the global challenges and opportunities in training teachers for equitable science education. Finally, critical studies could highlight the counter-narrative of teachers of Color to center their experiences in elementary education and advocate for changes in the teacher demographics within our schooling structures.

In conclusion, this mixed methods dissertation contributes to the growing body of literature on teacher education and equity, highlighting the critical role of self-efficacy in preparing future teachers to provide equitable science instruction. By addressing the gaps identified through this research, there is potential to enhance the quality of science education and foster a more inclusive and equitable society. To encapsulate the ethos of this research, I invoke the perspicacious words of Betina Love, who articulated, "*Theory does not solve issues—only action and solidarity can do that—but theory gives you*

language to fight, knowledge to stand on, and a humbling reality of what intersectional social justice is up against" (Love, 2019, p.132.

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Appendix A: SEBEST Survey

Which of the following best describes you. (Please select all that apply)

- ○ White
- ○ African American, Black
- ○ Asian, Asian American
- ○ Latin X
- ○ American Indian, Alaska Native
- ○ Native Hawaiian, Pacific Islander
- ○ Multiracial
- ○ Not Listed

Q1. I will be able to effectively teach science to children whose first language is not English.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q2 Girls can learn science if they receive effective science instruction.

- ○ Strongly agree
- ○ Somewhat Agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q3 I do not have the ability to teach science to children from economically disadvantaged backgrounds.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q4 Even when teachers use the most effective techniques in teaching science, some Native American children cannot achieve in science.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q5 I can do a great deal as a teacher to increase the science achievement of children who do not speak English as their first language.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q6 Good teaching cannot help children from low socioeconomic background achieve in science.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q7 I will be able to meet the learning needs of children of color when I teach science.

- ○ Strongly agree
- ○ Somewhat agree

- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q8 Girls are not as capable as boys in learning science even when effective instruction is provided.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q9 I do not know teaching strategies that will help children who are English Language Learners achieve in science.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q10 Effective science teaching can help children from low socioeconomic backgrounds overcome hurdles to become good science learners.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q11 I can help girls learn science at the same level as boys.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q12 Even when teachers use the most effective science techniques in teaching science, some children of color cannot achieve in science.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q13 I do not know how to teach science concepts to children who speak English as a second language.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q14 Effective science teaching cannot improve the science achievement of children from impoverished backgrounds.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q15 I will be effective in teaching science in a meaningful way to girls.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neither agree nor disagree
- ○ Somewhat disagree
- ○ Strongly disagree

Q16 Children of color can succeed in science when proven science teaching strategies are employed.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q17 I will have the ability to help children from low socioeconomic backgrounds be successful in science.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q18 Children who speak English as a second language are not able to achieve in science even when the instruction is effective.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q19 I will be able to successfully teach science to Native American children.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q20 Girls have the ability to compete academically with boys in science when they receive quality science instruction.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree

- Somewhat disagree
- Strongly disagree

Q21 I will not be able to teach science to children who speak English as a second language as effectively as I will to children who speak English as their first language.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q22 Children of color cannot learn science as well as other children even when effective science teaching instruction is provided.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q23 I cannot help girls learn science at the same level as boys.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q24 A good science teacher can help children from impoverished backgrounds achieve in science at the same level as children from higher socioeconomic backgrounds.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree

- Strongly disagree

Q25 I will be able to effectively monitor the science understanding of children who are English Language Learners.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q26 Girls can develop in science at the same level as boys if they receive science instruction that is effective.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Q27 I will not be able to successfully teach science to Asian children.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q28 Girls do not have the ability to learn science as well as boys, even when effective teaching techniques are used.

- Strongly disagree
- Somewhat disagree
- Neutral
- Somewhat Agree
- Strongly Agree

Q29 I will be able to successfully teach science to children of color.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q30 Children who are English Language Learners do not have the ability to be successful in science even when the science instruction is effective.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q31 I will be able to help girls learn science.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q32 White children can learn science as well as other children when effective science teaching is employed.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q33 I will not be able to teach science successfully to White children.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q34 Children who are English Language Learners can be successful in learning science if the teaching is effective

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q36 Describe any teaching experience you have, or experience working with kids.

_____

Q37 What is your major?

_____

Q38 What do you identify as for your gender?

- ○ Male
- ○ Female
- ○ Non Binary
- ○ Not listed

Q39 What is your age?

Appendix B: Pre-service Elementary Teachers Protocol A

Interview Protocol:

Thank you for agreeing to participate in this study. My name is Lily Bentley and I am a third year PHD student at UVA. The focus of this study to see how pre-service elementary teachers change in their self-efficacy towards teaching science to diverse learners because of their education during their teacher programs. I will be recording the interview so that I can transcribe it later. If at any point you feel uncomfortable and you want to stop the interview, please let me know. You do not have to participate. I want to hear your viewpoint because You are the expert. I may be taking notes during the interview, but I want you to know that even if I am not looking at you, I am listening. I will try to remain quiet to hear your thoughts. Your responses will be kept confidential and once the interview is transcribed, I will have you read through it to make sure I got it correct. At that time, I will delete all recordings. Do you have any questions for me before we start?

Interview Questions Warming up:

1. When did you first get the idea to become a teacher and how did that happen? Where did it come from?
2. Can you describe some of your experiences teaching kids?
3. Can you describe any moments as a learner where you felt super excited and engaged? What was the topic or lesson and why did you love it so much?
4. What about a moment where you felt overwhelmed? Have you ever had a moment where you were not excited or engaged, but stressed out because of a lesson or topic?
5. What are some ways people learn? Do you think all people learn in the same ways?

Efficacy:

1. How do you feel about teaching science?
2. Have you ever taught science? Can you explain what lesson you taught and how it went?
3. Did you ever take a science course that you really enjoyed? If not, why not, if yes, why did you enjoy it?
4. Do you think elementary students will be keen to learn science? Why or why not?
5. Are there any topics in science that you think will be challenging to teach? What resources will you use to organize and implement the lesson?
6. What about topics that will be easy to teach? What resources will you use to organize and implement the lesson?
7. What is the difference between these two topics? (The difficult one and the “easy” one?)
8. Do you think all students will be able to learn science in the same way? Why or why not?
9. Describe what an effective science lesson would look like? How will you know that you have successfully taught the topic? Or if you already taught one, how did it go?

Topic: Diversity

1. What does diversity mean to you?
2. What types of diversity might you see or interact with in an elementary classroom?
3. What are your thoughts about teaching science to diverse students?

4. What are some tools you can use to get to understand the diversity within all your students?
5. Can you describe any experiences teaching or working with diverse learners?

Probe: Can you describe some strategies you have learned to deliver science instruction to diverse learners?
Probe: Do you think there is a need to change instruction because of the diversity in your classroom?
Probe: What else do you need to learn about teaching science to diverse students?
Probe: What supports do you need or what supports do you think would have been helpful?

1. What does it mean to be good at science? Describe how these experiences come about.

2. Do you feel that there are some groups of students who are particularly good at science (gender, ESL students, high/low SES status,) or not particularly good at science? Why or why not?

Closing: What aspects of the teacher education program have helped you develop skills to teach science to diverse students?

Is there anything else you would like to add that would help me understand how you are feeling about teaching science to diverse learners?

Do you have any questions for me?

Thank you so much for your time 😊

Appendix C: Pre-service Elementary Teachers Protocol B

Interview Protocol:

Thank you for agreeing to participate in this study. My name is Lily Bentley and I am a third year PHD student at UVA. The focus of this study to see how pre-service elementary teachers change in their self-efficacy towards teaching science to diverse learners as a result of their education during their teacher programs. I will be recording the interview so that I can transcribe it later. If at any point you feel uncomfortable and you want to stop the interview, please let me know. You do not have to participate. I want to hear your viewpoint because You are the expert. I may be taking notes during the interview, but I want you to know that even if I am not looking at you, I am listening. I will try to remain quiet to hear your thoughts. Your responses will be kept confidential and once the interview is transcribed, I will have you read through it to make sure I got it correct. At that time, I will delete all recordings. Do you have any questions for me before we start?

Interview Questions Warming up:

6. When did you first get the idea to become a teacher and how did that happen? Where did it come from?
7. Can you describe some of your experiences teaching kids?
8. Can you describe any moments as a learner where you felt super excited and engaged? What was the topic or lesson and why did you love it so much?
9. What about a moment where you felt overwhelmed? Have you ever had a moment where you were not excited or engaged, but stressed out because of a lesson or topic?
10. What are some ways people learn? Do you think all people learn in the same ways?

Efficacy:

10. How do you feel about teaching science?
11. Have you ever taught science? Can you explain what lesson you taught and how it went?
12. Did you ever take a science course that you really enjoyed? If not, why not, if yes, why did you enjoy it?
13. Do you think elementary students will be keen to learn science? Why or why not?
14. Are there any topics in science that you think will be challenging to teach? What resources will you use to organize and implement the lesson?
15. What about topics that will be easy to teach? What resources will you use to organize and implement the lesson?
16. What is the difference between these two topics? (The difficult one and the "easy" one?)
17. Do you think all students will be able to learn science in the same way? Why or why not?
18. Describe what an effective science lesson would look like? How will you know that you have successfully taught the topic? Or if you already taught one, how did it go?

Topic: Equitable Science Instruction

1. What is equitable science instruction?
2. What are your thoughts about teaching science to students of different gender identities?
3. What are your thoughts about teaching science to multilingual learners?
4. What are your thoughts about teaching science to students with different ethnic/racial backgrounds than your own?
5. What are your thoughts about teaching science to students with different socioeconomic backgrounds?
6. What are some examples of how you might use students' assets in instructional practice?
7. What are some potential biases would you want to address or mitigate in your practice?
8. How will you advocate for your students?

9. Do you feel that there are some groups of students who are particularly good at science (gender, ESL students, high/low SES status,) or not particularly good at science? Why or why not?

Closing: What aspects of the teacher education program have helped you develop skills to teach science?

Is there anything else you would like to add that would help me understand how you are feeling about teaching equitable science?

Do you have any questions for me?

Thank you so much for your time 😊

Appendix D: Sample Codes for Narrative Interviews

Codes	Definition or sample
Personal Self Efficacy	I will be able to teach science to students
Outcome Expectancy	All students can learn science
Milner's Issues of Diversity (2010)	Sample Assertation
Colorblindness: Not accepting racial or ethnic differences and systemic oppression	Assertion 1: If I acknowledge the racial or ethnic background then I may be considered racist. Assertion 2: If I admit that people experience the world differently, I may be seen as "politically incorrect." I may offend others in the teacher education classroom discourse if I express my beliefs and reservations about race. Assertion 3: I should treat all my students the same regardless of who they are. Race does not matter.
Myth of mediocracy	Assertion 1: All groups of people were born with the same opportunities. Assertion 2: My grandparents immigrated to the United States. There is no excuse for other groups not to succeed. Assertion 3: If students fail, it is because they are not working hard enough.
Deficit Frames	Assertion 4: Some students just do not have the aptitude, ability, or skill for success.Assertion 1: I am being sensitive to culturally diverse students when I feel sorry for them. Assertion 2: Students need teachers who try to make up for what students are lacking Assertion 3 : It is my job to

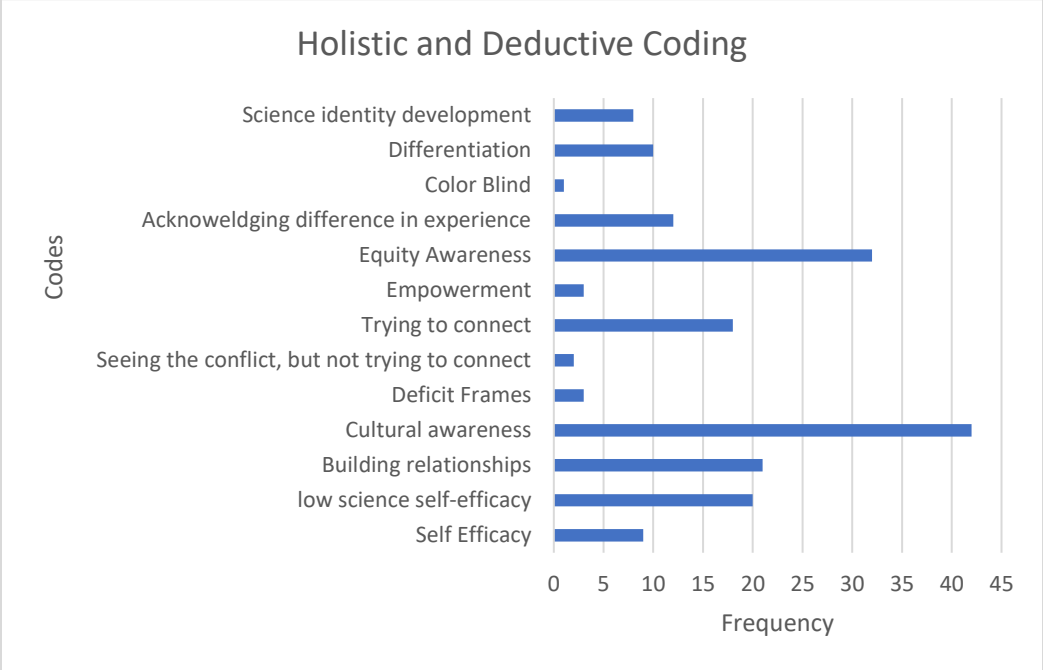
	concentrate mostly on students' test scores and to close the achievement gap
Lower Expectations	Assertion 1: I am actually helping to build self-esteem among my students when I give them "easy" work Assertion 2: "Those" poor students cannot meet high expectations because they do not have the resources to do Assertion 3: My job is to just allow certain students to get by and, at best, pass their standardized test.
Cultural Conflicts	Assertion 1: I must teach students based on how I teach my own biological children or based on how I was taught Assertion 2: I'm not going to tolerate students joking around with me during class. Assertion 3: Students need to adapt and assimilate into the culture of "my" classroom
Kolonich et al. (2018)	
co-construction of science knowledge.	Students should use their cultural knowledge to understand science. Students should be provided with opportunities to use and share multiple languages. The learning environment should value students' lived experiences as evidence.
The learning environment should promote the use of **students' critical lens to solve problems**	
Equity-Oriented Conceptual Framework for K-12 STEM literacy Jackson et al., 2021	
Problem solving and Utility	STEM learning environments provide rich learning

	experiences in which students have the opportunity to apply their critical thinking skills to solve complex problems. Applied further, students get to visualize and see the utility and applicability of the solutions to the complex problems. Utility and applicability address the extent that students recognize STEM as it relates to the real world and the skills associated with STEM areas that are useful to address real-world issues (e.g., STEM as worthwhile).
Empathy	A student's ability to mentally identify themselves with and fully comprehend another person can be described as empathy (Brown, 1996; Cohen, 2001; Cooper, 2011), which importantly focuses on "feeling with" and not just "feeling for."
Systems of Oppression and power	. The primary way to disrupt and continue to disrupt the systems of oppression is to provide access and opportunity to students, including minoritized students to high-quality integrated STEM learning experiences.
STEM dispostions	We operationalize productive STEM dispositions to include one's attitude toward, interest in, and motivation in STEM. It is important students have opportunities to explore STEM in the classroom or in informal learning environments so their interest, engagement, and achievement in STEM grows (National Academy of Engineering and National Research Council, 2014). Previous studies have shown that positive attitudes toward content is a key factor in increasing achievement in that

	content area (Simpson & Oliver, 1990). Therefore, quality STEM learning experiences that promote positive dispositions toward STEM are important in supporting student achievement in STEM.
STEM identity development	Promoting positive STEM identities extends to cultural and linguistic differences minoritized students bring to STEM learning experiences. Students' culture and native language must be attended to in STEM learning experiences (Jong et al., 2020; Savage et al., 2011), as valuing and using students' native language provides access to the learning environment (Zaval
Empowerment	Students reported feeling empowered because they had a choice over how to approach the content and how to design the device that would best meet the Jackson et al. International Journal of STEM Education (2021) 8:38 Page 9 of 16 engineering challenge (Chittum et al., 2017) tudents' positive dispositions toward STEM, curriculum and programs should include historical and current news and issues related to Black and Latinx communities so students understand societal issues that impact their communities and find the content meaningful and relevant (Coleman et al., 2018; Coleman & Ingram, 2015; Jackson et al., 2020; Jong et al., 2020). Incorporating culturally relevant pedagogy can show students STEM can be a part of their everyday lives, and not something that is challenging or

	atypical in the Black and Latinx communities
Societal Change Agents	Focusing on this as equity

Appendix E: Coding trends Deductive and Holistic Analysis



Appendix F: LLM Validity Example Text

1. **Equity Awareness:** Equity is achieved when everyone receives what they need to be on equal footing with others in the same environment while recognizing the systemic structures that create inequities in our socio-political environments. In the classroom, that might mean extra time, different support, and unique resources for some students to achieve their learning goals. Equity also deals with systemic structures that oppress groups of people by advocating for social reform through justice.

2. **Self-Efficacy**: Having the confidence to teach science.

3. **Cultural Awareness:** Cultural awareness or competence is "understanding your own culture, other's culture, and the role of culture in education." Taking a student's culture into account as "a basis for learning, communicating high expectations, and reshaping curriculum to reflect student's diversity leads to better educational outcomes.

4**. Empowerment**: Students can choose how to approach the content.

5. **Identity:** Making sure students see themselves in science. Science Identity can describe how an individual seeks to be a scientist, constructed through iterative interactions with scientific, social, and material contexts. A person with a strong science identity would exhibit a sense of community and affiliation built by consistent extrinsic and intrinsic attitudinal factors. This sense of identity can be made by participating in relevant activities and categorizing oneself as a member of the scientific community.

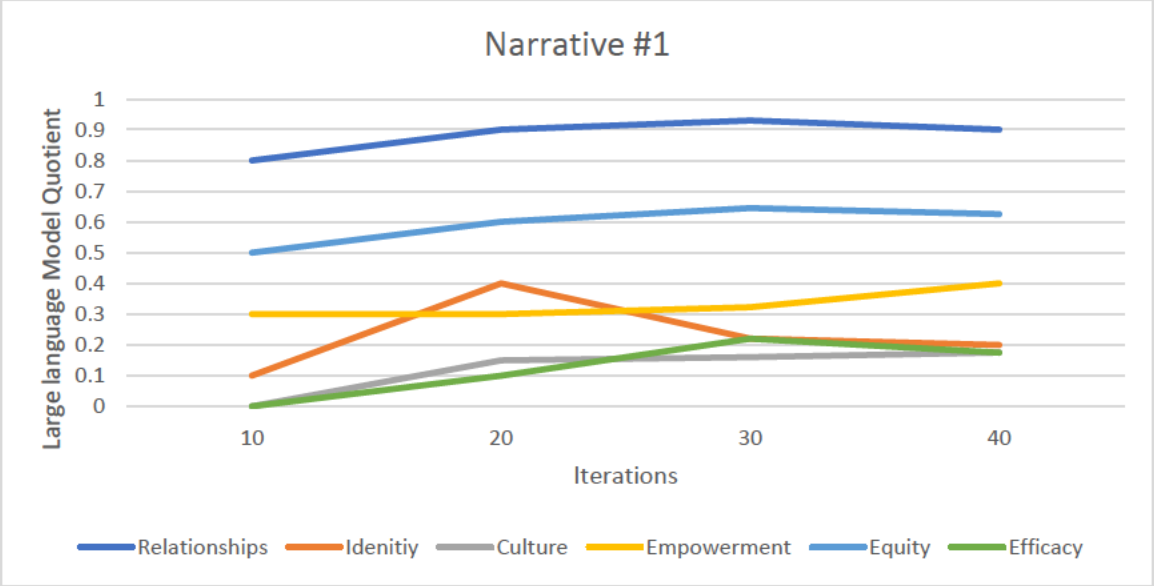
6. **Relationships:** Building trust and connections with students.

Can you find the six characteristics in the transcript below, yes or no? If yes, give us the quote.

Transcript:

"I reflected afterward because I had students who are jumping out of their seats and raising their hands, but I'd ignore them in favor of someone who was sitting quietly, and I reflected after my lesson about how they were like showing me their interest in a different way. So it's something I try to do a lot."

APPENDIX G: Graph of LLMq results for sample text in Appendix F



[i] I have intentionally left white lower-case to de-center whiteness in this dissertation.
[ii] Intentionally left white lower-case .
[iii] All survey results reported on 5-point Likert Scale
[iv] All survey items reported on a 5-point Likert Scale. 1=low efficacy; 5=high efficacy