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An Ecofeminist Investigation of How Research Experiences for Science Teachers Influence Their Conceptualization of the Nature of Science and Their Construction of Storied Science Identities

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Abstract

This study investigated how the figured world of the RET, and other figured worlds of science that teacher's experience, impacted their conceptions around the nature of science and their identities in science and as science teachers. The main premise behind RET programs is that by partnering science teachers with scientists as mentors, science teachers will glean insight about science they can bring back into their classrooms. Although there is a large body of literature around the impacts of RETs as sites of PD for science teachers, there are several gaps this study aimed to address, such as the use of ecofeminism as a tool for analysis and a focus specifically on identity. This study suggests as science teachers move through figured worlds of science, certain experiences can work to stabilize, or destabilize an identity as a science person or as someone who is not welcomed in science. Looking across science teachers' storied science identities, I identified four shared storylines: 1) The impact of elementary and middle school science figured worlds on science/teacher identity; 2) the roles of recognition and sense of belonging in the development of science/teacher identity; 3) science/teacher's identity informing pedagogical practice and commitments; and 4) science teachers feeling valued for their role as expert communicators in RETs. This study suggests that RETs, as figured worlds of science, shape science/teacher identities and their conceptions around the nature of science, in turn impacting science teachers' classroom practice. It also highlights the need for RETs to take an even more critical examination of the teachers who are participating, the scientists with whom teachers are paired, the students of the participating teachers teach, as well as the language used to describe science and the relationships between teachers and scientists.

Keywords: Research experiences for teachers (RETs), ecofeminism, science teacher identity, nature of science, figured worlds

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Dedication

I dedicate this dissertation to my husband Kurt,

who encouraged me every step of the way,

making me endless cups of tea and bowls of popcorn.

I love you.

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Chapter One: Introduction

Telling stories is an astonishing thing. We are a species whose main purpose is to tell each other about the expected and the surprises that upset the expected, and we do that through the stories we tell. (Bruner, 2002, p. 8)

These are the times of urgencies that need stories. (Haraway, 2016, p. 37)

Our field instructor asked for a volunteer. He asked the student to take a side of the manual fishing net and wade into the water with him. Slowly, they walked parallel, with the net submerged in the water between them. He said, “We should be able to see a significant number of organisms even this close to the shore.” The rest of us waited in anticipation on the sandy New Jersey shoreline, excited to learn about the environment outside of our usual four classroom walls. As a science teacher, I always tried to organize as many field trips as possible, despite the limited financial resources available and the obscene amount of paperwork required to obtain them. He said, “I think we have gone far enough.” He instructed the student to drop their end of the net on the beach so that the other students could see the biodiversity.

The students from my environmental science class were astounded to see the diverse amount of fish, just a few feet away from them off the shoreline. They were most amazed by the elaborately colored seahorse saying, “Who knew seahorses could be found this close to shore?” one student exclaimed. As the field guide discussed the diversity of the catch, and the reasons for which some researchers might use this method, some of the students began to notice that the fish we captured were not being returned.

As their bodies flapped side to side, every second nearer to death, I asked, “Are we just letting them die on the beach?” The field guide looked at me like I was hysterical, and in a

mocking way told me, “That’s part of the circle of life.” My response was to immediately start throwing the fish back in the water. “I do not see how this is part of any circle today,” I mumbled loud enough to be heard by the field guide I had convinced my district to pay to instruct the students for the day. As I hurriedly threw the fish back, students joined me. “Oh my gosh Ms. Poole, some of them have already died, what kind of environmental trip is this?” While we frantically attempted to prevent the senseless killing of innocent marine life, the instructor requested for another volunteer, to capture the next batch of unsuspecting marine victims.
At the time, I wondered how someone with little care for the organisms he was investigating could ever be placed in the position of teaching science to students.

Much of the consensus interpretation of the nature of science, as I will discuss in greater detail in a later section, has developed out of a belief that nature and non-human organisms are at the disposal of humans to be exploited in the pursuit of scientific knowledge. However, this “compulsion to dominate is one of the hallmarks of patriarchy” (Harvester & Blenkinsop, 2010, p. 123). This framework would suggest that the domination over marine life presented in my story echoes the larger historical narrative of domination over women, as well as all other sanctioned oppression. Reflecting upon this experience helped focus some key questions underpinning my dissertation. How does someone develop their beliefs about the nature of science? Second, how might science learning experiences shape the beliefs about the nature of science and scientific inquiry of teachers and their students? Lastly, how might individuals perpetuate patriarchal norms of domination in the way they understand the nature of science? Although this proposed study is primarily concerned with the experiences of teachers who participate in science professional development opportunities with working scientists, these are the broad questions in which this specific inquiry is located.

Research experiences for teachers (RETs) are regarded as the gold standard for science teacher professional development, giving teachers firsthand experiences with the practices of science by being placed in research settings with practicing scientists (Shanahan & Bechtel, 2019). By partnering science teachers with scientists as mentors, science teachers have opportunities to take on apprenticeship roles and gain experience in the practices of science. For this study, I will be defining RETs as professional development opportunities which provide science teachers with an extended research experience, where teachers are placed with a practicing science professional in their place of work on a current research project. In this case, place of work may be a university or commercial science laboratory, or field location. This decision supports the push by Darling-Hammond et al. (2017) for sustained professional development and is consistent with previous literature regarding the length of effective professional development to improve teacher learning (Cohen & Hill, 2001; Loucks-Horsley et al., 2010) and increased student achievement (Yoon et al., 2007).

The literature on RETs suggests that teachers bring what they learned from their real-world or authentic science experience back to the classroom, improving student performance in science (Silverstein et al., 2009). Researchers also argue that participating teachers report growth in understanding the nature of science, scientific inquiry, and the Next Generation Science Standards (NGSS), and the impact these new understandings have on their lesson design and implementation (Chowdhary et al., 2014; Hagan et al., 2020). This version of science professional development aims to fulfill the vision of the NGSS for K–12 students in science classrooms to explain real-world phenomena (NGSS, 2013).

There are a number of perspectives to critique the ethics and actions of the field instructor that day along the shore with my students, but the one that I suggest offers the greatest analytical power is that of ecofeminism. According to Gaard (1993), “Ecofeminism is a value system, a social movement, and a practice” which “offers a political analysis that explores the links between androcentrism and environmental destruction” (p. 18). By applying a lens of ecofeminism in this study, I hope to take a critical view of the nature of science (sometimes but not always abbreviated in the literature as NOS or NoS), as presented in the Next Generation Science Standards (NGSS), and as it relates to teacher learning and professional development in the science experiences in which they participate. By using a lens of ecofeminism, I am responding to the claim that “few educational researchers have engaged theoretically and practically with these [ecofeminist] approaches” (Lloro-Bidart, 2015, p. 136).

Statement of the Problem

The problem that I investigated in this dissertation study is situated between research experiences for teachers (RETs) and science teacher identities. My study aimed to address specifically how the portrayal of the nature of science in RETs, as one of the many building blocks of a science teacher's life experiences, shaped that science teacher’s identity in science. However, before I briefly discuss both of these areas, I begin this section by providing an overview of the way science was portrayed in U.S. schools, going as far back as the 1800s, paying particular attention to key organizations involved, policies, and national standards. I then include an overview of Research Experiences for Teachers (RETs). Finally, I conclude this section by presenting the current consensus of the nature of science, and how it has been presented in recent science education standards.

The Portrayal of Science in U.S. Science Education Standards

For much of the 1800s, science education in American classrooms consisted primarily of recitation of facts and was largely focused on the utilitarian purposes of science, with the government encouraging courses focused on agriculture or mechanics (Rudolph, 2020). Towards the end of the century, discussions around science education began to shift, with "arguments for the value of scientific study grounded in morality or virtue" becoming more prominent (Rudolph, 2020, p. 896). Although short-lived, this new way of thinking could be credited to a small group of scientists with experiences in Europe, "that prized inquiry for its own sake, a belief in the preeminence of 'pure science' without consideration of its practical application." (Rudolph, 2020, p. 898). Such a pragmatic approach held was considered as meeting the needs of a modern democratic society (Jewett, 2012). The belief that participation in laboratory science was the only path to understanding truth and virtue became prominent in circles of science education and led to the push for more lab work over text book learning in science classrooms. Rudolph (2020) noted that these were possibly the first set of science standards available in the United States.

Organizations such as the American Association for the Advancement of Science (AAAS), founded in 1848, the National Research Council (NRC), founded in 1916, and the National Science Foundation (NSF), founded in 1950, have promoted the advancement of science by pursuing research in the field of science education. Outcomes of this research tend to emphasize the need for teachers of science to increase their science literacy as well as the development of standards that seek to engage students with the nature of science and scientific inquiry. In the 1980s, and in response to the urge for the U.S. to "play catch up" in their science progression on the world stage (DeBoer, 2000), AAAS established Project 2061 as a long-term initiative with the aim of helping all Americans reach literacy in science, mathematics, and technology (AAAS, 1990). As a result, in 1989, Project 2061 established *Science for All Americans: A project 2061 report on literacy goals in science, mathematics, and technology,* laying out what the organization identified was essential for the next generation to reach scientific literacy. In this report, AAAS broadly defined science literacy as “the connections among ideas in the natural and social sciences, mathematics, and technology” (AAAS, 1990, p. para. 3) The recommendations laid out in this report were heralded by many as moving in the direction of a national set of science standards for all students (AAAS, 1990) The authors of this report also claimed that these recommendations could be used to help all K–12 teachers, in any subject matter or grade, to provide support in their science knowledge.

Since the 1960s, the NSF has been foundational in the development of programs aimed at increasing the understanding of scientific inquiry amongst science educators. Over the last three decades the NSF, as well as other organizations and universities, have funded specific programs aimed at partnering science teachers with scientists in extended professional development opportunities taking place in working laboratories. One such model of this type of professional development includes RETs. The NSF promoted these programs as supporting collaborations between K–12 teachers and university laboratories to increase teacher participation in science and engineering, with the aim of their experience impacting their classroom teaching (NSF, 2021). However, literature surrounding RETs is limited in showing a correlation between participation in RETs and the enactment of NGSS (DeJong et al., 2016).

In addition, there are a number of issues with making this broad assumption. For some, placing teachers in apprenticeships with practicing scientists implies the teacher will walk away with an understanding of what an authentic science experience looks like and a greater understanding of the nature of science. However, Abd-El-Khalick (2012) argued, “Such an approach conflates the concepts of nature of science and scientific inquiry” (p. 367). Additionally, this assumption implies that scientists, by default, have strong understandings of the nature of science. However, Wong and Hodson (2010) found that many scientists “never seriously pondered these [epistemological] questions” (p. 1442).

Research Experiences for Teachers (RETs)

According to the description by the National Science Foundation, RETs were designed to support “active participation in science, engineering, and education research by K–14 STEM educators” through authentic summer research experiences,” and by fostering “long-term collaborations between universities, community colleges, school districts, and industry partners” (NSF, 2021, para. 2). The NSF claimed that by partnering classroom science teachers with practicing scientists, teachers will develop a stronger understanding of their discipline as well as bring that understanding back to their classrooms through revised curriculum and lesson plans. It also suggested that through these partnerships, the practicing scientists gained a deeper understanding of what happens in science classrooms and the pedagogies employed by science teachers (NSF, 2021).

RETs take place across the country and in varying science disciplines, and aim to provide opportunities for science teachers to participate in authentic science experiences, leading to more meaningful and inquiry-based science representations of science for their students (Crawford, 2012; Loucks-Horsley et al., 2010; Wenglinsky, 2000; Windschitl, 2003). Furthermore, studies suggested that teachers who engage in science apprenticeships developed deep understandings about communities of practice that take place amongst working scientists (Varelas et al., 2005)

Although there is an extensive body of literature on the effectiveness of RETs on teachers’ beliefs about the nature of science and scientific inquiry that I discuss in a later section, there is little research surrounding science teacher identity and how their individual science stories impacted those beliefs both prior to and during their experiences with research.

Additionally, little work has been done to investigate the epistemological underpinnings of the version of science presented to science teachers during their research experiences (Davidson et al., 2021). Although some studies have suggested that teachers developed more sophisticated understandings of science after participation in research experiences (Blanchard et al., 2009; Buxner, 2015; Grove et al., 2009), most seemed to reinforce mainstream conceptions of science by assessing change in teacher beliefs by the vision for nature of science and inquiry put forth by the consensus view (Lederman, 2007). According to Erduran (2014), “Much work remains to be done in science teacher education to revisit how NoS is taught and how best to facilitate teachers’ learning to teach NoS from a broader and revised perspective” (p. 106). Therefore, I argue that if teachers are being asked to teach as well as participate in research experiences whose designers have not critically considered the sociopolitical and cultural aspects of the practices of science, RETs may end up reinforcing damaging perspectives for science teachers and their science identity. In the section that follows, I present a brief overview of the nature of science and how it is presented in recent U.S. science education standards.

The Nature of Science

In 1996, the NRC put forth the National Science Education Standards (NSES). This ‘new’ set of guidelines for science teacher professional development came in response to critiques of the *Science for all Americans report* (AAAS, 1990), suggesting a need for greater clarity on how scientific literacy would be achieved, not only what scientific literacy was. One example of these new guidelines stated that “All teachers of science must have a strong, broad base of scientific knowledge extensive enough for them to understand the nature of scientific inquiry, its central role in science, and how to use the skills and processes of scientific inquiry” (NRC, 1996a, p. 59). The NSES also emphasized that science instruction needed to be student-centered, modeling the work of scientists exploring the natural world (NRC, 1996a). Therefore, the development of standards by NRC (1996a) ensuring students would be able to "combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science" (p. 105), were inextricably linked to the goals laid out for teachers. These goals included becoming "familiar enough with a science discipline to take part in research activities in that discipline" (p. 60) and enhancing their "beliefs about the nature of science" (p. 616).

Shortly after, in 1998 the NRC released the report entitled *How people learn* (NRC, 1998). This report, in efforts to strengthen the research on the relationship between teaching and learning in science, claimed to provide "research-based messages that are clear and directly relevant to classroom practice" (NRC, 1998). Specifically, this report presented three main findings: 1) students come to the classroom with pre-conceptions, sometimes misconceptions, that teachers must access and help reorganize; 2) learning science required both the learning of facts as well as conceptual frameworks by which to organize information to identify patterns and problem solve; and 3) strategies "from the culture of inquiry" could be taught, could allow students to draw on connect both new and previously learned information, and could be taught in the context of different scientific disciplines (NRC, 1998, p. 2).

Most recently, and arguably in response to the three findings in the *How people learn* report, the NRC in coordination with the National Science Teaching Association (NSTA), AAAS, and Achieve, developed the Framework for K-12 Science Education, which presented their vision of science that all students in grades K-12 should know by the time they graduate high school (NGSS, 2013). The Next Generation Science Standards were presented as three interconnected and complimentary dimensions: *science and engineering practices*, *crosscutting* *concepts, and disciplinary core ideas*, to highlight what scientists do, and the shared ideas that span across scientific disciplines (NGSS, 2013). The authors of the NGSS presented the nature of science as situated at the intersection of these three dimensions, moving away from earlier conceptions of science which presented scientific practice like a recipe and scientific knowledge as distinct bodies of information. This new conception of science was grounded in the work of Latour and Woolgar (1979), who after spending two years with a “tribe” (p. 27) of practicing scientists in a working laboratory, found that what was perceived as well organized and unbiased, was actually quite the opposite. They claimed that the nature of science was messy, and situated within complicated social, cultural, and political networks which cannot be viewed as separate from the scientific work being conducted.

Despite presenting an overview of the nature of science in Appendix H of the NGSS, studies suggested this representation was lacking throughout the rest of the three dimensions, with even less presence in the themes and learning outcomes for lower grade levels (McComas & Nouri, 2017). These critics argued that the nature of science should not be a supplementary component, but rather the standards should be rewritten to include the NOS as the fourth dimension. Further, when looking across NGSS aligned resources provided by NSTA, Summers and Abd-El-Khalick (2019) found that the majority of materials presented NOS in naïve and implicit ways. Therefore, despite incorporating some of these ideas into the new set of standards, the nature of science may still be too vague for teachers to apply them to classroom practice, as well as fail to reflect the continued epistemological debates in the field. Additionally, I would argue the conception of the nature of science presented by NGSS perpetuates anthropocentric and hegemonic values.

According to Southerland et al. (2016), “If the goals of the NGSS are to be realized, the field must create, study, and refine models of PD that can be successful in supporting teachers’ disciplinary engagement in science so that this engagement can inform their teaching” (p. 2). Unfortunately, much of the research around science teacher preparation showed few science teachers have participated in authentic research experiences (Davis et al., 2006; Windschitl, 2003) and are unfamiliar with the science practices laid out in the NGSS. The Next Generation Science Standards (2013) recommended that a “fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge” (p. 2), and provided a description of its vision in an appendix to the NGSS titled “Understanding the Nature of Scientific Enterprise: The Nature of Science in the Next Generation Science Standards” (Appendix H). The key features of this vision include: (a) scientific knowledge is based on empirical evidence; (b) scientific knowledge is open to revision in light of new evidence; (c) science is a human endeavor; (d) scientific knowledge assumes an order and consistency in natural systems; (e) scientific models, laws, mechanisms, and theories explain natural phenomena; (f) scientific investigations use a variety of methods; (g) science addresses questions about the natural and material world; and (h) science is a way of knowing.

A contemporary research agenda on the understanding of the NOS by various stakeholders in science education was spearheaded by Lederman (Lederman, 2007, 2008, 2019), whose work heavily influenced the discussion around science education and the nature of science, as well as influenced the development of the aspects of the nature of science found in the NGSS. According to Lederman (2007), the NOS is critical in defining one’s scientific understanding (Lederman, 2007; Schwartz et al., 2004). Lederman’s construct of the nature of science “refers to the characteristics of scientific knowledge” (Lederman, 2019, p. 250) and scientific inquiry which designated the "processes of how scientists do their work and how the resulting scientific knowledge is generated and accepted" (Lederman, 2007, p. 66). In collaboration with colleagues, Schwartz et al. (2004) put forth a characterization of the nature of science presented in seven basic tenets, later expanded to ten tenets. Below the nature of science as offered by (Abd-El-Khalick, 2012), a more recent adaptation, building off the work of Abd-El-Khalick (2012); Lederman et al. (2002), are presented in Table 1.1.

Table 1.1

Conceptions of the nature of science (Abd-El-Khalick, 2012)

Component	Definition
Empirical	Scientific claims are derived from, and/or consistent with, observations of natural phenomena
Creative	Science is not an entirely rational or systematic activity.
Theory-laden	Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, and expectations influence their work.
Tentative	Scientific knowledge is reliable and durable, but never absolute or certain.
Cultural embeddedness	Science is a human enterprise embedded and practiced in the context of a larger cultural milieu.
Scientific theories	Scientific theories are well-established, highly substantiated, internally consistent systems of explanations.
Scientific law	In general, laws are descriptive statements of relationships among observable phenomena.
Social dimensions	Scientific knowledge is socially negotiated
Inferential	There is a crucial distinction between observations and inferences
Myth of the scientific method	This myth is often manifested in the belief that there is a recipe-like step-wise procedure that typifies all scientific practice.

Although widely accepted, there have been critiques of Lederman's approach (Erduran, 2014; Galili, 2019). Some have criticized the current consensus around the nature of science as being too broad and suggested modifications to make them more discipline specific (Rudolph, 2020). Other critiques pushed for more traditional understandings of scientific empiricism, valuing the achievement of objectivity in scientific research and knowledge (Galili, 2019), while Erduran (2014) suggested that the current accepted aspects of NOS are “limited in their depiction of science” and may present the nature of science from a positivist perspective” (p. 24). Erduran (2014) called for more “theoretical perspectives on science that target understanding from a range of perspectives” (p. 94). Tolbert et al. (2018) echoed this argument, when they wrote, “Traditional approaches to research and scholarship in science and science education have often been rooted in dominant, positivist perspectives of objectivity and empiricism” (p. 800). Therefore, for this study I am choosing to approach the topic of nature of science from an ecofeminist lens.

In a later section I provide a brief overview of the theoretical framework of ecofeminism and the way it has been used to critique science education, paying specific attention the human/nature binary and technology as a solution to environmental degradation. I then offer a critique of the conception of the nature of science in Table 1.1, drawing upon ecofeminist ideas. In the next section I briefly discuss current research surrounding science teacher identity before introducing my research questions.

Science Teacher Identities

According to Chung-Parsons and Bailey (2019), the role of science teachers' identities and teaching practices in facilitating students' science identity development “warrants consideration given teachers' central role in affecting student learning, achievement, and identity development” (p. 40). Unfortunately, current literature around science teacher learning suggests that most science teachers do not identify as scientists or experts in science (Davis et al., 2006) and have had very little experience working in non-prescriptive laboratory settings cultivated for them during their undergraduate science degree (Banilower et al., 2013). If the goal of science education is to develop the science identities of students, then we must first focus on the ways in which science teacher identities are shaped by their own experiences with science and how these identities manifest within science classrooms.

In the context of science education, Avraamidou (2019a) reexamined the concept of identity by highlighting the origins of the term. She explained that the word "identity" originally stemmed from the word "same." She further clarified, "Identity then refers to the state or fact of remaining the same one, the condition of being oneself and not another, and the characteristics of determining who or what a person is" (p. 324). Definitions of identity highlight both the individual and social natures of identity and identity formation. Not only is identity constructed around what makes individuals unique but also how someone fits within the different social contexts of which they are a part of. Avraamidou (2019a) echoed the theories of Wenger (1998) when she suggested:

> We define ourselves by what we are not as well as by what we are, by the communities we do not belong to as well as by the ones we do. These relationships change. We move from community to community. In doing so, we carry a bit of each as we go around. (p. 239)

Godwin et al. (2020) suggested that when individuals are searching for identity they ask: "Who am I, who can I be, and where do I belong?" (p. 267). This broadens the scope of identity by reinforcing the idea that identity is not stagnant or finite but occurs along a continuum. Identity construction takes place across spaces, times, and places, and can be explained as how individuals "come to 'figure' who they are, through the 'worlds' in which they participate

(Urrieta, 2007, p. 107). Holland et al. (1998) introduced the term "figured worlds" to describe this identity formation, in which identity is shaped within the "practices and activities situated in historically contingent, socially enacted, culturally constructed" figured worlds (p. 7). In this study, I considered science teacher identity construction as situated within a series of sociocultural contexts and experiences.

Not only can identity development be understood by figured worlds, but each individual consists of multiple identities dependent on the worlds in which they are participating in at any given moment. For this study, I am most concerned with the construction of science teachers' identity as it relates to their understandings of the nature of science and how that understanding influences their science teaching. In order to better realize the science identities of science teachers, researchers must take up the task of questioning how different experiences with science have impacted science teachers and what perceptions of science those identities carry with them. By using the framework of figured worlds, I was able to organize participants narratives and develop their individual storied identities by the different worlds in which they engaged with science. Below I present my research questions.

My dissertation study will focus on the following questions:

1. How do individual teachers conceptualize the nature of science after participating in research experiences for teachers (RETs)?
2. How do research experiences for teachers (RETs) influence the science teachers' storied science identities?
3. How does the portrayal of the nature of science in research experiences for teachers (RETs) influence their collective storied identities as secondary school science teachers?

As discussed below, an extensive review of the literature revealed little has been done to question which version of science is presented to participating teachers. Given how common positivist and anthropocentric views of science are in the mainstream scientific community, it is possible that RETs have mixed benefits for teachers' science instruction: while they may support teachers in better understandings of the research process, they also may convey a limited view of science to their students. The literature is also limited in its critique of the NGSS both within and outside of the RET context, which I examine in greater detail in a later section. Very little has been said regarding topics of environmental justice, the push for technocratic solutions over systemic societal change to the issues of climate change and environmental degradation, as well as the lack of clarity of the terms real-world and authentic.

Lastly, current literature is limited in its attention to the various power dynamics inherent to RET design and implementation including but not limited to that between the researcher and science teacher, science teacher and classroom student, science teacher and the selection committee, and researcher and research subject. Therefore, this study aimed to analyze the experiences of teachers who participated in RETs and examined how teachers talked about the nature of science after participating in an RET. My stance in this study was that each individual has a science story impacted by experiences in science, including science teachers. RETs therefore impact science teachers' stories and the way those stories are communicated to the students of that individual. In the following chapter I provide an extensive review of the literature on RETs, science teacher identity, and the frameworks by which I developed my study and analyzed my data.

Chapter Two: Literature Review and Theoretical Frameworks

In the following sections I present a look at the current literature around RETs in order to provide an overview of the literature as well highlight gaps related to my research questions. I then present an overview of my theoretical and conceptual frameworks.

Literature Review

The National Science Foundation (2021) defined Research Experience for Teachers (RET) as programs of professional development which support “authentic” research experiences for STEM educators, where teachers are engaged in “active participation” in STEM fields, a designation adopted by other similarly federally funded programs. However, across the literature similar programs were referred to as “Research Student/Teacher–Scientist Partnership” (Blanchard et al., 2009); “Industry-Education Partnership” (Harpole et al., 2010); "Student-Scientist Partnership" (Shell et al., 2011); Science Teacher Collaborations (Caton et al., 2000; Drayton & Falk, 2006). Though I selected participants from NSF-funded RET programs in this study, in this review of the literature I focused on a wider array of studies describing partnerships that could reasonably be categorized as RETs, as they detailed the range of work being done in science teacher apprenticeship style professional development.

For this study, I have specifically reviewed literature discussing professional development opportunities that provided science teachers with an extended research experience and that took place in the workplace of a practicing scientist. Therefore, articles discussing programs that did not meet this criterion, such as those discussing workshops taking place over a few days, were excluded. Although my study is focused on in-service secondary science teachers, I elected to include literature related to pre-service teachers, as well as teachers of elementary and middle grades. This decision was made due to the number of articles centered around topics of teacher beliefs, the nature of science, and identity, and therefore contributed to the greater understanding around researcher experiences and the teaching of science. Since most RETs accept teachers along the teacher continuum with varying levels of experience, I also made no effort to exclude articles focused on teachers with a specific number of years of experience. Finally, although research experiences do exist for teachers in content areas outside of science, this review focuses on articles discussing programs for science and/or STEM teachers in order to align to the guiding questions undergirding this study.

It was common for science teacher apprenticeship programs to make the assumption that by pairing teachers with scientists, experts in the field of science, teachers can gain insight into what often is referred to in the RET literature as authentic/real-world (Buxner, 2015; Enderle et al., 2014; Southerland et al., 2016) practices and knowledge of science, to better equip teachers of science in their classrooms. While this was the most common positioning of scientist and teacher, it was not uniform across all models. A close look at the design and implementation of RETs in the following sections revealed the variety of approaches taken for this work. For clarity, I referred to all programs in the literature review as RETs. First, I provide a brief overview of the literature on these programs, where they took place, what the discipline foci were, how the teacher participants were selected, and which teachers participated.

A Brief Overview of the Literature on RETs

What Are RETs?

By placing teachers in apprenticeships with scientists, RETs attempt to fulfill a variety of goals, most generally being that "as teachers do some of the day-to-day work of scientists, teachers will transform this knowledge into better classroom teaching" (Buxner, 2015, p. 54). However, other purposes included giving teachers a broader understanding of the possible STEM careers/majors available for their students (Autenrieth et al., 2017; Blake et al., 2015; Burrows et al., 2014); curriculum development (Autenrieth et al., 2017; Barnes et al., 2006; Dixon & Wilke, 2007; Hardre et al., 2010; Juuti et al., 2021); science teacher literacy and increased teacher content knowledge (Chowdhary et al., 2014; Darwiche et al., 2017; Hardrè et al., 2020); science teacher emotions (Thomson & Turner, 2019); partnerships between teachers and scientists (Baumgartner et al., 2009; Darwiche et al., 2017); changed teacher beliefs and understandings about the nature of science and scientific inquiry (Blanchard et al., 2009; Brey et al., 2015; Burrows et al., 2014); improved teacher self-efficacy (Pinnel, 2018); and increased teacher retention (Baker & Keller, 2010). Other scholars asked questions of the RET experiences themselves, such as which teachers had access and/or chose to participate (Morabito, 2018; Pop et al., 2010; Saka, 2013) and which teachers were most impacted by an RET experience (Enderle et al., 2014). The majority of studies focused on science teacher/scientist partnerships addressed teacher outcomes and did not provide information on the impact of K-12 students of the participating teachers. Exceptions to these included studies analyzing student performance (Basile, 2015; Silverstein et al., 2009) and student learning (Brey et al., 2015). Collectively, these studies highlighted a critical role for research looking to understand the impact of RETs on the students of participating teachers.

Where Do RETs Take Place?

With the intention of research immersion, the majority of RETs took place in university settings, and provided teachers with a laboratory-based research experience. A small percentage of programs took place in commercial laboratories (Fraser-abder & Leonhardt, 1996; Rushton & Reiss, 2019) while others took place at a field-based research location. Some examples of field-based locations included an alpine field ecological research station (Bencze & Elshof, 2004) and the Teachers in the Woods program (Dresner, 2002; Dresner & Worley, 2006b), which "provided ecology research experiences for science educators at a variety of national forests and national parks" (Dresner, 2002, p. 3)

What Are the Discipline Foci of RETs?

Programs pairing teachers with scientists comprised a wide scope of disciplines. While some studies had teachers participate in a singular area of research (Blake et al., 2015), others placed each participant in a different science discipline (Basile, 2015). One study emphasized the interdisciplinary nature of the research experience (Chowdhary et al., 2014), placing teachers alongside graduate and undergraduate students of science, where they worked on the natural remediation of acid mine drainage (Feldman et al., 2013).

How Are Teacher Participants Selected for RETs?

Programs pairing science teachers with scientists often considered themselves as "rigorous" (Baker & Keller, 2010, p. 23) or "competitive" (Barnes et al., 2006, p. 245; Baumgartner et al., 2009, p. 31), requiring extensive applications for teachers to participate. Such applications included essays/personal statements (Barnes et al., 2006; Chowdhary et al., 2014), videotaped lessons (Blanchard et al., 2009; Grove et al., 2009), and/or a letter of recommendation from a school administrator (Barnes et al, 2006). Others reported admittance based on a "first-come, first-served" basis (Blanchard et al, 2009) and recruited teachers through "mailing lists from previous professional development programs" (Dresner, 2002).

Which Teachers Participate in RETs?

Depending on the goals of the program, different RETs targeted different populations of teachers. Some programs accepted applicants from grades K-12 (Baumgartner et al., 2009; Dixon & Wilke, 2007; Hardre et al., 2010), while others only accepted teachers of secondary science (Blake et al., 2015; Buck, 2003). However, it was often the case that grade level data was not provided. Despite the limited attention placed on grade level, Enderle et al. (2014) were particularly interested in which teachers would experience the most change from participating in an RET. This study specifically compared the changes in practice and beliefs about science inquiry (as measured by the RTOP, a tool I discuss in greater detail in a future section) between elementary and secondary science teachers, and found that “only secondary teachers showed significant differences” (p. 1102).

The majority of the programs represented in the literature only accepted science teachers (Blake et al., 2015; Blanchard et al., 2009; Cattadori et al., 2011; Cutucache et al., 2017; Dresner, 2002; Dresner & Worley, 2006a; Enderle et al., 2014; McLaughlin & MacFadden, 2014; Morrison & Estes, 2017; Rushton & Reiss, 2019; Westerlund et al., 2002), while few accepted both science and math (Autenrieth et al., 2017; Faber et al., 2014; Hardre et al., 2010). However, similar to grade level data, most studies did not report the participant’s specific teaching discipline or whether participating teachers taught similar science disciplines to one another. Although discussed in greater detail in a later section with attention to the tool by which changes were evaluated, Miranda and Damico (2015) found that teachers of “math-laden” and “higher-level” courses had the most difficulty in changing their teaching practices from teacher-centered to inquiry-based, and retained positivist approaches to labs and activities. Therefore, Miranda and Damico (2015) put forth “the possibility that RET-PLC programs might be more effective if they were developed to target specific science content” (p. 31). This finding was unique and not found in much of the extant literature on RETS, prompting Miranda and Damico (2015) to suggest the impact of RETs on individual disciplines and the development of discipline specific program experiences as a fruitful avenue for further research.

Overall, studies provided limited demographic data for their participants. In studies that did include sex-based data, there were either more female participants than male (Enderle et al., 2014; Grove et al., 2009; Miranda & Damico, 2013, 2015; Pop et al., 2017; Robertson et al., 2009; Westerlund et al., 2002), or an equal number of male and female participants (Autenrieth et al., 2017; Buck, 2003; Dejong et al., 2016; Herrington et al., 2016; Hughes et al., 2012; McLaughlin & MacFadden, 2014). Rarely did studies indicate a male majority (Page et al., 2013). Additionally, when the sex of the scientists was mentioned in the literature, (whether by pronoun or title), the majority of science mentors were males (Blanchard et al, 2009; Hughes et al, 2012; Mirando & D'Amico, 2013; Dixon & Wilke, 2007; Barnes et al, 2006). This occurrence in the literature, whether intentional or not, preserves the stereotype that those who do science are men and that "female ways of interacting are nonconventional in science" (Barton, 1997, p. 156). The inconsistent reporting of sex demographics in the studies reviewed supported exploration of the possible imbalance of power in the relationships between the mentor scientist and the teacher participants, especially if RETs often indicated that female science teachers were paired with male scientists. By stating this, I acknowledge that an imbalance of power can exist between a male scientist and male teacher participant. However, by applying a lens of ecofeminism to individual teachers' experiences within RETs, this study aimed to critically examine the dynamics between teacher and scientist and their possible perpetuation of historical domination of men in positions of power over women, something that, to my knowledge was absent in the RET literature.

Similarly, when analyzing demographic data, very few studies discussed participating teacher ethnicity. Nevertheless, the majority of participants reported are white. In the few cases where researchers specifically reported that their pool of participants was "diverse," evidential ethnicity data was left out (Baker & Kelly, 2010; Dresner & Worley, 2006; Enderle et al., 2014; Grove et al., 2009). Additionally, across the RET literature, it was common for researchers to focus on a subsample of participants in the study, rather than include the entire population of teachers that participated in any given program. Although subsamples are practical for data collection, it decreased the ability to clearly understand the demographics of teachers who generally participated in RETs.

Far fewer studies reported on the demographics of the students of the participating teachers or the type of community (i.e. urban, suburban, or rural) in which the teachers worked. When researchers reported on the socioeconomic status of participating teachers' students, teachers tended to work in low-income schools (Autenrieth et al., 2017; Chowdhary et al., 2014; Dresner & Worley, 2006; Herrington et al., 2016), and/or described student populations as "minority" or "racially diverse" (Dresner & Worley, 2006; Blanchard et al., 2009; Miranda & Damico, 2013; Chowdhary et al., 2014; Herrington et al., 2016; Autenrieth et al., 2017). For the limited studies which described community type, some reported teachers worked only in urban schools (Blanchard et al., 2009; Buck, 2003; Grove et al., 2009), while others reported their study focused on teachers working in either urban, rural, and/or suburban settings (Hardre et al., 2010; Westerlund et al., 2002). Researchers rarely included the type of school system (i.e., public, private, or charter) in which teachers worked, however in the cases where the type of school was included, teachers worked in public or private schools, and none reported teachers were employed in a charter system. Taken together, these studies supported the notion that despite an NSF goal "to increase the participation of underrepresented groups" (NSF, 2021, p. para 3) in research experiences, the literature rarely indicated diversity as a priority in teacher recruitment or the student populations those teachers served.

The literature on RETs suggested that they are most commonly framed as apprenticeships designed to provide authentic real-world experiences that involve teachers in scientific inquiry. In a comprehensive review of the literature on RET's using search terms, I identified the following four themes: 1) the centrality of the apprenticeship model; 2) the wide-ranging use of the terms real/authentic; 3) inconsistencies in measures of change in beliefs from teacher's RET experiences; and 4) valuable but limited attention in the RET literature to science teacher identity. In the sections that follow, I explore each of these themes as well as subthemes that I identified within them.

Theme 1: The Centrality of the Apprenticeship Model

Across multiple content areas and especially in secondary school, where there is a long tradition of teachers being viewed as having subject-matter expertise, a variety of programs served to cultivate and strengthen teachers' content-area knowledge. Such programs were often framed as connecting teachers with authentic or real-world disciplinary knowledge, and implemented through apprenticeship models.

Apprenticeships can be traced back to the pre-industrial age, where the apprentice learned from the master of a particular trade, and the transfer of knowledge occurred from the master/expert, "a conservative and static transmission model of learning, where only the apprentices are learners" and "the expert is the only teacher" (Griffiths & Woolf, 2009, p. 560). Historically speaking, these individuals most often consisted of both a male master and apprentice (La Croix et al., 2018). This positioning of apprenticeship still continues today with examples in several fields of trade, such as plumbing, electrical work, and bricklaying, and has been modeled by other professions such as in medicine and teacher learning. The concept of apprenticeship as learning introduced by Lave and Wenger (1991), suggested "learning is not merely situated in practice—as if it were some independently reifiable process that just happened to be located somewhere; learning is an integral part of generative social practice in the lived-in world" (p. 35). Framing apprenticeship as an "analytical viewpoint on learning" and introducing the terminology of "legitimate peripheral participation," Lave and Wenger (1991) provided a model of apprenticeship founded in socio-cultural theory, where learning takes place within communities of practice (p. 55). According to Lave and Wenger (1991), the feeling of legitimacy is, "more important than conferring learning" (p. 92), rather legitimate peripheral participation is how learning is defined. Lave and Wenger (1991) emphasized a blurring of the boundary between master and novice, one of the biggest changes from the older conception of apprenticeship to the analytical frame of communities of practice.

Teacher professional development using a model of situated learning through an apprenticeship is not new and can be seen across content areas. For example, The Nottingham Apprenticeship Model, where teachers were paired with artists and other creative practitioners (Griffiths & Woolf, 2009). In science, one of the most well-known apprenticeship style programs paired science teachers with scientists in research experiences.

Most scholars reported programs where a practicing scientist worked in collaboration with teachers, however the role of the mentor varied. Inconsistencies included the process of mentor selection, the method of matching teachers with their mentor scientists, as well as the number of teachers paired with each scientist mentor. Traditional conceptions of apprenticeships imply one expert working with one novice, however the study by Fraser-abder and Leonhardt (1996) was the only study which clearly reported a scientist/teacher pairing of one to one. The majority of studies failed to report details on how teachers and scientists were paired, and the majority suggested little to no teacher involvement, where program coordinators/administrators matched teachers according to their content area. In contrast, Fraser-abder and Leonhardt (1996) described the participating scientists selecting which teacher they wanted to work with based on the teacher's "background and interests" and whether teacher interests "aligned with their current research" (p. 33).

Although applications were included for participating teachers, the study by Cutucache et al. (2017) included the submission of formal applications by the scientists in order to participate as mentors. In contrast, most RET studies suggested that mentor scientists did not have previous experience working with teachers in this capacity. Buck (2003) found that "because the lead scientists had (almost universally) not conducted this kind of teacher enhancement project before, some were not prepared for the great time requirements for training large numbers of participants" (p. 51). Cutucache et al. (2017) found that "the relationship between the research pairs [scientist and teacher] was mutually beneficial, and many mentors and teachers-maintained contact after the summer research period" where mentors visited "teacher's classroom, hosting the cooperating teacher's students in a visit to his or her research lab, and/or providing supplies and guidance for developing and implementing new laboratory activities in the teacher's classroom" (p. 734).

Other studies noted the importance of the mentor scientist's disposition and availability, suggesting "the nature of the relationships formed in RETs is emerging as an important aspect of the experience, as teachers who work with a supportive mentor are more likely to enact changes in their teaching practice" (p. 1083). Mirando and D'Amico (2013) pointed out that "mentor availability and support were sensitive and influential" (p. 169) to teacher's experiences. In contrast, Barnes et al. (2006) found that teachers "who were dissatisfied with the lab experience had professors who were absent much of the time" which led to teachers feeling a "need for more guidance" (p. 256). Hardre et al. (2010) asked the question "if the mentors spoon-fed teachers their classroom strategies, if they scaffolded them too much, would they be being robbed of the opportunity and challenge to create, to discover, even to have an authentic research experience at all?" (p.174). The evidence presented in this section suggested that the role of the mentor scientists was influential in the experience of the teacher participant, however, this role was not clearly delineated across programs and not all teacher participants reported having the same level of support. This finding suggested a more focused approach to examining how scientists are prepared for their position as mentor, and how this preparation may be replicated across RET programs.

Mentor relationships and the quality of the mentor not only influenced the learning of the teachers but also made teachers feel welcome in the space of the scientist. As one participant in the study by Hughes et al. (2012) stated, "The idea that Dr. Vector [the participants mentor scientist] was involved and interested in her results, because he had 'never seen it,' made her feel like a legitimate participant (Lave & Wenger, 1991) in the laboratory" (p. 923). The literature on RET professional development was frequently presented as being grounded in the framework of situated learning and communities of practices (Brown & Melear, 2007; Buxner, 2015; Dixon & Wilke, 2007; Feldman et al., 2012; Hughes et al., 2012). However, even when referencing communities of practice (Lave & Wenger, 1991), the description of RETs often mirrored that of the historic context of an apprenticeship, where the scientist was the one holding the knowledge and authority. For example, Brown and Melear (2007) claimed the program in their study exemplified an "apprenticeship model" (p. 566) that was "supported by situated cognition research" (p. 566). However, in the explanation of the anticipated goals for the preservice teachers in their study, (Brown & Melear, 2007) stated "skills would be transferred from the expert scientist to the novice pre-service teacher" (p. 575). Although this study acknowledged that the teachers and scientists were from "different worlds" (p. 566), Brown and Melear (2007) made language choices which placed greater value on the world of the scientist.

It was evident that language choice mattered in the researchers' presentation of their work. The historic notion of apprenticeship was perpetuated through certain language choices, such as referring to the scientist as "master" (Buxner, 2015); and using the metaphor of working "at the elbow" of the scientist (Blanchard et al., 2009; Brown & Melear, 2007; McLaughlin & MacFadden, 2014). This metaphor, although presented from a positive perspective, did not necessarily connote a positive experience, or represent a true community of practice (Lave & Wenger, 1991). The phrase being "at the elbow," originating in the 1500s, was used to describe a traditional apprenticeship relationship where the apprentice was "constantly at the master's elbow" (Dictionary, 2002). Although the metaphor may suggest that one was learning from or providing assistance to the master, this metaphor also implied that the one "at the elbow" was a nuisance and getting in the way of the master's work.

Few studies used language representative of a true community of practice, where all members were valued as legitimate participants. Examples included when "participating mentors agreed that the teachers would be active, contributing members of a research team" (Miranda & Damico, 2015, p. 23) or when an RET "sought to build a mutually beneficial relationship between scientists and teachers by positioning science teachers as expert contributors alongside their scientific partners" (Shanahan & Bechtel, 2019, p. 357). Davidson et al. (2021) chose not to use the term apprenticeship and borrowed terminology from the communities of practice literature (Lave & Wenger, 1991), suggesting that mentors were selected based on their reputation for being "open, patient, knowledgeable, and have a willingness to include teachers in their lab groups as full participants" (Davidson et al., 2021, p. 8). Overall, evidence indicated that the majority of participating teachers were not experiencing true communities of practice during their experiences in RETs, even when placed in an apprenticeship "at the elbow" of a practicing scientist/expert. Literature also indicated that scholars were not always intentional about the terms and metaphors they used to describe the relationships between teachers and scientists in an RET. In the next section I focus particularly on how scholars of RET literature use the terms real-world and authentic.

Theme 2: The Wide-Ranging Use of the Terms Real-World and Authentic

When the National Research Council (1996) envisioned future science education, it involved students working to "address real issues and solve real problems" (p. 85). More recently, the authors of the Next Generation Science Standards promoted learning that is not only relevant to students, but authentic to that of practicing scientists (NGSS, 2013). The terms real-world and authentic, despite their ubiquitous use in the RET literature and often found in the introduction section and study titles, were infrequently defined by the authors. The RET literature tended to equate an apprenticeship with a scientist as having a real-world or authentic experience in a real-world or authentic space. In some studies, the terms real-world, authentic, and apprenticeship are used interchangeably, which made it even more difficult to discern their meanings.

Many studies used authentic or real-world when laying out the importance of the RET, indicating that teachers have limited conceptions of scientific inquiry due to their "lack of experience with authentic science research" (Miranda & Damico, 2015, p. 23), mentioning the fact that "much of the undergraduate preparation for science teachers precludes authentic research experiences" (Southerland et al., 2016b, p. 2). Authors foreground their studies (Pop et al., 2010; Saka et al., 2009) with the terms real-world and authentic with the implication that by working alongside a practicing scientist on an active research project, in a location that typically employs working scientists, would change the teacher's conception of science.

Buxner (2015) and Herrington et al. (2016) used the term "authentic" as the goal of the RET, describing authentic experiences as those in which a science teacher was "doing research alongside scientists in an authentic setting" (Buxner, 2015, p. 54) and learning "authentic scientific practices" in order to better translate those practices into their classroom (Buxner, 2015, p. 54). Herrington et al. (2016) suggested that by participating in an RET, teachers could improve the way they "communicate real-world use of science practices to their students through classroom instruction (p. 184). In such studies, authenticity was indirectly defined as doing something that a scientist was doing in a place where a scientist was working, and an understanding of real-world/authentic science could be achieved by participating in the scientific practices and activities during experiences such as RETs.

In one study, Chowdhary et al. (2017) used the term "real" multiple times in their findings, such as describing "real-life problems" as those "connected to students' lives" (p. 873). also referred to the term "real" when they stated that one of their participants was "exposed to the research process that scientists conducted in the real-world" (p. 873) when he worked with professors in the "civil, structural, and environmental engineering" (p. 873) departments of the university in which he was placed. Later, when discussing a different participant, they explained that by working with a STEM graduate student, the teacher was able to develop a lesson for her students that reflected "how scientists diagnose and detect cancer in the real-world" (p. 878). Chowdhary et al. (2017) used the term real-world in three separate ways: 1) by portraying "real" as something that is relevant to classroom students; 2) as the work done by practicing scientists at a university; and 3) by implying that the real science being done by scientists can be replicated in some manner in the classroom for students. This third finding echoed that of Herrington et al. (2016), described above.

In contrast, Miranda and Damico (2015) implied that real-world science was conducted by individuals working at local research institutions holding advanced degrees in a science field (in this case all participating mentors held either a M.D. or PhD), and not the science conducted in K-12 science classrooms. Miranda and Damico (2015) most often used the term “real-world” in excerpts from teacher interviews. For example, they included the following quote from one of their participants: “Having this kind of practical experience in a real research situation has really tied everything together for me and connected all of the puzzle pieces” (p. 1252). Another participant stated that being able “to analyze authentic, real-life data’’ (p. 1253) allowed him to feel a sense of achievement. Later Miranda and Damico (2015) stated that “After participating in their summer RET program, teachers were better able to recognize the characteristics of authentic, real-world scientific inquiry” (p. 1257). Miranda and Damico (2015) explicitly named the “dichotomy of real-world and classroom science” (p. 1258) and suggested that this dichotomy must be considered in the design of future RET programs. However, in one section of their paper, they discussed how teachers planned “to make science content more real-world, relevant, and rigorous for their students in the upcoming academic year” (p. 1255). By suggesting that science teachers can have their students participate in real-world science in their classrooms, Miranda and Damico (2015) posed a contradiction to the way they had previously defined real-world science.

Other studies used the term real to describe the particular way in which science information was learned. Southerland et al. (2016b) quoted Little (1993): “Judging by teachers’ accounts, such institutes and centers offer substantive depth and focus, adequate time to grapple with ideas and materials, the sense of doing real work rather than being talked at" (Little, 1993, p. 137). By quoting Little (1993), they suggested that for someone to be participating in real science, they must do more than be presented with scientific information. Rather, teachers need to be exposed to real science results from having some form of hands-on experience. However, it was unclear if hands-on experiences were "real" if they are taking place in a science classroom, or if they could only be designated as real if they took place in a laboratory setting. Southerland et al. (2016) also used the term authentic when they described the experience of teachers who participated in more self-directed projects, stating teachers had research experiences that were authentic to them personally, even "if not [authentic] to the larger field of science" (p. 13). This implied that when a research experience was relatable to the researcher, the experience became more "authentic." This use of the term of authentic was unique within the scholarship on RETs.

Although becoming immersed in the field is essential for communities of practice to contribute to learning, Lave and Wenger (1991) recognized that "any given attempt to analyze a form of learning through legitimate peripheral participation must involve analysis of the political and social organization of that form, its historical development, and the effects of both of them on the sustained possibilities for learning" (p. 64). By placing science teachers with scientists, with the expectation that beliefs about science held by the scientist/expert will be taken up by those teachers, designers of RETs were assuming that the scientist was holding a version of science that they wanted teachers to take up. However, as mentioned in the introduction, scientists do not always consider the epistemological underpinnings of their views about the nature of science (Wong & Hodson, 2010).

In some of the RET literature, scholars recognized an experience as real or authentic by citing evidence that perpetuated a positivist view of science, where science was the process of discovering right answers, in line with the view that there was an objective, external reality that could be measured. For example, Dresner and Worley (2006) expressed that one teacher had left the RET with a more authentic view of science, citing a quote from a participant stating "even if the students do not discover the right thing, they get the experience of the process" (p. 8). Other studies promoted a positivist notion of science rooted in anthropocentric ways of thinking, where non-human animals were at the disposal of humans in the pursuit of scientific knowledge. For example, in one study, Blanchard et al. (2009) discussed the ways in which the program met its goals for teachers "to experience scientific inquiry from its inception, from initial observations through development of a hypothesis, experimentation, and findings" portraying "scientific activity authentic not only to science but also to the participants" (p. 328), and included the following excerpt:

> For instance, when a group investigating whether changes in salinity affected snails climbing the marsh grass proposed, "We are going to put the snails under water for ten minutes and see how many of them survive," the staff scientist asked, "How will this test the effect of salinity on the snail?" Given that this was a new skill for many of the teachers, it was very difficult for them to determine how to test their hypotheses. A "tool talk" by the scientists as the teachers were developing experimental designs demonstrated equipment and techniques that might be useful, such as ways that snail shells could be superglued to dental floss and tethered at intervals in the water, or how to use a refractometer to gauge water salinity. Once a team decided on research protocols, they needed to try out these methods and refine them, again very focused on whether the data

> they collected would indeed answer the question they were trying to answer. During the data collection phase, teams would sometimes realize the weaknesses of their experimental design, and some revised their methods or materials, collecting additional data (Blanchard et al., 2009, p. 328).

The above quote exemplifies how despite a research experiences inclusion of the refinement of skills in a scientific study, something that would be praised as a movement away from more static interpretations of the nature of science, they did so in a way that exploited non-human organisms as tools of/for investigation.

Similarly, in the study by McLaughlin and MacFadden (2014), researchers reported that their RET allowed "science teachers to participate in the investigation of real-world phenomena with scientists help teachers conceptualize science as a creative process rather than as a body of knowledge" (p. 943). In an attempt to highlight one teacher's implementation of "the inquiry process of scientists rather than the methodical steps from a cookbook worksheet" (McLaughlin & MacFadden, 2014, p. 941) they included the following in their findings:

> In an attempt to change his students' view of the linearity of the scientific process, Mark adopted a guided inquiry approach to explore questions that relate to the concepts being taught but that are more aligned with students' interests. He shared a sample lesson plan, in which his students collectively designed an experiment aimed at determining the purpose of a moth's antennae. In their experiment, students removed the moths' antennae and allowed the moths to move through a choice chamber in which pheromones were used as a means of attraction. Their control experiment I involved moths with intact antennae. For both the experimental and the control experiments, students measured the speed of the moth as it travelled through the chamber and compared results to interrogate

their hypotheses. The guided inquiry approach employed by Mark allowed students to become involved in a process of asking questions and planning investigations in an attempt to address their observations about a natural phenomenon (McLaughlin & MacFadden, 2014, p. 941).

Together, these studies indicated the terms authentic and real are used in varying ways, and that authentic experiences often reflected positivist and/or anthropocentric views, resulting in a lack of clarity and an overly simplistic view of science promulgated within RET scholarship. In terms of varying definitions of authentic, some studies used the terms authentic and real-world science simply referred to what scientists do in the places that they do it. For others it represented an idealistic version of science practiced by scientists but that could also be brought back into the classroom. Often, the RET literature discussed real-world and authentic science as taking place in the laboratory/field of a scientist and not in the classroom, however the goal was for participating teachers to become better at real-world/authentic science in the classroom. One of the goals of my study was to develop a clearer understanding of these two terms and what they mean when it comes to the teaching of classroom science.

Not only are real-world and authentic used without clarity in meaning, in some studies researchers have promoted positivist and/or anthropocentric views of science. Alarmingly, RET scholars remained silent regarding topics of environmental injustice and the push for technocratic solutions over systemic societal change to the issues of climate change and environmental degradation. The framework of ecofeminism afforded me the opportunity to examine those perceptions from a lens that differs from the current conception and critically consider how RETs may or may not have perpetuated impoverished views of science. This literature suggested a need for RET scholarship to address the use of language in studies with the goal of becoming more intentional about the terms used to convey the experiences of teachers. If the intention is for teachers to undergo real-world and authentic apprenticeships in science, scholars and program designers must first determine what is meant when use these words. By using an ecofeminist theoretical frame, this study placed heightened importance on the language used by participants. Finally, although studies reported that RET experiences led to changes in teachers' beliefs, often justified in the conceptions of the nature of science in the NGSS and Lederman et al. (2002), the changes scholars reported tended to perpetuate uncritical versions of science.

Theme 3: Inconsistencies in Measures of Teacher Success and Change in Beliefs from RET Experiences

RET apprenticeship experiences are valued as successful models for science teacher professional development, with the literature reporting increased teacher content knowledge (Barnes et al., 2006; Brown & Melear, 2007; Dixon & Wilke, 2007) and the intention to implement laboratory activities, skills, and other changes to their classroom pedagogy (Barnes et al., 2006; Basile, 2015; Buck, 2003). In addition to the increased implementation of teachers' lab skills in the classroom, literature suggested RETs had the potential to change science teachers' views and perceptions regarding science. This assumes not only that the apprenticeship model provided a structure for teachers to follow when they returned to their classrooms, but that teachers had a change in their beliefs about the nature of science, driving the way they represented science when they returned to their classrooms.

This assumption was supported by the idea that "beliefs are part of a group of constructs that describe the structure and content of a person's thinking that are presumed to drive his/her actions" (Bryan & Atwater, 2002, p. 823), and by studies which suggested the strategies teachers used in their classrooms were linked to their beliefs (Gunel, 2009; Haney & McArthur, 2002;

Mansour, 2009). Therefore, if RET experiences failed to shift teacher practices in the classroom (Dixon & Wilke, 2007), it may be because teachers had experienced a shift their beliefs about the nature of science. Likewise, literature suggested that even when teachers did experience a change in their beliefs, those changes were slight and differ across participants (Buxner, 2015; Dresner & Worley, 2006; Herrington et al., 2016; Miranda & Damico, 2015). For the remainder of this section, I highlight studies that focused on a change in teacher beliefs about the nature of science and/or scientific inquiry and the way the researchers chose to measure and/or categorize that change in beliefs.

Buxner (2015), measured teachers' beliefs about inquiry and the nature of science using a modified version of the Views of Nature of Science and Views on Scientific Inquiry surveys developed by and based on the conceptions of Lederman et al. (2002). This modified tool was used to evaluate and rank teacher statements as either “naïve, mixed, or informed” (Buxner, 2015, p. 60). The following is an example of the way (Buxner, 2015) categorized teacher statements as either naïve or informed in regards to the “tentative nature of science” (Lederman et al., 2002):

> Naïve: “Science is a continuous process by which different scientific methods are used to prove a hypothesis. The very goal of scientific inquiry is to find an answer to a question and prove it to be correct and valid. (AZ-7)
>
> Informed: “Science is different from other disciplines because it evolves as the knowledge base grows, but also as technology grows. It is rare as a discipline in that it accepts that “Laws” may change as new evidence is presented.”

Despite slight changes to teacher beliefs, (Buxner, 2015) found that teachers who entered the program with informed understandings, left with informed understandings, whereas those who entered with naïve understandings or a mix of naïve and informed understandings, only experienced small changes and in only certain areas, and most often retained. One example of a teacher statement defined as naïve after participating in the RET was as follows: “Their belief in the objective and universal nature of science or the rigid belief that experiments were the only way to gather scientific data” (p. 62).

Other researchers in the field centered their studies on identifying the specific aspects of an RET apprenticeship which led to change and whether those aspects could be replicated in other RET apprenticeship style programs. Such aspects included increasing the autonomy teachers had over their research experience and relating the experience to teachers’ interests (Enderle et al., 2014; Southerland et al., 2016), as well as increased duration of the RET experience (Herrington et al., 2016; Miranda & Damico, 2015).

Southerland et al. (2016) examined in their study “the specific features of teachers’ thinking that are most influential in shaping the learning that occurs in RETs” suggesting previous research has treated RETs as “black boxes,” where outcomes were identified without investigating the “essential features of these experiences” which led to such outcomes (p. 3). They questioned both the aspects of the experience that resulted in outcomes as well as how teacher’s thinking and affective state leading up to the program, specifically “teaching self-efficacy, pedagogical discontentment, and beliefs about teaching,” (p. 2) could both impact and be impacted by their experience in research. This study also sought to compare two different forms of an RET, one with a heavier focus on research experience (SciRes) and the other which emphasized teacher pedagogical practice (SciPed).

Southerland et al. (2016) anchored their estimation of teacher beliefs in the Next Generation Science Standards conception of “science inquiry as practices” (p. 4). Tools were used to analyze a wide variety of data collected "before, during, and after the RET experience" and included "quantitative survey instruments, interview protocols, observations of research activities, and video recordings of classroom practice" (p. 4). In this review, I include a discussion of such tools only when they examined the change of teachers' beliefs about science. Tools examining other features of RETs such as teacher self-efficacy, were excluded.

One of the tools used by Southerland et al. (2016) was the Teaching Science as Inquiry Instrument (TSI), which intended to measure "teachers' fundamental beliefs about science teaching and learning," (p. 5). Based on the theoretical framework of self-efficacy developed by Bandura (1977), and the "five essential features of classroom inquiry" (NRC, 1996a), the TSI is a "69-item Likert scale" quantitative tool (Dira-Smolleck, 2004, p. iii).[1] The researchers (Southerland et al., 2016) suggested the TSI mapped "well onto the eight practices of science of the NGSS" claiming "each of the eight practices are represented multiple times on the instrument" (p. 5).

Southerland et al. (2016) also used the Teacher Belief Inventory (Luft & Roehng, 2007), described in the study as "a seven-item semi structured interview protocol used to elicit teaching and learning beliefs in science and mathematics" (p. 7). This study had several important findings. First, through use of the Teaching Science as Inquiry Instrument, Southerland et al. (2016) identified "the importance of teachers' incoming affective states" (p. 10). In short,

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[1] The five essential features of inquiry outlined by the NRC (1996) include: 1. Learner engages in scientifically oriented questions; 2. Learner gives priority to evidence in responding to questions; 3. Learner formulates explanations from evidence; 4. Learner connects explanations to scientific knowledge; 5. Learner communicates and justifies explanations.

teachers who entered their programs feeling less successful in their abilities to teach science, were less likely to believe they could improve in their teaching of science even after participating in an RET. Southerland et al. (2016) also found that "teachers with more confidence in their ability to teach through inquiry selected an RET model that involved less social interaction" (p. 10), in this case the SciRes program.[2] On its own, this finding may not appear to relate to changes in teachers beliefs. However, Southerland et al. (2016) identified, using the Teacher Beliefs Instrument, one of the most influential features was the social nature of the RET, providing teachers the opportunity to communicate with others about their experiences and science teaching. When discussing this study in the earlier section on real-world and authentic science, I emphasized the use of the term authentic, as "personally relevant" (p. 13) to the science teacher and not necessarily "new to science" (p. 13). Social interactions and personal relevancy were more prevalent in the SciPed program than the SciRes program. This finding was important, as it continued to speak to the need for clarity in RET program design. Despite the literature emphasizing the need to place teachers in authentic spaces and in authentic experiences, similar to that of the SciRes program discussed in this study, teachers had a greater change in their beliefs about science and teaching science when they participated in a program that some might deem less "authentic." Other research in the field found that it was the collaboration between teacher and scientist, that led to the biggest changes in teachers, such as changes to content knowledge (Brown & Melear, 2007), their beliefs about the nature of science and scientific inquiry (Herrington et al., 2016; Miranda & Damico, 2013, 2015), and their beliefs about teaching scientific inquiry (Herrington et al., 2016; Pop et al., 2010).

[2] In this study teachers often used the terms confidence and self-efficacy interchangeably.

In a study evaluating the use of inquiry using the Reformed Teaching Observation Protocol (RTOP), Miranda and Damico (2015) studied a group of teachers taking part in a year-long professional learning community after participating in an RET. Miranda and Damico (2015) did not cite any previous conceptions of inquiry in this study, which made it difficult to determine what version of the nature of science and inquiry researchers held outside of the RTOP tool. However, they found that only half of the teachers in their sample shifted their classroom approach to reflect more “inquiry-based” lessons (p. 30). Additionally, teachers of “math-laden and higher level” courses had less of a change to their instructional practices, and retained traditional “cook-book lab activities” (Miranda & Damico, 2015, p. 31).

Furthermore, Herrington et al. (2016) researched teachers who participated in a two-year professional development program, which included a six-week summer RET experience, with the goal of changing participating teacher “beliefs, attitudes, and values” about teaching inquiry (p. 187). The researchers evaluated teachers' beliefs using a combination of two tools: the Inquiry Teaching Beliefs instrument (Harwood et al., 2006) and the “Researcher-created teacher inquiry beliefs system spectrum” (Herrington et al., 2016, p. 183). These tools included a “card-sorting” process used to identity teachers’ implicit understandings of inquiry (Herrington et al., 2016, p. 190) as well as changes to teacher beliefs through the use of open-ended questions, respectively. Teachers’ beliefs would then be coded as having either “no change; belief change; attitude change; or value change” (Herrington et al., 2016, p. 191). These categories were developed based on the researchers' conceptions of science inquiry, grounded in the Next Generation Science standards vision for science teaching. Herrington et al. (2016) found that although all teachers had “some degree of a belief change” (p. 194), the teachers who experienced the most change were male teachers with predominantly white student populations.

Herrington et al. (2016) also found that teachers' change in beliefs could not solely be attributed to their experience in the RET but also from their “experiences outside of, both before and during, the RET” (Herrington et al., 2016, p. 200).

In the study by McLaughlin and MacFadden (2014), researchers investigated changes to teacher beliefs about science inquiry after participating in an RET, and emphasized that the program incorporated several features of effective professional development program. These features included: teacher reflection on their pre-existing conceptions of scientific inquiry, the immersion of teachers into ongoing scientific practice, and teacher support for classroom application. McLaughlin and MacFadden (2014) noted that the view of the nature of science undergirding their study was based in the conception put forth by the NGSS. Using a grounded theory approach, rather than a quantitative instrument, McLaughlin and MacFadden (2014) identified three themes around teachers’ new understandings of inquiry: “science is messy” (p. 936), “seeing the community of scientists” (p. 940), and “the multidisciplinary approach” (p. 941). Researchers provided rich descriptions of teacher experiences and how those experiences impacted teacher beliefs about science and impacted their classrooms, claiming that by engaging teachers in an RET experience, teachers were able to reflect on their conceptions of the nature of science and teaching of scientific inquiry. However, McLaughlin and MacFadden (2014) acknowledged that their pool of participants was small. It is also important to note that the studies included in this section, which reported change in their participants beliefs about the nature of science, were also included in the earlier section of this review in an attempt to highlight scholars who have implicitly promoted an anthropocentric view of science.

Davidson et al. (2021) asked the following question of a single science teacher: “How certain events within their RET participation might shape their understandings about the discipline of science?" (p. 3). They explained their conception of disciplinary understandings about science as encompassing: "the characteristics and features of scientific work; the norms, practices, and tools of the community in which that work occurs; the sociopolitical and cultural contexts that influence science, the humanity, individuality, and identities of scientists; and the conceptual knowledge and epistemological reasoning scientists use to develop new understandings about the natural world" (p. 4). This was the only study that I identified in my review of the literature on RETs that incorporated socio-political and cultural contexts in their discussion of science, and what I chose to define as their understanding of the nature of science.

Davidson et al. (2021) applied a lens of critical events and found that by participating in an RET, their participant "came to experience shifts in her understandings about science, shifts toward understandings that resonate with those held by the fields of history, philosophy, and sociology of science, as well as science education" (p. 19). They attributed teachers' change in "beliefs, practices, and knowledge around science and science teaching" (p. 22) to the social nature of the RET, particularly "the development of relationships with multiple scientists" (p. 21). Davidson et al. (2021) went explained that "while not directly related to the programmatic features of the RET, Ava [participant] was given explicit opportunities to reflect upon, connect, and unpack her laboratory research and other experiences at the Lab during interviews" and "were able to identify emergent and shifting views of Ava's understandings about science" (p. 22). Previous work on RETs expected teachers to participate in their experience, have a change in beliefs, and be able to incorporate that change of beliefs into their classroom teaching. However, this finding suggested that eliciting science teachers' understandings about the nature of science through the interview process and allowing them the opportunity to unpack the critical events that shaped their understandings, may in fact have led to a greater impact of an RET on teacher beliefs and classroom practice. Therefore, although literature from teacher learning suggested a correlation between teacher beliefs and teaching practices (Gunel, 2009; Mansour, 2009), the evidence presented in this section suggested that participation alone "does not guarantee that teachers will come away with more sophisticated understandings about disciplinary content, practices, or epistemologies in science" (Davidson et al., 2021, p. 2).

Davidson et al. (2021) elected to use critical event analysis because this qualitative framework "contends that all people have lived experiences that shape the narratives they hold about their beliefs, attitudes, and understandings about the world and themselves" (p. 6). Although they highlighted three unique critical events that contributed to a singular teacher's disciplinary understandings, they pointed out that "for another teacher, it is likely that a critical event analysis would highlight very different critical experiences and, therefore, different lessons learned" (p. 21). They argued one of the contributions of their work to the field was the use of critical event analysis as a methodological tool. Davidson et al. (2021) suggested that this tool be used to examine the disciplinary understandings to groups of teachers, specifically "how groups of teachers may think, feel, and learn in relation to collectively experienced events in professional learning settings" (p. 24).

In summary, there are four main takeaways from the studies discussed in this section that relate to inconsistencies in measures of change in beliefs from teacher's RET experiences as reported in the literature. First, although RETs have made an impact in changes to teachers practice and content knowledge, literature suggested the impact of RETs on teacher beliefs is inconsistent, minimal, and not guaranteed even with increased duration and intentional links to teacher interest and classroom pedagogy. Second, even when changes to teachers' beliefs have occurred, the way those changes were measured varies (RTOP, TIBSS, TBI, TSI, etc.), and qualitative methods provided avenues for studying science teacher beliefs about the nature of science that were more transparent, rich, and less reducible than quantitative tools. Third, the majority of studies used the conception of the nature of science put forth by Lederman et al. (2002) or the Next Generation Science Standards to evaluate science teacher beliefs, and very little work has been done to apply critical frameworks to the views of science that teachers were being presented with and bringing back to their classrooms. Lastly, within the large body of RET literature centered around science teacher beliefs about science, very few studies took into account how teachers made sense of the experiences that shaped those beliefs as well as the way their identity impacted how teachers perceived their experiences and how experiences shaped their identities within science. It also should be noted, that for the vast majority of literature on RETs, researchers relied on self-reported data when developing understandings about the change to teachers' classroom practice. Although my study did not include data collection in teachers' classrooms due to the limitations of the COVID 19 pandemic, it remains a gap in the literature that requires further investigation.

Theme 4: The limited RET Literature Dedicated to Science Teacher Identity

While researchers have documented how RETs may shape teacher beliefs, as described above, there has been little attention to how RETs may shape science teachers' identities more broadly. In this section I included studies that discussed how science teacher participants "come to 'figure' who they are within the figured world of RETs" (Urrieta, 2007, p. 107), and how their identities have been shaped by the practices and activities in which they have participated. Limited studies include those which examined teachers as scientists and researchers (Faber et al., 2014; Rushton & Reiss, 2019) or teachers as experts (Shanahan & Bechtel, 2019).

In examining science teachers' identities as scientists and researchers, Rushton and Reiss (2019) found that teachers who participated in a science research experience developed "a multi-faceted professional identity" that included "teacher, scientist, researcher, collaborator and mentor" (p. 33). This new identity was attributed to teacher interaction with "scientists, academics, other teachers and students" (p. 34). Specifically, they found that when teachers were considered as members "of a community of scientists and researchers" (p. 32), teachers incorporated aspects of that community into a "a sense of self that is both teacher and scientist" (p. 32). More than being placed "at the elbow" (McLaughlin & MacFadden, 2014), teachers were considered as collaborators. Teachers attributed this new "sense of self" to their participation in "furthering understanding and knowledge of scientific topics and potentially providing solutions to problems that impact the wider world" (Rushton & Reiss, 2019, p. 33). Therefore, Rushton and Reiss (2019) suggested using the term "teacher scientists" to describe science teachers who actively participated in a science research experience. They also point out that their study may not have captured the negative experiences other science teachers may have had and neglected to consider the variety of experiences that may have contributed to their changes in identity, suggesting "further research could try to capture these experiences so that the challenges of research and the barriers to becoming a teacher scientist are better understood" (p. 36).

Although the following two studies did not emphasize the term identity, I included the studies by Shanahan and Bechtel (2019) and Faber et al. (2014) in this section because of the way the researchers framed their study around teachers as either becoming scientist (Faber et al., 2014) or as already being experts (Shanahan & Bechtel, 2019).

In their study, Faber et al. (2014) questioned "what aspects of their [science teachers] experience was essential to their development as scientists?" Although similar to studies discussed in earlier sections looking to identify which aspects led to a change in teacher beliefs about science, Faber et al. (2014) were more concerned with locating the key features of RETs, if any, that contributed to the way in which teachers perceived themselves as scientists. In this study, researchers looked across three RET programs with similar program goals, features, and deliverables. Rather than using the term identity, they elected to use the term “functionality” (p. 787). In order to “assess changes in the teachers’ functionality as scientists during the course of the RET program,” they developed a five point “functionality scale” (p. 787). Of the five categories, only three were relevant to teachers as becoming scientists. These three categories included: “independence (autonomy in the research environment), structure (need for structured research environment), and relationship with mentors (interaction with mentors as peers)” (p. 789). They evaluated teachers in each category as either “low, low-middle, high-middle, or high” (p. 788), using this hierarchical classification as a qualitative coding scheme when they analyzed their data. After evaluation, they found that “of the 27 teachers who completed an exit interview” only seven “reached high functionality in all five constructs” (p. 792) at the end of the RET experience. Additionally, six teachers reached “high functionality in four of the five constructs, six reached high functionality in three of the five constructs, seven reached high functionality in two of the five constructs, four reached high functionality in one of the five constructs, and three did not reach high functionality in any of the constructs” (p. 792). In this case, the assessment of Faber et al. (2014) as having high functionality was equivalent with their labeling teachers as having functionality as scientists.

Faber et al. (2014) found that difference in functionality did not appear to be dependent on teacher demographics, specifically across “race, gender, undergraduate degree, graduate degree, years of teaching experience, subject and grade taught, and previous research experience" (p. 801), a finding that is inconsistent across the RET literature when it comes to teacher beliefs. However, they did identify stark differences in the experiences of those teachers who reached high functionality compared with those who were labeled as having low functionality. Specifically, they found that "teachers within the high science functionality group adjusted to an open-ended environment, transitioned from a guided experience to freedom, felt useful in the laboratory, and were self-motivated" (p. 802), while they described those in the lower functionality group as not taking part in a "true research project" (802). They further explained that the teachers who did not experience a "true research project" were those whose experience was "primarily focused on the teaching aspect" (p. 802) and "did not display a transition of responsibilities" (p. 802). Rather than referring to science experiences as "real" or "authentic," Faber et al. (2014) used the term "true" to designate the science experience teachers were supposed to have when participating in an apprenticeship with a scientist, and disclosed their conception of a "true" experience as one that was not focused on teaching, where the teacher was able to take on some of the responsibilities within the lab community and become a peer with their mentor scientist.

Shanahan and Bechtel (2019) took a novel approach to the analysis of RETs when they examined "Expertise that science teachers and scientists bring to a collaborative project," in response to the "deprivileging of science teachers' expertise in curriculum development" (p. 355). They used the term "real" when talking about expertise, stating that expertise is "the real and substantive possession of groups of experts" (p. 357), and suggested that expertise can be established through "immersion" and "socialization" with experts (p. 357). This use of the term real, although not used to describe a science experience as earlier studies in this review did, did offer something to the discussion of teacher identity. By relating the terms real and expert, Shanahan and Bechtel (2019) signaled two things, the first being that both teachers and scientists were already considered as having an identity as expert. Second, by participating in true communities of practice (Lave & Wenger, 1991), something we know from close examination of the literature rarely comes to fruition in RET programs, teachers and scientists could share their expertise with each other, with the possibility of becoming experts in each other's real knowledge, expanding their own identities within science.

Taken together, the studies included in this section on teacher identity further supported the importance of RETs as communities of practice, where teachers developed a sense of self within the figured world of practicing scientists, while at the same time maintaining the sense of self developed within the figured world of teaching, where value is placed on both spaces as contributing to expert knowledge. However, this same literature further contributed to the lack of clarity in RET scholarship around what was meant by a research experience and what the expectation of that research experience was for participating teachers and scientists, particularly with respect to their identities in science as well as the views of the nature of science that were perpetuated by RET programs. Finally, the evidence reviewed here seemed to suggest a pertinent role for studies on RETs centered around identity, where identity is explicitly named within the scholarship. If RETs are meant to impact the way teachers perceive the nature of science, then researchers must take up the task of examining how experiences with research impact those perceptions. By focusing particularly on the figured worlds of science teachers, this study aimed to address this gap in the literature. In the following section I provide an overview of the frameworks I used to both construct my study and analyze my data.

Theoretical and Analytical Frameworks: Ecofeminism, Figured Worlds, and Storied Identities

Ecofeminism

According to Birkland (1993), “ecofeminism is a value system, a social movement, and a practice” that offers “a political analysis that explores the links between androcentrism and environmental destruction” (p. 18). For ecofeminists, “values and action are inseparable: one cannot care without acting” (Birkland, 1993, p. 19). As a subset of feminism, ecofeminism “goes beyond concepts of social justice alone” with a deeper concern of “cultivating an ecological ethic” (Birkland, 1993, p. 17) Although ecofeminism shares its foundations with other forms of feminism, in that it pushes against the male-dominated system of values present in western ways of thinking, this framework highlights the ways women and nature have been likened to one another through delegitimizing language and parallel acts of oppression (Warren, 2000). Drawing from the work of post structural feminism, ecofeminists place emphasis on language and the way it has been used to maintain hegemonic structures within society (Warren, 2000). By using similar language to discuss women, non-human animals, and nature, their domination is sanctioned through the promotion of dualisms and hierarchies central to patriarchal ways of knowing and thinking (Warren, 2000). More recent characterizations of ecofeminism broadened that construction to include people of color (Kings, 2017).

The term *ecofeminism* was coined in 1974 by Francoise D'eaubonne, widely considered the founder of the ecological movement in feminism. This term was established during the green movement and second wave feminism and shares relationships with both: “a concern about the impact of human activities on the non-human world” and “the view of humanity as gendered in ways that subordinate, exploit and oppress women” (Mellor, 1997, p. 1). Ecofeminists see the exploitation of women present in western ways of thinking as sharing the same epistemic underpinnings as the exploitation of nature. Therefore, ecofeminists call for a fundamental change to ways of thinking and doing in current societal structures, including the way we present the nature of science.

An Ecofeminist Critique of the Portrayal of Science in U.S. Science Education. Although the NGSS and other more modern takes on science teaching and learning have attempted to portray the multidimensional nature of science, an ecofeminist perspective would highlight the way that these standards still present the nature of science as constructed meet the needs of humans. The NGSS (2012) were explicit in their anthropocentric view when they stated:

> Humans have a need to know and understand the world around them. And they have the need to change their environment using technology in order to accommodate what they understand or desire. In some cases, the need to know originates in satisfying basic needs in the face of potential dangers. Sometimes it is a natural curiosity and, in other cases, the promise of a better, more comfortable life. Science is the pursuit of explanations of the natural world, and technology and engineering are means of accommodating human needs, intellectual curiosity, and aspirations. (NGSS, 2012, p. 2)

In a comprehensive review of the way animals were presented in environmental education, Spannring (2016) found "the curriculum, disciplinary boundaries, teaching locales and tools reinforce the marginalization of the nonhuman animal" (p. 66). From an ecofeminist perspective, this portrayal of science by the NGSS positioned nature as an object to be studied in order to benefit the success of humans. It is a small step from there to the implication that humans exist at the top of the organismal hierarchy as the most valuable of species.

According to Lloro-Bidart (2015), “scant education research even acknowledges that dualisms exist, leading to problematic subject-object and nature-culture divides that pervade both research and practice” (p. 141). By compartmentalizing humans from the environment, a deficit view of the environment is maintained as existing solely as ecological goods and services for humans to exploit. In a study conducted using critical discourse analysis, Hufnagel et al. (2018) found the NGSS continued to perpetuate the philosophical standpoint that humans are distinct from the environment they are trying to protect. Hufnagel et al., 2018 stated, “NGSS’s positioning of humans as somehow distinct from an external ‘nature’ continues the modernist cultural pattern in science of situating humans as distinct and apart from the environment” (p. 749), echoing earlier critiques by Latour (1998). By maintaining the human/environment binary in environmental education, ecofeminist epistemology might contend it removes responsibility from enacting deep social and systemic change (Harvester & Blenkinsop, 2010).

The NGSS also privileges a perspective on mitigating ecological crises solely through the development of scientific, technological, and engineering advancements for solutions, rather than any modifications to the global industrial complex and capitalism. (Hufnagel et al., 2018) found in their analysis of the NGSS that “when solutions to environmental issues are included, the focus is on technoscience” (p. 748). They argued, by focusing on techno-solutions, the NGSS are inadvertently “sidelining the important and relevant social and political aspects of these problems” (p. 748). As noted by Ladson-Billings (1998), such calls for techno-solutions over systemic change, implies a choice to rationalize oppression. In addition, the language choices to present climate change within NGSS reflects their fear of acknowledging and disrupting the threads of capitalism that are currently embedded in the scientific enterprise.

The term *Anthropocene* was initially proposed by Paul Crutzen, winner of a Nobel Prize for his work in atmospheric chemistry and biologist Eugene F. Stoermer, to name the current epoch. They selected this term to highlight the ways in which human activities influenced the current state of the planet, emphasizing the "central role of mankind in geology and ecology" (Crutzen & Stoermer, 2000, p. 17). However, Malm (2013) introduced the term "Capitalocene" to replace the term Anthropocene. This term suggested "capitalism as a "World-ecology that joins the accumulation of capital, the pursuit of power, and the co-production of nature in successive historical configurations" (Moore, 2014, p. 249). Currently, the NGSS neglects to use either term when talking about human impact on environmental degradation. Although there is an assumption in the construction of the NGSS that teachers will use their own understanding of science to convey big ideas and concepts to students, Plutzer et al. (2016) found that only 30% of the middle school science teachers and 45% of high school science teachers thought climate change resulted from human causes. This supports the argument for the standards to include more explicit links between human actions and environmental degradation.

One of the goals of NGSS is the preparation of students for 21st century careers and/or university by connecting science to real-world situations (NGSS, 2013). However, they neglect to explain what is meant by real-world and whose world they are encouraging students to investigate. From an ecofeminist perspective, by failing to specifically name issues of environmental injustice and the historicity of economic policies that have led to the degradation of the planet, the NGSS aid in the preservation of limited views of environmental science and the NOS that perpetuate the racist and patriarchic norms inherent within a capitalist society.

Other efforts to teach environmental science overemphasize personal behaviors as a solution. Two dangers arise from these limited perspectives. The first is that individuals who may not experience direct environmental impacts may also fail to acknowledge the severity of those impacts. Second, by focusing environmental change on individual acts, it ignores the systemic nature of environmental degradation, resulting overtime by western industrialization and capitalism (Moore, 2016). Focusing on environmental action at the individual level has the potential of placing an enormous amount of responsibility and feelings of guilt on students and teachers in environmental classrooms who could never mitigate global issues of environmental degradation exclusively through personal efforts (Lloro-Bidart, 2015).

Though limited, there has been some effort to deploy ecofeminism as a lens for understanding issues in science education. Some used the lens to critique national standards for science education (Lloro-Bidart, 2015) to develop practical approaches to classroom practices and/or curricula (Barton & Osborne, 2002; Pierce, 2011; Zell, 1998), to compare and contrast the approaches of males and females and their teaching of environmental science (Gough & Whitehouse, 2018), or by which to review the literature on environmental education (Spannring, 2016) and sustainability (Odrowaz-Coates, 2021). Currently, no scholars have applied a lens of ecofeminism to studies centered around science teacher identity or conceptualizations of the nature of science in the RET literature.

When examining the current conception of the nature of science, presented in an earlier section, deficiencies remain. Specifically, these lists neglect to address which scientists were/are allowed the space for creativity, who was/is considered in in the impacts of scientific enterprise, and which collaborators in the scientific enterprise were/are given notoriety for their contributions.

Toward an Ecofeminist Portrayal of the Nature of Science. I now briefly elaborate on each one of these areas of deficiency and why I would consider them lacking or missing entirely from the current conceptions of the nature of science. Specifically, I discuss how I pulled from the work of ecofeminist/feminist researchers to suggest modifications to the consensus views of the nature of science.

Whose Creativity? As shown in Table 1.1, the nature of science is presented as the scientific endeavor resulting from the creative imagination of human scientists and the questions they have about natural phenomena. This conception suggests that these questions result from the many "disciplinary commitments, beliefs, prior knowledge, training, and expectations" (Abd-El-Khalick, 2012, p. 357) of those practicing science. This conception also describes science as constructed and conducted within the boundaries of social and cultural contexts. However, using the lens of ecofeminism, it becomes evident that this view is meant to answer questions about the natural world, as perceived by a particular group of people within particular social and cultural contexts.

Although Table 1.1 may offer a portrayal of science as other than purely objective, it does little to expand upon the term's subjectivity and objectivity. This dilemma led to the development of a feminist empiricism. According to Intemann (2010) in her overview of the work of Longino (1990), "feminist empiricism is normative in that aims, cognitive values, and other background assumptions of a research context can depend on social, ethical, or political values" (p. 780). Although this statement alone may seem like it aligns with the consensus view, it calls attention to the need of making visible both the implicit personal values of individual scientists and the assumptions guiding their practices.

Barton and Osborne (2002) argued that "neither scientific knowledge nor the constructor of that knowledge can be defined separately from the other" (p. 176). To support this argument, Intemann (2010) provided the example of the categorization of women and people of color pronounced as intellectually inferior to white males. This is only one example of the ways in which traditional empirical approaches have supported discriminatory views and practices, and aligned with institutions of power (Foucault, 1980). Therefore, feminist empiricists have argued that the scientific enterprise become more holistic, where "common-sense experiences and beliefs about sex/gender and politics" are included (Intemann, 2010, p. 780). This is not to discredit the expertise of practicing scientists, but rather to acknowledge that "the language of science has promoted a worldview that has normalized masculine, white, and middle-upper class" ways of knowing (Barton, 1997, p. 159).

Who Is Considered? Because construction of scientific knowledge is dependent on those who are doing the constructing, limited diversity in the scientific community may result in limited considerations for those who have been excluded. Within the portrayal of the nature of science in Table 1.1 there appears to be little to no consideration given to the often-unequal impacts of the scientific endeavor on different groups of people and non-human organisms. According to recent data (NSF, 2018) in 2015, 67% of all laborers employed in the fields of science and engineering were white and only 28% were women (categories established by the NSF). Although these numbers have improved over time, and vary across the science disciplines, there remains a stark demographic divide in who participates in scientific communities likely leading to a perpetuation of dominant discourses.

In a summary of Longino's (1990) work, Intemann (2010) argued that a "scientific community comprised of individuals with diverse values and interests will be more likely to identify the ways that values influence the reasoning of individual scientists" (p. 782). This highlights an additional feature of feminist empiricism, "social epistemology," which suggests the responsibility of the scientific enterprise be removed from individuals and placed on the community of researchers. This feature, although on the surface may sound similar to the consensus view that science is "socially negotiated" (Abd-El-Khalick, 2012), insists that scientific communities be filled with diversity in order to "achieve a higher degree of objectivity to the extent that they are structured in ways to help minimize the negative effects of such biases" (Intemann, 2010, p. 781). However, often when communities do begin to tackle issues of diversity, they do only as much as necessary to fulfill diversity requirements, and neglect to consider the inclusion of non-human organisms.

Which Collaborators? Francis Bacon is often credited as the father of empiricism, and included in science textbooks for his contributions to scientific practice, perpetuating "the unrelenting and insidious nature of heteronormative ideology" (van der Toorn et al., 2020, p. 160). Particular contributions to Bacon include strict observation and inductive reasoning, which have led to his accreditation as the originator of our modern conception of the "scientific method." Although the current consensus acknowledged the "myths of the scientific method" (Abd-El-Khalick, 2012; Dewey, 1910; Rudolph, 2019), it failed to critique the way the nature of science continues to neglect the many non-human collaborators involved in scientific advancements. Merchant (2006) described the work of Francis Bacon as a product of his cultural influences. However, although the consensus around the nature of science acknowledges "science is a human enterprise embedded and practiced in the context of a larger cultural milieu" (Alshamrani, 2008) it does little to address possible impoverished views that may be perpetuated by certain cultural norms.

For Francis Bacon, the cultural milieu of his day was embedded in an attitude of torture and interrogation (Merchant, 2006). Although he did not apply these societal norms to research on human subjects, his non-human and non-living subjects were less fortunate. As written by

Merchant (2006), Bacon promoted an experimental process and applied to nature the use of "rhetoric that implied and even condoned torture verbs such as, vex, hound, drive, constrain, straiten, mold, bind, enslave, spy on, and transmute. Such words were metaphors for the interrogation of nature" (p. 525). McIntosh (1996) pointed out that according to Bacon, "scientists must be the 'searchers and spies of nature' in order to discover 'her' plots and secrets (p. 5).

In discussing the third feature of feminist empiricism, Intemann (2010) wrote: it "is contextualist in that it takes the justification of scientific theories to occur within a particular set of assumptions, including assumptions about the aims of the research, appropriate methodology, and criteria for theory choice" (p. 780). Bacon's view of the nature of science therefore assumed a human dominant perspective, where the appropriate methodology assumed nature, including non-human organisms, should be exploited for the purpose of scientific advancement. Therefore, ecofeminist researchers call for scientists to practice science with care and moral consideration for both humans and nonhumans (Gough & Whitehouse, 2018; Merchant, 2006) recognizing the many collaborators that often go unnamed.

An Ecofeminist Characterization of the Nature of Science. Considering all of the above, I present here a revised characterization of the nature of science that incorporates the critique as discussed above as a sort of aspirational exercise of what an ecofeminist conception of the nature of science could look like. I include it to provide my readers with an idea of how my own understandings of the NOS, influenced by the framework of ecofeminism, may impact how I interacted with teacher's conceptions throughout the development of this study and in the analysis of my findings. This revised characterization, shown in Table 2.1, uses existing nature of science aspects (Abd-El-Khalick, 2012; Lederman et al., 2002) as a starting point, and then revises them by drawing upon themes from ecofeminism (Lloro-Bidart, 2015; Merchant, 2006) and feminist empiricism (Intemann, 2010; Longino, 1990).

Table 2.1

Ecofeminist Characterization of the Nature of Science

Component	Definition
Empirical	Scientific Claims are empirically derived (Abd-El-Khalick, 2012; Lederman et al., 2002), within a particular set of assumptions (Longino, 1990)
Scientific Community	Scientific knowledge derives from a scientific community (Abd-El-Khalick, 2012), that is diverse, and includes women, people of color, and non-human organisms (Merchant, 2006).
Objectivity	Scientific knowledge can never be purely objective because scientific practice (Abd-El-Khalick, 2012; Lederman et al., 2002) and those practicing science can never be viewed in isolation from their own cultural, ethical, and epistemological understandings (Longino, 1990).
Tentative	Scientific knowledge is open to revision (Abd-El-Khalick, 2012) and previous scientific work should be re-evaluated for impoverished views of the cultural milieu in which it was constructed (Merchant, 2006).
Cultural embeddedness	Scientific knowledge is science is constructed and conducted within the boundaries of social and cultural contexts (Abd-El-Khalick, 2012), and is often determined by dominant discourse in the science community (Longino, 1990).
Scientific theories	Scientific knowledge assumes consistency and order within natural systems to explain natural phenomena and leads to the development of scientific models, laws, and theories (Abd-El-Khalick, 2012)
Social dimensions	Scientific knowledge is developed through social negotiation (Abd-El-Khalick, 2012). However, dominant discourses support science as a strictly human endeavor, neglecting collaboration with non-human organisms and non-living material, as well as with local community participation (Lloro-Bidart, 2015; Merchant, 2006).
Limited	Scientists cannot answer all questions (Abd-El-Khalick, 2012), however the questions they do develop should consider a moral obligation and an ethic of care for both humans and non-humans (Merchant, 2006).
Myth of the scientific method	Although there is no step-by-step scientific method (Abd-El-Khalick, 2012), much of our present scientific practices are founded in anthropocentric values traced back to early models of western science (Merchant, 2006).

In the next section I discuss the analytical frameworks of figured worlds and storied identities and how they were used as lenses for examining science teacher identities and in collaboration with my theoretical framework of ecofeminism.

Figured Worlds

A central premise of this research study was that science teachers develop their identity in response to their participation in numerous science related worlds, emphasizing the idea that "what and how teachers learn is also shaped by and situated in their identities, both as teachers and as learners" (Drake et al., 2001, p. 2). According to the figured worlds framework, identity formation is not finite, but rather is in constant flux. Individual's various figured worlds are not held in isolation from one another, but each contribute to an individual's identity in overlapping and interconnected ways and "give us form as our lives intersect with them" (Holland et al., 1998, p. 41). Teachers in RETs are experiencing multiple figured worlds, each being "socially organized and reproduced" (Holland et al., 1998, p. 41) where science teachers find themselves "structurally marked" (Holland et al., 1998, p. 7). For example, a science teacher in her classroom may be considered the science expert, but a science teacher entering the space of a practicing scientist may be structurally marked as lacking in scientific knowledge.

According to Holland et al. (1998), "figured worlds, like activities, are social encounters in which participant's positions matter" (p. 41). Further, "identities are a key means through which people . . . care for what is going on around them" (p. 5), and claims identity is formed both "dialectically and dialogically" (p. 49). By focusing on the positionality of the science teacher in their experiences with science, what they cared about in their understanding of the nature of science, and how they chose to think and talk about science, I argue there is considerable overlap between the frameworks of figured worlds and ecofeminism.

The framework of figured worlds also emphasizes the "figurative, narrativized, and dramatized" (Holland et al., 1998, p. 54) nature of worlds, which suggests the best way to understand an individual's experience and how they relate to each world, how each world is situated in relation to that individual's other worlds, and how an individual's world may relate to other individuals' worlds "over time and across different time/place/space contexts" may be through story (Urrieta, 2007, p. 109).

Researchers have looked at identity and applied the framework of figured worlds in science education to science teachers' classroom practice (Chung-Parsons & Bailey, 2019), preservice teachers (Saunders & Ash, 2013), elementary science teachers (Avraamidou, 2014, 2019b), female science students (Tan & Barton, 2008, 2010), science curriculum development (Price & McNeil, 2013), and science teacher educators (Weinberg et al., 2021). However, no research before this study had applied this framework to the science identity of experienced teachers after participating in a RET.

Although not aligning to the typical dissertation format, I made the decision to include my positionality as researcher in the section that follows. The reason for this decision was based in the way I decided to portray my positionality as situated within the framework of figured worlds. By incorporating this section next, I am providing an example of how I used the figured worlds framework to organize the stories of my participants in the first draft of my participants storied science identities in my findings, something I discuss in greater detail at the start of chapter four.

Positionality

In this section, I present my positionality as a white middle-class woman, scholar, science educator, and ecofeminist. As an attempt to both discuss how my personal experiences have brought me to this point of my dissertation research as well as foreshadow the use of figured worlds and narrative inquiry to organize and present my findings, I present my positionality in this proposal as an abbreviated storied identity. The categories of figured worlds are ones that I may use in my participants' stories, however individual stories highlight different experiences, therefore each participant may have slightly different figured world categories. Although identity is shaped by a multitude of experiences, for this study I am focusing on the experiences with science that have shaped my own science identity.

"Home" World. Although I am white and middle-class, my experiences do not mirror others who share similar descriptors and demographics. At 7 days old I was adopted into a very conservative Christian family where I regularly attended purity conferences, which left me with feelings of shame for thoughts that I had or actions that I did. Probably and most importantly, I was being shamed for simply being "imperfect." Striving to be perfect is difficult when you are taught, however inadvertently, that you are less than and you will only find meaning in the future husband you will have. For as long as I can remember, I wanted to be an oral surgeon. One operation smile advertisement during whatever evening television series I was watching, and I was hooked. I can also remember my father's support of this professional goal. I have many memories of him telling others, even when he was not asked, that his daughter was going to become an oral surgeon and provide him free dental care. Although this would sometimes come off as a joke, his continued support in my aspirations to pursue the field of medicine never wavered.

As I look back now, I have always felt a deep connection to both the nature of science and caring for others. Additionally, being adopted, I had the feeling that I was out of place and always felt a sense of wanting to find where I belong, and the people with whom I shared my genes. This led to an early fascination with biology, and questions surrounding nature versus nurture. These passions only amplified when my adoptive mother passed away from cancer when I was 11. Feelings of losing two mothers, one that I shared genetics with and the other whom her own genetics having caused her illness, coupled with an adolescent diagnosis of Rheumatoid Arthritis is what I consider led to my deep passion for science. Science was the lens by which I began to view the world around me.

"Early Education" World. In elementary school, I remember very little about science class. However, one distinct memory I have was of a science fair project entitled "Why is the juice cloudy?" I had no idea what the experiment was that we were conducting or how the data we collected would help to answer that research question. I am not placing blame on the elementary teachers that I had and the little attention they paid to science content, since we know that it is rare for elementary school teachers to feel confident in their understanding of the nature of science or in their presentation of science to their students.

However, I remember my middle school science experience vividly, where a large part of the science curriculum centered around the annual science fair. For the first few years I received a first-place ribbon for my projects, which can still be found neatly stored in my proud father's attic. These projects however would be better labeled as research projects than science experiments. In the 8th grade, the school provided new guidelines which stipulated all projects be based around experiments and not just research about a topic of interest. I remember not fully understanding what this meant and why the projects I had completed in previous years did not qualify. However, examples provide by my science teacher, I was on my way to developing my very first science fair experiment comparing the stain removing power of two common household detergents.

“High-School” World. In high school, my first science class was earth science, a class everyone hated, rarely felt they learned from, and which was taught by a long-term substitute, who was also parent of one of the students at my small private Christian school. Although I cannot be certain, I am pretty sure she had no science experience or science teacher training and successfully convinced an entire grade that they hated earth science, at least for that school year. I am proud to say one of my fellow students is currently working for NASA as a flight controller. Sophomore year, I took what would become the first of many biology classes. Here I learned that science is about taking copious notes down from the chalkboard before the science teacher erased them and memorize them before the next test. I was extremely skilled at this process, which gave me a false sense of assurance in what I began to consider the field of science. I also learned how Christians needed to be “armed” with the ability to refute evolution. Of course, my teacher's lack of knowledge in the subject matter did not make for a very profound explanation of evolutionary biology, but it did support the belief in literal creation theory laid out in the Biblical book of Genesis.

Just as I was told to submit to my husband by my Christian community, science class seemed to mirror the situating of females as less than. My textbooks touted Watson and Crick as the discoverers of the double helix but failed to mention the way in which they stole their data from Rosalind Franklin. They described the way in which Tim Hunt discovered cyclins but did not include the misogyny that pervaded his research lab. And when I was one of the two females in my advanced chemistry class in high school, this notion continued to be reinforced. It led to a constant feeling of doubt in my abilities to investigate the world from a scientific standpoint. I always questioned if I was as smart or as capable as the boy in the next row.

“College” World. As I pursued becoming an oral surgeon, my consistent career path until my final year of college, I declared my major as pre-med. Throughout my college career my perceptions of what a science course looked like did not change much. I was filled with anxiety preparing for each test, which would consist mainly of multiple-choice questions with some having over 5 answer options. Is it a? Is it b? Is it c? Is it a and b? Is it a, b, and c? Is it none of the above? Even if I did in fact memorize all the information necessary, the format of the test was still another steppingstone to failure. During my first college level biology course, titled Cells and Genetics, I received my very first failing grade. I still am not sure how I passed the course and can’t recall much more than one of the professors singing a cell related jingle on the guitar during one of the class sessions. Somehow, my lack of ability in this course did not deter me from registering for the other courses necessary to complete my pre-medical degree. Although the majority of my classes still presented a science degree as an unending pursuit of content memorization, there was one course that impacted the way I would interact with science content forever. As part of the medical profession’s degree, students were required to complete a medical ethics course. This was the first time I remember ever asking questions about whether something related to science could be right or wrong, or neither, or both. It was the first time I considered how the perspective of the person asking the question could determine whether or not the science was justified. At this point in my life, I was still bounded by the belief that things were black or white, and never gray. Not only was the topic of the course drastically different from my other science courses thus far, but so was the seating arrangement. I distinctly remember sitting in a circle as we discussed the different cases. Only much later, during my student teaching, would I come to realize that the professor of the medical ethics course was utilizing a Socratic Circle, a strategy I would come to use in almost every science course I taught.

Although each of the cases caused me to think about the ethics surrounding a particular medical decision, there was one in particular that I can still recall quite vividly. The case was about a lesbian couple, both of whom belonged to the deaf community, wanting to use in-vitro fertilization to ensure that their future child would also be deaf. For this couple, being deaf was not considered a disability but rather a community of which they were a part. I remember immediately feeling enraged that this would even be considered by a medical ethics board and expressed my own feelings without hesitation to my peers in the class. I can still remember how shocked I was that there were individuals who disagreed with me. My opinion at the time was developed based upon my impoverished views of both homosexuality and disability studies.

In the fall of my junior year in college I travelled to New Zealand for a study abroad program entitled Creation Care. I chose this program because it was one of the few programs where I could fulfill necessary biology credits. Little did I know this experience would change the way I perceived biology and the world around me forever. It was here that I was introduced to the concepts of sustainable development and cycles of disenfranchisement. I had never heard of these phrases before, but they would become concepts which would impact my worldview for the rest of my life. During my time there I took several ecology courses, interacting with nature, and also spending time with indigenous communities in both New Zealand and Samoa. I, for the first time, was viewing the world from outside of my very white, American, conservative Christian upbringing. I would leave New Zealand not only with a renewed passion for science, but with a particular interest in sustainable science and social justice. This new lens encouraged me to pursue a career in science teaching where I felt I would be able to combine my passions for science and social justice.

"Science Research" World. After graduating with my biology degree, I made the decision not to go to Dental School. I realized that the passion I had for pursuing oral medicine was centered in a desire to help those without a voice and less about fixing their teeth. I decided to sign up as a field assistant to a white PhD student from the United States, collecting data on human interference on wildlife in Tanzania. Once I arrived, there was a stark contrast between who was considered researcher and who was considered assistant. Those who were researchers were white and from "western" countries, including the US, England, and Italy, despite the research position listed as participating with a program who provided well-paying jobs to locals and valued local individuals' expertise. This experience broadened my perspectives on the ways in which "western countries" exploit "non-western" countries in order to meet their needs, even within small organizations. The country of Tanzania is also considered a Muslim country and much of my time was spent with individuals who practices Islam. This again influenced my perspectives of those who I was taught as a child and young adult to "pray for" which in fact meant to judge and hate.

"Science Teacher" World. When I returned from Tanzania, I needed to figure out another career path. I applied for several research jobs but did not have the necessary experience. I found a program at Montclair State University that provided a stipend to complete a Masters in Teaching, the Newark Montclair Urban Teacher Residency (NMUTR) Program. By providing a stipend and fully paid tuition, participants were required to spend at least three years teaching in Newark, NJ. I had said several times in my life that I did not want to become a teacher, and held to the belief that those who can't do, teach. However, what I found appealing was the idea of promoting social justice by being a teacher in a low socioeconomic setting. I had no idea at the time what a savior complex was, or that I had one.

I applied and was accepted to the NMUTR. The program had a focus of antiracist teaching and introduced me to many of the limited views on diversity and social justice I was holding. Additionally, although my Christian schools were comprised of diverse populations, they did not have diversity of thought, and often perpetuated white, heteronormative views. By working in the city of Newark, I became further exposed to views outside of the one's I was raised to learn, and through the voices of my students and co-workers, I became deeply knowledgeable of the ways in which many in the city of Newark experience systemic racism, both economically and environmentally. I also became familiar with being asked what it is like to work in Newark, NJ. How are the students?? Do you feel safe? Working with and teaching predominantly non-white individuals was once again eye-opening, but it was so much more than that. I came to value the community I was working in, doing my best to lower my own voice in order to amplify the voices of others. I did my best to see my teaching experience as not only teaching science in a classroom but also learning from my students and my colleagues, which contributed to the perspectives I now hold as a science teacher and teacher educator.

"RET" World. As a young science teacher, grappling to make connections between myself and the content, I applied to the Columbia University Summer Research Program for Science Teachers (CURSP). Through my three years of experience working in Environmental Engineering labs my views on science were changed and the confidence I had as a female science teacher increased. I saw the collaborative, cross-content, and demographic diversity of the labs in which I worked. I saw the way in which individuals worked with each other as well as included me as a part of their community of practice. This was not the science I had learned about but it was the science I had unknowingly loved. However, listening to my fellow RET participants, I realized their experiences were not nearly as fruitful or fulfilling as mine.

As my confidence in my science understanding grew, I felt more confident in critiquing the science content and allowing myself and the students in my classroom to explore the different ways in which science has not been accessible to myself or to them. In order for someone to be critical of something they must first know it well. I felt capable as well as obligated to use poststructuralism (although I was not familiar with this term) to break down definitions in cellular biology, discuss the ethics of dissection in anatomy, see the lack of women and people of color throughout the pages of our science textbooks, and identify the many ways our capitalist society interacted with the environmental science curriculum.

My own science story has brought me to where I am today and has been foundational for the development of my dissertation study in which I hope to highlight the science stories of other science educators and how their different experiences with science have shaped their science identity and views of the nature of science.

In the next section, I describe in more detail the analytical tool of storied identities, placing emphasis on the importance of stories in being and becoming. In keeping with ecofeminist tradition, I hold to the idea that dialogue and storytelling have the ability to "deconstruct power imbalances, make space for relationality, respect" and "the need to listen to the stories of the more-than-human" (Piersol & Timmerman, 2017, p. 16), extending the feminist tradition to "include animals as 'knowers' and 'storytellers'" (Harvester & Blenkinsop, 2010, p. 130). By analyzing science teacher stories through a lens of ecofeminism I hoped to disengage from the dominant discourse of the patriarchy and amplify the voices of the oppressed (Harvester & Blenkinsop, 2010). In this study, my intention was to highlight, through story, the ways in which science teachers be and become in their identities with science from their experiences in their various figured worlds.

Storied Identities

"Humans are storytelling organisms who, individually and socially, lead storied lives" (Connelly & Clandinin, 1990, p. 2) and by accessing an individual's story, one can gain a better sense of self and identity (Drake et al., 2001). Using story as a method of knowledge construction and development is not novel and is considered "integral to traditional Indigenous epistemologies" (Cajete, 2017, p. 115). Cajete (2017) wrote, "Story is one of the most basic ways that the human brain structures and relates human experience" (p. 115).

For this study I modelled my conception of storied identity after Ibourk's (2018) definition, as science teacher identities shaped by the stories of how they came to understand inquiry, the nature of science, and what they understood real-world science to mean prior to their participation in their RET and how/if the RET shaped their new understandings. By focusing on the stories teachers tell, I was able to understand as the researcher, how the science learning of that teacher took place during their participation in their RET as well as leading up to that experience.

The current literature using storied identities in the field of teaching is limited and includes identity research on elementary school teachers dependent on subject-matter contexts (Drake et al., 2001), mediocre teachers and reasons for staying in the profession (D'Souza, 2018), and preservice teachers in both math (Lloyd, 2006) and science (Ibourk, 2018). However, there are no current studies, until this one, that have looked at the identity of experienced science teachers, or science teachers who have participated in an RET.

Chapter 3: Methodology

This study was centered around uncovering science teachers' perspectives and ideas of the nature of science both prior to and after their participation in a research experience, as well as the way in which different events and experiences may have shaped their identity. Although organizations run similar programs under a myriad of names, this study focused primarily on Research Experiences for Teachers (RETs) funded by the National Science Foundation (NSF). I used the research methodologies of narrative inquiry and storytelling. Specifically, I used the analytical frameworks of narrative inquiry and visual narrative analysis to collect teacher stories and the theoretical frameworks of figured worlds and ecofeminism to organize and present their narratives as storied science identities.

In this section I begin by describing the methodological approach of narrative inquiry. Following this description, I provide my decisions for participant and site selection, as well as a description of my data sources and tools. Finally, I conclude this section by addressing how I attend to show validity and reliability in my study, including the presentation of my positionality as a researcher.

Narrative Inquiry

In narrative inquiry it is important to draw a distinction between the terms story and narrative, even though these two terms can often be conflated. According to Connelly & Clandinin (1990), "People by nature lead storied lives and tell stories of those lives, whereas narrative researchers describe such lives, collect and tell stories of them, and write narratives of experience" (p. 2). According to Webster and Mertova (2007), narrative inquiry as a methodology "captures and analyzes life stories" (p. 11) and "features of the learners' thinking and learning needs that may have been neglected through more traditional research methods (p.

14). By using stories as a methodology, researchers gain a deeper understanding of how a particular experience has impacted the person who has lived out that experience (Webster & Mertova, 2007). Individuals are not only shaped by those experiences, but by telling their stories, participants in collaboration with researchers are provided an opportunity to "interpret their past in terms of these stories" (Connelly & Clandinin, 2006, p. 479).

Davidson et al. (2021) found that researchers found that teachers were better able to explain how their experiences shaped their understanding of the nature of science during the interview experience, when given the opportunity to unpack them. Along similar lines, narrative inquiry moves away from a method of research where the researcher is simply researching the participant, but rather emphasizes an ongoing relationship between researcher and participant through the process of learning and making sense (Connelly & Clandinin, 2006). By breaking down the distinctions between researcher and researched, narrative inquiry diverges from traditional notions of positivity in research, where the participant is the object to be studied. In this way, by using the methodological approach of narrative inquiry, I am able to apply the framework of ecofeminism, my particular view (Connelly & Clandinin, 2006), not only to the topic that I am choosing to study but also my methodological approach. Traditionally, the narrative approach has been identified as human centered (Webster & Mertova, 2007). However, by incorporating the lens of ecofeminism, I also attend to the stories of non-humans.

Narrative inquirers designed this methodology leveraging the work of Dewey (1938) and his theory of experience. Specifically, Clandinin and Connelly (2000) used Dewey's work to develop three dimensions to analyze one's story within the qualitative practice of narrative inquiry. These three dimensions include: "1) the personal and social (interaction) along one dimension; 2) past, present and future (continuity) along a second dimension; and 3) place (situation) along a third dimension" (p. 54). More simply, researchers acknowledge that the lives of their participants are important sources of knowledge that have developed through experience with others and across different spaces and time. By acknowledging the importance of the three dimensions, the relational aspect of narrative inquiry is highlighted (Connelly & Clandinin, 2006). The researcher, as a person sharing the dimensions of space and time with the participant, becomes a part of the very experiences of the participants they are interested in examining. In this way, an attempt to achieve the positivist notion of objectivity by removing oneself from the data becomes futile. The figured worlds framework served as a tool for organizing my data, and highlighted the interactions and experiences of teachers in their particular worlds that shaped their understanding of the nature of science. Below I describe in more detail the methodology of visual narrative inquiry.

Visual Narrative Analysis

In order to examine teachers' understandings of the nature of science, in addition to the experiences and events which teachers described as influential to the development of those understandings, I intentionally incorporated a visual component to my data collection. Visuals are a central component of visual narrative methodology (Bach, 2007). When looking across studies that included both visuals and writing in their narrative inquiry analysis of the lives of teachers, Johnson (2004) found "that visual–verbal language offers greater possibilities for understanding teacher identity than is possible through a single source" (p. 424). Bach (2007) explained in her study using photographs, by including the use of visuals she was able to "add layers of meaning to stories lived and told" p. 283). By adding imagery in my data collection, I was able to further enhance the "three-dimensional narrative inquiry space" (Clandinin & Connelly, 2000, p. 50).

Waldrip and Prain (2012) suggest that the construction and revision of visuals can lead to greater understandings in science, which is evident in the scientific practice of modeling in the Next Generation Science Standards. However, the literature on the nature of science in education maintains a focus on deriving texts and lists (Lederman et al., 2002; NGSS, 2013). Additionally, Erduran and Kaya (2018) pointed out that “although the NOS and visualization literatures have been studied extensively, the intersection of these bodies of literature has been minimal” (p. 1133).

Erduran and Kaya (2018) argued that by incorporating visuals, individuals can better develop “epistemic insight,” which they defined as one’s “knowledge about knowledge” (p. 1134). They have proposed that “future science teacher education will benefit from developing further strategies to support teachers’ use of visual representations to express and interrogate epistemic foundations of science” (p. 1147). Therefore, the use of a visual tool, which provided teachers an alternative to verbal explanation in their descriptions of the nature of science, was in direct response to the suggestion by Erduran and Kaya (2018). The visual tool that I used in this study is described in a later section of this chapter.

In the sections that follow, I provide an overview of the specific research choices I made, including: participant selection, site selection, data collection tools, methods, and analysis, and a description of how I attended to trustworthiness in this study.

Data Collection, Sources, and Tools

My data collection took place over a period of nine months. This timeline allowed me to gather one, one to two-hour long interview from each participant as well as a shorter member checking interview once I completed the initial draft of their storied science identities, which I shared with them via Google documents. I provided participants commenting access, encouraging participants to make comments within the document prior to our conversation. In order to elicit the fullest versions of teacher stories, highlighting their experiences with science, my data collection included a variety of sources including hand-drawn visual representations of the nature of science developed by science teacher participants (see Appendix A), teacher interviews (see Appendix B), artifacts teachers from the participants experiences of teaching science, as well as RET program materials.

Methodological Choices

Participant Selection

To identify participants for selection, I contacted the program directors and managers of the RETs, and asked them to help me identify and contact science teachers of any science discipline whom they feel represent a successful RET participant. By successful, I was not implying this science teacher was better than other science teachers but rather administrators of the RET perceived that they took up the values about the nature of science the RET intended to portray. Many researchers in the field of education look to identify factors lead to teacher retention (Ingersoll, 2003, 2011) and although an implication from this study may reflect that RETs influence teacher retention in some way, I chose to focuse on the perceptions of the nature of science teachers incorporated into their own science identity after participating in a research experience and not whether that experience influenced their decision to remain in teaching or not. Classroom practice is an important indicator of science identity, therefore However, I incorporated classroom materials that teachers produced after their participation in an RET. Therefore, as long as a teacher remained in teaching for at least one year after participating in their RET, they were considered for inclusion in this study.

Although some programs do include elementary school teachers, due to the differences in teaching expectations, where elementary teachers are typically not specifically science certified or concentrated solely on teaching science in their classrooms, I focused on teachers who only taught science designated classes in their schools. Therefore, I included teachers of grades 6-12. Although some RETs include both science and math teachers, I specifically focused on science teacher identities around the nature of science, and therefore those who taught math exclusively were excluded from the pool of participants. The participants are in-service teachers or teachers who have left the classroom to move into higher education, as well as one science teach who retired. Most of RETs are designed for teachers who are already in the classroom. For similar reasons, I made no effort to exclude participants based on their experience level. Most RET's accept teachers along the teacher continuum with varying levels of experience. This choice was made in response to the study conducted by Buxner (2015), who found that "the amount of teaching experience was not a factor that could be used to distinguish participants' understandings of scientific inquiry" (p. 63).

Although I ideally wanted my participants to have completed an RET recently, due to recent events surrounding the COVID-19 pandemic, I included participants who completed an RET in the summers of 2017 through 2019. Given the time between the RET and the data collection, I was able to learn about their experience in the RET as well as how their participation in the RET impacted new understandings of the nature of science as well as their classroom practice. Any teacher who participated in an RET later than 2019 was excluded due to the bounds of this study. This study does not consider the ways in which science teachers' portrayal of the nature of science and scientific inquiry may have been altered due to online learning environments. I did not necessarily exclude science teachers who participated in years prior to 2018, but I preferred teachers to have better recall of the events and experiences that took place. I considered possible participants from programs which are not funded by the National Science Foundation, as long as the program they participated in shares much overlap in criteria with NSF funded RETs. Detailed information regarding my participants is presented in Table 3.1 below.

Table 3.1

Participant Demographics

Participant Name (Pseudonyms)	Demographics (Self-Identified)	Primary Teaching Discipline/# of teaching years (at time of study)	RET (Pseudonym)
Oliver	American, born in South America	Chemistry/11	Neutron
Helen	Born in South America	Chemistry and physics/14	Neutron
Steven	Caucasian, male	Physics/17	Neutron
John	Old, White guy	Biology/37 (retired)	Biosphere
Louise	Western European, White, middle class, female	Middle school science/20	Biosphere
Denise	Caucasian, straight female	Middle school science/6	Biosphere

Lastly, I interviewed three science teacher participants from each of the two RETs included in this study, in order to examine the experiences of multiple participants at each site (Buxner, 2015). I also interviewed two program coordinators from one RET and the principal investigator from the other, all of which were involved in the program at the same time as the participants. All participants were offered a $25 Visa gift card for their participation as well as a copy of their final story upon completion of the study.

Site Selection

I focused specifically on U.S. based RET programs funded by the National Science Foundation. This choice was deliberate in a few ways. First, due to convenience and time constraints, I was limited in the number of programs I could include in this study. Additionally, my own experience in an RET took place through a U.S. based program. By choosing NSF funded programs I ensured a level of quality in the RET such as the location of the research experience and the mentors selected. In addition to this line of reasoning, I included only NSF funded RET programs to increase reliability when looking across programs, due to consistency in program design and implementation. For example, each program met the NSF requirement for an RET of at least 6 weeks in length and taking place during the summer.

NSF funded programs take place across the country and in various locations. In order to provide a broad and diverse understanding of RET experiences and life experiences, I aimed to select RET programs from the five different regions of the United States: The Northeast, Southwest, West, Southeast, and Midwest. However, due to limitations in obtaining participants, I included two RET programs in this study, one from the North East (Neutron RET) and one with teacher participants from the South East and West (Biosphere). Even within NSF funded programs, there are some inconsistencies with which goals are implemented, therefore two additional criteria: 1) science teachers must be paired with a professional scientist currently working in their field; and 2) science teachers must participate in an investigation with a practicing scientist. This decision was consistent with overall purpose of this study to examine how experiences with research influence a science teachers' perception of the nature of science.

Visual Tool

As described in an earlier section of this chapter, I included a visual tool in my data collection to strengthen the development of teacher's identities in science, paying particular attention to the version of the nature of science teachers possess. During our Zoom calls, after I asked teachers a little bit about themselves as well as doing my best to make them feel comfortable, I introduced the visual component of the interview. Working on Zoom, I asked teachers if they had something to draw and draw with, I informed them of the task, which went something like this: "I am hoping that you will draw for me your understanding of what science is. You can draw as many or as little images as you would like, and you can include some words if that helps you to convey your ideas or label items in your drawing, but I am hoping for fewer words and more images." I purposely did not want to over describe my expectation for teachers to limit placing my own understanding of the nature of science on the teacher participants. Teachers were initially told they had 15 minutes to complete the drawing, however some teachers took as little as five minutes to complete the task, while others needed some additional time. By incorporating the visual as well as the individual's description of the visual, I provided the space for teachers to interact with their epistemic insight in regards to the nature of science. This component of the research was loosely modeled after the Draw a Scientist literature (Miller et al., 2018) in order to uncover possible implicit or unspoken conceptions about the nature of science participants may be holding. Additionally, my analysis of the visual was based on the participant's descriptions of their visual, not on my personal interpretation of the visual.

Interviews

If I simply asked participants to tell their story—a common and valid approach to narrative inquiry—I could do my best to decipher which parts of this story may be linked to teachers' beliefs about the nature of science. However, I believe such an approach would have limited my ability to develop rich storied identities around the particular figured worlds, experiences, and events that have led to teachers' understandings of the nature of science. Therefore, I took a different approach. For this study, I constructed an interview guide with specific questions, as a tool for eliciting "conversation" (Riessman, 1993, p. 58). In the examination of their own narrative inquiry approaches, Messias and DeJoseph (2004) shared that "having a focused conversation allowed for a free flow of thoughts and encouraged participants to participate more fully in the research by offering their own interpretations of their life experiences and contexts" (p. 43). By treating the interview as a conversation rather than interrogation, I intentionally centered traditions of narrative inquiry and moved away from positivist methods of research.

Initially I planned to have two interviews, each approximately one-hour in length, with each participant. My intention was for the first interview to focus on teachers' descriptions of the nature of science, including their visuals, and the second to focus on teacher's experiences with science and the way they represented science in their classrooms. However, at the preference of all teachers included in this study, I conducted one long interview with each participant, in which I interview questions. Although this was unplanned, it allowed for much easier transitions from one topic to the next and did not break the train of thought for the participant. By having participants take part in one longer interview. I was able to effortless move back and forth across my interview guide.

Although my interview was developed as a guide, I still intended to move through it in order, first asking teachers about their figured worlds of science and then moving into their figured worlds as science teachers, and ending with their figured worlds of the RET. However, not long into my first participant interview did I realize that it would be difficult for teachers to provide stories that fit neatly into each figured world. Although I was well versed of the figured world lens, I developed a greater understanding of the framework as I implemented it into my work. The framework of figured worlds highlights how identity work takes place across the different worlds in which individuals come to figure who they are and what they understand, and these worlds are not discrete from one another and cannot be neatly defined within the boundaries of a beginning and an end (Urrieta, 2007). Therefore, my initial thoughts regarding the implementation of my interview guide, especially in thinking I could easily split the interview in half and apply it in two separate interviews, was naïve.

All interviews took place via Zoom and were transcribed and recorded using Zoom. Teachers were asked to provide additional data sources, such as classroom artifacts that they identified as representative of the way they portrayed the nature of science and science inquiry in their classrooms both prior to and after participating in an RET. Although teachers were informed prior to the interview of this task. However, five out of six participants provided classroom artifacts, and out of those who provided, only three provided materials both before and after the RET.

In addition to interviewing science teachers, I interviewed two program administrators from the Neutron RET as well as the Principal Investigator of the Biosphere RET. This interview centered around the visions and goals of the RET, particularly in shaping science teachers' ideas around the nature of science and scientific inquiry (See appendix B). Additional materials were obtained in order to triangulate the data including any materials detailing program design and implementation.

Program Materials

In addition to the visual tool, interviews, and classroom artifacts, I also incorporated RET program materials as data sources. Program materials included the RETs call for applications, the applications of the participants selected for this study, and any participant available products which resulted from their participation in their RET (i.e., lesson plans, poster presentation, or papers). By expanding my data sources to more than interviews, I was able to develop a fuller picture of teacher experiences as it relates to the RET in which they participated in. As mentioned earlier, narrative inquiry considers individuals stories across time and space, and I would argue that materials developed from their experience in the RET provided a richer description of those dimensions.

Crystallization

In developing teachers' storied science identities, I elicited teachers' understandings from multiple data sources including verbal interviews, the development and description of the teacher's visual representation of the nature of science, as well as the artifacts they selected as representative of their understanding and teaching of the nature of science in their classrooms. These additional data sources were used to bolster teacher stories and descriptions, providing insight into components that teachers may have struggled to articulate verbally. I refrain from using the term triangulation as I make connections across individual data sources, for triangulation emphasizes the limited assumption that there are only three sides to each story

(Richardson & St. Pierre, 2008), and that through the process of triangulation researchers will reach a singular point or idea. Rather, Richardson and St. Pierre (2008) suggested the metaphor of "crystallization" (p. 480), during data analysis, allowing for more complex interpretations of the data. As an ecofeminist researcher within the traditionally strict scholarship of science education, the metaphor of the crystal holds even greater explanatory power.

The process of X-ray crystallography has commonly been used in scientific research as a non-destructive method of chemical and molecular analysis. A fitting example of this methodology is that of Rosalind Franklin, well known for her work in the late 1940s and early 1950s, using x-ray crystallography to deduce the double-helix structure of the DNA molecule. As a female in a male dominated field, she underwent countless forms of discrimination, both during her life and even after her death. Her work, stolen by Crick and Watson, was foundational to our current understanding of the DNA molecule, something she never received credit for while she was living. The two men who stole her data went on to receive the Nobel prize for their discovery of the double helix structure of DNA. Her name would have been left unrecognized if it were not for Watson's damaging descriptions of her in his widely published book, *The Double Helix*. Although this account may not be deemed pertinent to my methodology section, I refuse to include Rosalind Franklin's storied science identity as a footnote, as many have already done throughout the last century.

Although the method of x-ray crystallography diffraction allows researchers to gaze beyond the surface to reveal a deeper understanding of structures, it does so in a non-destructive manner. This metaphor for analysis speaks to the importance of my work as a narrative inquirer, as I worked to develop a deeper understanding of my participants through relationship building, over the historically positivist and destructive norms of dissection, interrogation, objectification, and exploration. Rather than looking to isolate one particular component of the structure, crystallography has been used to look for patterns that, "record the history of interaction, interference, reinforcement, difference" (Barad, 2007, p. 71). This emphasis on difference stands in contrast, or rather as a compliment, to the qualitative tool of reflexivity. Rather than looking in, the metaphor of diffraction as a way of sense-making, will allow me to look outward at the ways my work was different than that of current RET literature, as well as the differences it will make in the field.

Trustworthiness

In qualitative research, validity can be referred to as "the integrity and application of the methods undertaken and the precision in which the findings accurately reflect the data (Noble & Smith, 2015, p. 1). However, due to the nature of the study, and the use of narrative inquiry, traditional approaches of validity were not applicable. Therefore, I refer to this section as trustworthiness, and use the criteria by Richardson (2000) as a guide to ensuring the value of my study: substantive contribution, aesthetic merit, reflexivity, impactfulness, and an expression of reality.

Substantive Contribution

When evaluating the trustworthiness of research Richardson (2000) started by asking, "Does the piece contribute to our understanding of social life?" (p. 15). Although this study was not categorized as participatory, the very nature of narrative inquiry relies on the relationships between researcher and participant, in shared spaces and time. I wanted to consider my theoretical framework not only in the examination of teacher's conceptions of the nature of science, but in every aspect of this study including the collecting of stories and the development of teachers' storied science identities. By doing so, I was conscious of the ways in which I as researcher may have inadvertently acted in a dominant manner over the participant and actively worked against the norms of traditional research practices.

Additionally, by approaching my work through a lens of ecofeminism, I was careful to listen to the stories of those who have been silenced. In their description of narrative inquiry, Connelly and Clandinin (1990) explained that “the practitioner, who has long been silenced in the research relationship, is given the time and space to tell her or his story so that it too gains the authority and validity that the research story has long” (p. 4). In this study, the stories of the silenced included those of the teacher participant, as well as those of the non-human subjects of research in their laboratory, field experience, or classroom.

In acknowledging the relational component of narrative inquiry, Messias and DeJoseph (2004) pointed out that “the quality and substance of the data produced at the moment of each researcher-participant interaction is dependent on the interpersonal quality of that interaction, as well as the participant’s perceived value of the experience and its retelling” (p. 45). Therefore, as the researcher, I first developed a feeling of mutual respect between myself and the participant, doing my best to honor the lived experiences and stories they were willing to share with me, and the storied identities I wrote.

Although I did not collaborate with other researchers, I looked to my participants to help explain their stories through the method of member checking the qualitative method by which participants have an opportunity to examine the researcher’s interpretation of the data and provide feedback (Lincoln & Guba, 1985). Although not obligated, I sent participants a draft of their storied identities, providing them the opportunity to make comments or suggestions. By asking participants to contribute to the storytelling, I made my findings more substantive.

Aesthetic Merit

In her second criteria, Richardson (2000) asked the following: “Does this piece succeed aesthetically?” and “Is the text artistically shaped, satisfyingly complex, and not boring?” (p. 15). As referenced in the review of the literature, much of the research on RETs measured teacher beliefs through the use of quantitative instruments, usually with the intention to increase their reliability across studies, despite the lack of consistency with the tools used. By emphasizing the need for reliability across studies, RET scholars implement historically positivistic measures to both evaluate and present teacher change. In some cases, RET scholars attempted to marry the two methods together, using a quantitative instrument to evaluate change, followed by survey results with descriptive accounts from interviews or observations. Very few have elected to rely solely on qualitative research methods.

I argue that quantitative methods have limited the research around RETs in two distinct ways. First being an obvious lack of agreement between researchers on which quantitative tools best identified the ways in which teachers experience change from RETs. Second, the literature which has relied mainly on quantitative tools comes up short in capturing more complete pictures of teacher change, perhaps leaving researchers to “wonder about the stories, words, and other linguistic accounts their research masks” (Pinnegar & Daynes, 2006, p. 19). In this study, by taking up the methodology of narrative inquiry I presented my findings in the form of stories. By their very nature, stories make way for more robust and creative depictions of the world around us. By using teacher stories and visuals, I pushed back on the distinctions often made between science and art, and argue that this study was an effort to bring feminist perspectives to the current field of RETs. I included these stories in both the generation of data as well as the presentation of my findings.

Reflexivity

Throughout my research process I considered how my own "assumptions, investments, and decisions" influenced the research process through the process of reflexivity (Bailey, 2012). I came to this research with a feminist perspective. Rather than attempting to identify a singular truth about the nature of science, I was interested in revealing the many and diverse understandings about the nature of science that science teachers have developed throughout their critical experiences with learning science, interacting with science, and in scientific communities. By moving away from traditional positivist notions of validity, I argue it did not reduce the legitimacy of this study.

Impactfulness

Richardson (2000) encouraged researchers to ask: "Does this affect me emotionally and/or intellectually? Does it generate new questions or move me to action?" (p. 16). I came to this research as an ecofeminist researcher in the field of science education. Although I believe this work will serve the wider RET community, it is also deeply personal. As expressed in my positionality statement, I developed my own storied identity out of the figured worlds in which I participated, which I then presented in the pages of this dissertation. However, storied identities of teachers are currently not valued in the science community in the construction of the nature of science in science education. By introducing a lens of ecofeminism, I contributed new ways of thinking and acting in the field of RETs around the topic of nature of science.

Expresses a Reality

In narrative inquiry, although I focused on the details of individual data sources, I viewed teachers' storied identities holistically. Critical to narrative inquiry approaches, researchers must maintain "a sense of the whole" (Connelly & Clandinin, 1990, p. 7) in the stories that are constructed. In this study, although I presented the events and experiences that took place in various figured worlds, I worked to present a cohesive storied identity of my participants.

By considering all aspects of teachers' experiences with science, those that teachers may pose as either negative or positive, or those that may not neatly be organized in either of those categories, I moved away from the binary as well as resisted the appeal of “narrative smoothing” (Spencer, 1986). Connelly and Clandinin (1990) described narrative smoothing as presenting a story as “the Hollywood plot” where “everything works out well in the end” (p. 10). Although smoothing of the data may be attractive, it removes the necessity of grappling with the difficult and often complicated components of an individual’s identity.

In western ways of thinking, stories are typically constructed chronologically, and written within particular storytelling structures. However, as I constructed the storied identities of the teacher participants through a lens of figured worlds, I acknowledged the figured worlds in which teachers participate in are overlapping and intersect across space and time. This may not lend itself to always presenting a story in chronological order (Messias & DeJoseph, 2004). An example might be that of the figured world of mother and research participant. During a summer research experience, these two figured worlds may collide to produce two stories unfolding simultaneously during a single event. As teacher participants described events that took place, the storytelling itself rooted out additional stories that took place both before and after the initial story the teacher was telling. Therefore, I moved “back and forward several times in a single document” (Connelly & Clandinin, 1990, p. 7). By capturing the messy and intermingled nature of figured worlds in the storied identities I constructed, I pushed back against the patriarchal tendency to view events and experiences as discrete and do my best to “stay with the trouble” (Haraway, 2016).

Data Management and Analysis

In an earlier section, I made explicit the ecofeminist framework that I used as both an analytical lens and as a framework by which I conducted my study. I also discussed the ways in which an ecofeminist lens can be used to revise current conceptions of the nature of science, predominantly those being used to support changes to teacher conceptions during and after participating in an RET, as well as those that have been used within the most recent set of national standards in science education (Table 1.1). Specifically, I outlined the ways in which the current conceptions (Table 1.1) of the nature of science fall short when viewed in light of the principles of ecofeminist research (Merchant, 2006; Warren, 2000) and the criteria of feminist empiricism (Longino, 1990) I reference in Table 2.1. I used the framework of ecofeminism as a lens by which I viewed my participants stories about their science/teacher identities as well as their conceptions around the nature of science and the language they used to share those stories with me. The ecofeminist framework is present throughout this paper, from the development of the research questions, to the construction of the storied science identities, as well as in the discussion in chapter five.

Construction of the Storied Science Identities

In this study, I constructed teachers' storied science identities shaped by their experiences both before and after their participation in an RET, drawing upon the varying figured worlds teachers use to make sense of their lives in relation to their understanding the nature of science and science teaching. Specifically, I answered the following research questions: 1) How do individual teachers conceptualize the nature of science after participating in research experiences for teachers (RETs) and other experiences throughout their lives? 2) How do research experiences for teachers (RETs), as well as other experiences throughout their lives, influence teachers' storied science identities? 3) How does the portrayal of the nature of science in research experiences for teachers (RETs) influence their collective storied identities as secondary school science teachers?

Specific stories of interest included those related to how the teacher came to understand the nature of science and what they considered real/authentic science to be through both before and after their participation in a RET. By highlighting how teachers chose to talk about the nature of science, I followed in the ecofeminist tradition that places importance on language. Using a variety of data sources described in the previous section, I extended opportunities for the participants and me to answer my research questions more fully. Additionally, by looking across their many experiences with science, I was better able to develop their storied science identities, taking place across their figured worlds. Eliciting these stories was the main component of my data collection, whereas reconstructing teachers' storied science identities was the core of my data analysis. This process is described in greater detail in the sections that follow.

After conducting interviews and collecting artifacts, I stored the data and organized using an external hard drive, and all interview data was uploaded to NVivo for qualitative analysis. Through the use of NVivo, I coded and recoded my data in order to identify patterns that led to the development of my participants' storied science identities. I used both a priori coding as well as descriptive coding. I began the coding process with a limited number of a priori codes derived from the language of figured worlds in order to bring to the forefront the stories related to individuals' experiences with science, which included the following three codes: PEOPLE, PLACES, and EVENTS. I also used a priori codes related to my theoretical framework of ecofeminism which included: ECOFEMINISM and REAL SCIENCE. From this point, I coded the first interview. As I coded the first interview, I developed descriptive codes. As I moved to the next interview the descriptive codes from the first interview became a priori codes in the next interview. This process continued as I coded all interviews. I then returned to the first interview looking for codes that I developed in consecutive interviews. In this way the coding process was both iterative and cyclical.

Examples of additional codes developed through the process of descriptive included WHAT IS SCIENCE, TEACHING SCIENCE, and EXPERTISE. Some codes eventually became parent codes to children codes. For example, the descriptive code WHAT IS SCIENCE became a parent code to the following children codes: SCIENCE IS A PROCESS, SCIENCE IS PHENOMENA, SCIENCE IS A CYCLE, SCIENCE IS A WAY TO IMPROVE THE WORLD, SCIENCE IS OBJECTIVE, SCIENCE IS CREATIVE, SCIENCE IS INTERDISCIPLINARY.

Once all participant interviews were coded, I began constructing their individual science storied identities. Alongside coded interview data, I incorporated my participant's description of their visual as well as their classroom artifacts (all but Helen provided artifacts) as a way to bolster my codes and support my findings. This process of construction was also iterative and cyclical. As discussed earlier, I recognized that by using the frameworks of figured worlds and ecofeminism, my participants storied science identities may not be chronological or follow a western version of storytelling, which may include a beginning, middle, and end or the typical components of story construction, such as a plot. Therefore, my construction came from the presentation of my participant's experiences in science rather than fitting their experiences into a preformulated format. However, for clarity in presentation and for ease of understanding for my readers, I still wanted to construct the storied science identities uniformly while still maintaining the unique identities of my participants. This proved to be a challenging but worthwhile task.

Construction of the storied science identities first involved organizing participants stories based on their figured worlds. I started with Helen. After constructing the first version of Helen's storied science identity, I felt my construction failed to address my first two research questions. It was as if the nature of science as well as her science identity was making an appearance of the story of the figured world, rather than the other way around. Therefore, I worked towards constructing the storied science identity of my participants using a different format. The second format was organized around storylines central to the participant's understanding of the nature of science. For example, in the first version of Steven's storied science identity, one of the storylines was "Science and Creativity go Hand in Hand." Although this format highlighted different understandings of the NOS of the participant's, storylines included experiences taking place both within and outside of their RET experience, making it difficult for readers to ascertain the impact of the RET. It also placed little emphasis on my participants science identities, which I would eventually refer to as science/teacher identities, as I discuss at the start of chapter four.

In addition to lacking clarity in regard to my participants conception of the NOS, the development of their science/teacher identities, as well as the impact of the RET, this format was extremely long. I struggled to pare down the data from teacher interviews in order to answer my research questions concisely, while at the same remaining true to the participants' voices. After much revision of the data, what resulted is the format currently presented in chapter four which includes the following sections: an introduction to the participant, storylines related to their conceptions of the nature of science and/or their science/teacher identities, as well as a final section emphasizing the ways the RET impacted those conceptions and identities.

The final step of constructing my findings involved the presentation of the participants' visual narratives. At first, I simply included their descriptions in narrative form as well as the image within their storied science identities. However, this presentation seemed forced and did not fit cohesively within the storied science identity. After much toiling over where the visuals belonged within chapter four, and upon further analysis of the visuals both within and across participant's stories, I decided the teachers' visuals emphasized different aspects of their relationship to science than their stories did, highlighting their understanding of what science was as well as the purpose of science, rather than their own relationships to science. Therefore, I chose to present participant's visuals in a separate section as way to both reinforce what was already presented in their storied science identities or as a way to highlight something new that was not presented before.

Chapter 4: Findings

In this chapter I organized my findings in what I refer to as the participants storied science identities. The construction of the storied science identities resulted from using the conceptual framework of figured worlds to identify different experiences, individuals, and moments in time and space that participants felt contributed to their understanding of the nature of science. By using this framework as a guide to construct my research questions, I was able to elicit particular stories from participants. Therefore, the stories of the participants are presented in storied science identities. However, I must admit it was difficult to organize and construct my participants' storied science identities. I found myself constantly going through the process of re/organizing in order to achieve multiple things, much of which was related to the adherence to validity I presented in chapter 3. First and foremost, I wanted to ensure I was honoring the voices of my participants, and did my best not to analyze to the point that their voices were lost and overshadowed by my own voice and ideas. Second, I wanted the chapter to have aesthetic merit (Richardson & St. Pierre, 2008), not merely constructing stories that were enjoyable to read and flowed from one section to the next, but more importantly as an indication of my commitment to communicate with clarity to both my participants and readers.

I recognized that individual identity work may not take place within a western framing, chronologically, pointing to the usefulness of figured worlds as a framework for analysis, which represents identity work through a series of overlapping and intermingled experiences (or figured worlds) with others (human and non-human), places, and events. By pushing back against the traditional western conception of storytelling, with a distinct beginning, middle, and end, I am also participating in what I argue is an ecofeminist approach to identity research. I expected overlap between individuals' science experiences in different figured worlds, making it difficult to ascertain which particular experience may have shaped their science identity versus their science teacher identity. However, as I analyzed my findings it became clear that it would not be possible to distinguish one from another because of how entangled these two identities were for my participants. Therefore, I made the choice to refer to participant's identity throughout chapters 4 and 5 as science/teacher identity.

As I worked and reworked the chapter, it became evident that organizing and using categories of the different figured worlds that participant's inhabited did not lend itself to a cohesive presentation of my participants' identity making and their conceptions around the nature of science. I made further attempts to organize individuals' stories based on major conceptions of science that I perceived their individual stories supported. This resulted in something that provided a comprehensive look at my data, and the stories teachers provided, but for purposes of this study, included far too much data, and some not always related to the research questions undergirding this study. However, through the process of paring down, two important noticings took place. The first was how difficult it was to distinguish between a teacher's conception of the nature of science and their own identity in science and/or as science teachers. This qualitative work with my data supported the work of Helms (1998), when she posited that dimensions of teachers' identities are defined by their subject matter. Specifically, when looking at the identities of science teachers, Helms (1998) found that science teachers "construct an identity in direct relation to science" (p. 831). In the case of my participants, it was often difficult to discern what was an identity piece and what was a nature of science piece, reinforcing the intermingled nature of individuals' identity between spaces and time, how they experienced the world/s around them, and made meaning of those experiences. Therefore, when I discuss my participant’s science/teacher identities and conceptions of the nature of science in this chapter, they may not always be presented as distinct but rather as interrelated.

The second noticing that took place throughout this process of pruning was the aspect of science/teacher identities participants maintained as they moved through their different figured worlds of science. Holland and Leander (2004) used the metaphor of lamination as a tool, suggesting that an individual’s identity becomes laminated over time from a series of repetitious events that help to stabilize a component of one’s identity, resulting in what they refer to as durable identities. However, although similar, my work more closely models that of Barton et al. (2013) who referred to certain aspects of identity development in science as becoming more or less stabilized, evidenced in the stories my participants shared. Although I attempt to refrain from the use of language-supporting binaries, the terms stabilizing and destabilizing provided a tangible way of discussing identity moves between and across the figured worlds of my participants.

Therefore, in this chapter, I refer to certain components of my participants' identities as becoming stabilized or destabilized across space and time and in relation to their conceptions of the nature of science, while also acknowledging that these identities are not fixed and most definitely should not be considered comprehensive of who the participant is, was, or is becoming. Additionally, because of how linked one’s identity in science is to their conceptions of science, I also used the terms stabilize and destabilize regarding the development of their conceptions of the nature of science.

At the center of this research was the way in which RETs, as one figured world in which my participants inhabited, impacted their conceptions of the nature of science and therefore shaped their science/teacher identity. Similar to Avraamidou (2014), I looked for ways to uncover how participants' identities and conceptions of science may have been influenced by and shifted through their experiences with science, especially experiences in RETs. Urrieta (2007) noted, ‘‘Through participation in figured worlds, people can reconceptualize who they are, or shift who they understand themselves to be, as individuals or members of collectives” (p. 120). Therefore, each participant’s storied science identity includes a section specific to the ways in which, if at all, participant’s conceptions of NOS and/or their science/teacher identity shifted, or became stabilized or destabilized through their participation in the RET.

I feel that it is important to emphasize and acknowledge that my findings are based on the stories participants shared with me, and therefore what I presented is limited by the conversations we had and should not be considered as comprehensive of my participants identities or conceptions within science.

Throughout the individual storied science identities presented by the participants, I attempted to answer my first two research questions:

1. How do individual teachers conceptualize the nature of science after participating in research experiences for teachers (RETs) and other experiences with science?
2. How do research experiences for teachers (RETs) and other experiences with science influence science teachers’ individual storied science identities?

Each storied science identity begins with an introduction of the participant, followed by their journey to the RET. According to (Clandinin, 2013), by including autobiographical information, what she referred to as “narrative beginnings,” (p. 43), researchers demonstrate a level of integrity within their work. I then include a section where I discuss the storylines, I uncovered from the stories shared by my participant’s, relevant to their science/teacher identities and/or their conceptions of the nature of science, and impacted by their figured worlds of science outside of the RET. Next, I present clearly the influence of the RET, based on their stories about their understandings of NOS and/or their science/teacher identity. I end this chapter by presenting an overview of the teachers' visual narratives in response to the prompt I provided them at the start of our interview (see Appendix A). Particularly, I provide each teacher's visual as well as an overview of their description of the visual, looking for ways in which their descriptions both support their storied science identities as well as offer additional insight into their science/teacher identities and/or conceptions of the nature of science. However, before I present my participant's storied science identities, I begin this chapter with an overview of the two RET programs I included in this study, the Neutron RET and the Biosphere RET.

Program Overviews

By presenting an overview of the programs in which the teachers in this study participated, I hope to provide greater context for the findings in this study as well as better situate the stories provided by participants in relation to their experiences in their respective RET programs.

Neutron RET

The Neutron RET took place at a university valued for their commitments to research and world class facilities, and located about two hours from a large urban center in the eastern United States. Despite its proximity to a major city, the institution is situated within what NCES classifies as a small city, and within a county that includes a wide variety of classifications including suburban, town, and rural. Unique to RET models, the Neutron RET is facilitated by two former teachers, Tim, a Caucasian male, who taught middle school science and Anita, a woman of color, who taught both math and English at both the middle and secondary level. According to the program facilitators, and in response to the call by NSF, the Neutron RET hoped to include teacher participants who teach in districts where students have less access to science such as students from the large urban center as well as teachers from rural areas. In line with the program's goal of increasing the participation of underrepresented groups in science, the program coordinators also oversaw a large lending library of science curriculum and materials available nationwide, targeted towards schools of low socioeconomic status in both urban and rural areas. Additionally, they worked to collaborate with other universities in the development of these resources, including historically black colleges and universities. The Neutron RET was unique in its design, having two different models for teacher participation, a team RET, and an individual RET. The team RET was the first year of the RET whereas the individual RET was only available to teachers who had already completed the team RET.[3] An overview of the two models is presented in Table 4.1 and described more fully in the section that follows.

Table 4.1

Overview of the Neutron RET Models

Model	# of Participants	Duration	Main Objectives
Team RET	Team of 3 teachers	6 weeks	Introduction to several research labs (1/week), create lesson plans
Independent RET	1 teacher per research group	6 weeks	Participate in an ongoing research project in one research lab for the duration of the 6 weeks, create lesson plans

[3] Participation in the team RET and individual RET did not have to take place over consecutive summers.

The Neutron RET Team Model. The team RET was described by one of the program coordinators as a STEM candy store, where a group of three or four teachers have the chance to explore a variety of different labs over the period of six weeks with fellow teachers in their cohort. Teachers are required to submit an application, along with a resume, to be considered to participate. Additionally, and in contrast with the individual model, coordinators also conducted a zoom interview in order to find teachers that might work well with each other. Teachers selected for the team model RET, also the first year of the Neutron RET, spend the summer learning about the research, as well as the scientific tools and instruments involved, in various facilities at the university with the facilities managers of the different labs and graduate students. Examples of projects done by team RET participants included using an electron scanning microscope to identify if a teacher's ring was made of actual diamonds, observing the number of blades on different razors, as well as looking at the composition of different types of make-up. Each of these projects was initiated and based on teacher developed questions and interest, but led by the facility managers.

The Neutron RET Individual Model. The individual model, for participants who already completed the team RET model and who chose to apply for a second year, mirrored more closely the common model for an NSF funded RET program. Teachers were placed independently in a laboratory of a principal investigator at the university, where they spent the entirety of their six weeks. Typically, a "professor comes up with a project that can be done within that time frame and the teacher does research and collects data, and then they [the teacher] present that research at the end of the six weeks as well" (Anita Interview, April 14, 2022). The program managers explained they took into consideration teacher input when placing them in the different laboratories, allowing teachers the opportunity to choose, out of a couple of possible professors, the research that most interested them.

> They'll (the teachers) say to me, you know I'm looking for something in chemistry and so I'll find a couple groups that I think might be a good fit. And I'll send those and they'll go on to their group websites, and sort of look and see what kind of research is going on and what might interest them. And then they'll let me know and I'll contact the professors and say, "Hey I've got a teacher who would like to come up to work in your lab. Here's a resume, here's their background, would you be willing to host them?" (Tim Interview, March 29, 2022)

In addition to teacher interests, program coordinators considered professors who they felt worked well with teachers. Tim explained that within their department on campus, there was a dichotomy of professors, those who like to do outreach and those who want nothing to do with it. The program coordinators tried to target those professors and their research groups who were inclined to do outreach. University professors typically agreed to host a teacher when invited, however those who declined often did so because of workload or limited capacity to support having a teacher in their lab.

Once the labs were identified as hosts for participating teachers in the individual model, Tim coordinated with the PI of the lab as to what the teacher's role would be for the summer. Oftentimes, teachers in the independent model would work more closely with a graduate student rather than the PI of the laboratory. Tim described the graduate student as "a buddy in the lab who works with them and helps them out" and the teacher as a "lab assistant" (Tim Interview, March 29, 2022).

Anita explained that originally the program only consisted of the individual model of the RET. However, in response to teacher feedback and her own observations, the program coordinators realized the teachers were afraid to come on campus.

> What I learned was that, they said that they didn't think they were smart enough to be on [university name]. So, what we did was we split the program in two. . . You will work with a team of teachers. And you'll go through the various facilities, see all the microscopes, how all the equipment works. They get to be hands-on. And then they get to meet the grad students and the faculty through the different activities or ideas that we're trying to develop for classroom use. And what happened was, with that first program they said, ‘Can we come back?’ (Anita Interview, April 14, 2022).

Anita also explained how they used teacher feedback to make changes from one year to the next within the Neutron RET. For example, because the Neutron RET accepts applicants from all over the state, and some that live quite a distance from the university at which it takes place, participants are provided with housing. Teacher feedback was also used to provide guidance to the way the research groups integrated the teachers and foster a sense of belonging, a theme I return to later in this chapter in participant storied science identities as well as the shared storylines across participants in chapter five. Anita explained:

> What I learned was in the first couple of years, at the end some [teachers] said they felt lonely. And I was like, what? And what I discovered was that I needed to talk to the faculty and the grad and undergrad in that [research] group and say, look, you need to integrate this person. They need to go to your group meetings; you need to check in with them so that they don't spend their whole life doing research. You know, they've just got out of the classroom and now you need to be more hands on. And so, over the years, to

> make them feel included, that was huge, a sense of belonging is important. (Anita Interview, April 14, 2022)

In order to better facilitate this "sense of belonging" for teachers in the lab groups, Anita explained they became more intentional in regards to scientist selection:

> We're a lot more careful with the matching and we do more check-ins with both the group as well as the mentors as well as the teacher, to make sure things are going well. For the last couple of years, it has gone well. We've got good matches, good mentors, especially the grads and postdocs. The faculty realize they need to find someone who's a good communicator as well and they [the teachers] have had a little bit richer of an experience. (Anita Interview, April 14, 2022)

Anita explained that many teachers would come onto campus feeling fearful about working with fancy equipment that they may not have had experience with or thinking they are not smart enough to be welcomed into the research community, and would have imposter syndrome. Therefore, for the program coordinators, they considered the program a success when teachers feel comfortable in the research spaces at the university. Anita shared, "I think the biggest compliment we frequently get is that they [teachers] were treated with respect. And so, they want to come back and have an experience in the Individual RET" (Anita Interview, April 14, 2022). In addition to providing teachers with a sense of belonging, the Neutron RET had several other goals for participating teachers which I describe in the following section.

Goals of the Neutron RET. One of the goals of the Neutron RET included designing a hands-on activity that was inspired by something they did in the lab. An expectation was that their activities would be presented at the end of the summer to their peers and possibly at workshops for teachers outside of the RET. In addition to teachers developing a tangible activity to implement in their classrooms, the program coordinators discussed intangible goals they had for the participating teachers. One of these goals included exposing teachers to the wide variety of research taking place at the University as well as for the teachers to go back and tell their students about it. Tim said that one of the most common responses he received from teachers was how eye-opening the experience was in regards to the different types of research and career options there are available in science. Tim explained that he encouraged graduate students to talk with teachers about "what got them interested in science, what inspired them" in order to engage with teachers about the possible work they could do in their classrooms to inspire the next generation of scientists (Tim Interview, March 29, 2022). Specifically, Tim explained that much of the research to which teachers are exposed in the program tended to be related to the purposes of science, such as sustainability and making the world better. He explained that the research at the university tended to emphasize sustainability, such as the development of sustainable materials.

Another intangible goal for participating teachers was to expand teachers' understanding of who participates in science. Tim pointed out that,

> There's a stereotype I guess of, you know, who a scientist is. So, coming up here, for the teachers as well, and seeing the diverse group of grad students that are up here. It's not just these geeky old white men in lab coats and stuff, it's a lot of different people from various backgrounds who are up here doing their research. (Tim Interview, March 29, 2022).

One of the less expected outcomes for the program coordinators of the RET, which became a goal for future iterations of the program, was teachers walking away with a sense of appreciation for the work they do as educators.

> You know a lot of the professors, you know will say, our job is difficult, but your guy's job [the teachers] is even more difficult. And just to let them know that they're appreciated and their job is important. Because I don't think they [teachers] always feel that. You know, they don't feel like they're always treated with respect, by their class, the kids, the teachers, the parents, the admin. So, for them to get some, what's the word I'm looking for, I guess acknowledgement of what they do and what they accomplish, is nice for them as well. (Anita Interview, April 14, 2022)

Finally, one of the biggest takeaways for teachers was to develop a deeper understanding of science. The next section discusses in detail what the program coordinators wanted the teachers to take away from the RET related to the nature of science.

Neutron RETs' Vision of the Nature of Science. When speaking with the program coordinators, I wanted to get an idea of what version of the nature of science they wanted teachers to attain after participating in the Neutron RET. Sometimes it became difficult for the program coordinators to differentiate between what science is and what science teaching should look like. Four big factors seemed to emerge from our conversations: 1) science is messy; 2) science is a "verb;" 3) science is interdisciplinary; and 4) science involves communication.

Science is Messy. For both program coordinators, the theme that science is not picture perfect seemed was an idea that they wanted teachers to learn. As Tim remarked, "I really want to stress on teachers, nothing ever goes perfect" (Tim Interview, March 29, 2022). He pointed out that from his own teaching experience, his interactions with RET participants, as well as his visits to schools in the state through one of the other programs with which he and Anita have been involved, he still sees science taught as cookie cutter.

Tim went on to say that the messiness of science is often conveyed to teachers in the Neutron RET through observation of the graduate students:

> When they're [teachers] doing their projects in the facilities or when they visit labs and do a lab activity, something invariably does not work out great. So, I always tell the grad students, “Don't panic, use it as a teaching moment.” So, it didn't work out perfectly. Talk about your projects and how you know things don't always go well. (Tim Interview, March 29, 2022)

Anita expressed that by going through the process of making mistakes in the lab, teachers were better able to relate to what their students experience in the classroom

Science is a Verb. Tim stated, “To me science is a verb, you’ve got to be doing science” (Tim Interview, March 29, 2022). In addition to teachers developing an understanding of science that included a process of making mistakes, Tim also wanted to teachers to do as many hands-on things as possible. This is one example of the conflation between the programs view of what science is and what science teaching should look like. Once again from his own experience as a science teacher and through his visits to various science classrooms, Tim felt that too many teachers still tend to stick to lecture style instruction.

Science is Interdisciplinary. Another component of science that the program coordinators wanted teachers to come away with after their time in the Neutron RET was the idea that science is interdisciplinary. They felt that their program, situated in a materials science facility, provided an opportunity to see the interdisciplinary nature of science in action. Anita shared that by emphasizing the interdisciplinary nature of science, the Neutron RET supported the goals laid out in the Next Generation Science Standards.

Science Involves Communication. The theme of communication was presented in a variety of ways throughout my conversations with the program coordinators. One example was the way in which the graduate students needed to improve their communication skills in order to better present their knowledge to the teachers, and in their work to help teachers develop classroom materials.

> And they all know the lingo and the jargon and when they talk to somebody outside that field it's a little more difficult to communicate and convey—So, the [graduate] students that were involved realized they needed to work on their communication skills. They couldn't just throw out these words and acronyms. That they need to explain at a level that the average person can understand. And that some teachers have different levels of understanding . . . And we then encouraged that. (Tim Interview, March 29, 2022)

Anita explained the skill of communication was not only necessary for the graduate students to learn, but a skill from which the faculty of the labs could also benefit. According to Anita, by working with teachers in curriculum development, scientists were given a glimpse into the challenges teachers face in designing lessons, such as time, classroom management, lack of classroom supplies, as well as the need to align lessons to standards. Facilitators emphasized the importance of having the teachers, scientists, and graduate students improve in their communication skills as a result of the Neutron RET.

The Biosphere RET

The Biosphere RET took place across multiple sites, including one in South America, and two in North America. The Principal Investigator (PI) of the Biosphere RET, Gary, who both developed and operated the RET, was a professor of Paleontology who is deeply committed to, and teaches a course on, the broader impacts of science. In the Biosphere RET, teachers worked “alongside professional paleontologists and graduate students who are majoring in stem or science” and collected fossils (Gary Interview, May 7, 2022). In addition to speaking with Gary, I spoke with three participants from the Biosphere RET: John, Denise, and Louise. All three participants were middle school science teachers at the time of their participation in the Biosphere RET, and all three have since left the classroom. John is currently retired, but uses some of his free time to teach science to his daughter’s third grade students, Denise and Louise now work at the university level, for a teacher program partnering science teachers with scientists, and in a position of new teacher mentorship and training, respectively.

The Biosphere RET took place over three consecutive summers and provided three cohorts of science teachers an opportunity to travel both to South America as well as to different states. Whilst in South America, science teachers worked alongside researchers in the field of paleontology. Specifically, each year ten teachers worked with five scientists. The Biosphere RET featured several phases of professional development including an orientation, two weeks in South America, an online professional community after the trip, and a follow up meeting with each individual cohort during the school year.

Goals of the Biosphere RET. During our conversations, Gary described several of the goals of the Biosphere RET. The first goal was to have teachers participate in authentic research experiences; what Gary defined as having teachers do what the scientists do. The second was the development of lesson plans aligned to the research teachers participated in during the RET, the Next Generation Science Standards, and in line with what Gary referred to as place-based learning. The last goal was the development of formal and informal relationships between teachers as well as between teachers and scientists.

According to Gary, it was important for teachers to engage in “authentic research experiences collecting fossils alongside professional paleontologists and graduate students who are majoring in stem or science” (Gary Interview, May 7, 2022). Equally as important, teachers were expected to develop curriculum in order to take what they learned back into the classroom.

> We expected each teacher to produce at least one, vetted lesson plan. Vetted meaning implemented, improved, implemented, improved, you know iteratively improved, and maybe even shared with some of their teachers in the cohort, along with colleagues, and other schools. (Gary Interview, May 7, 2022)

Along with lesson plans, teachers were invited to present with graduate students on papers that they co-authored at different professional societies. These presentations would discuss their experiences in the field as well as their development of lesson plans.

In an effort to develop what Gary described as a “community of practice,” the Biosphere RET was organized in a cohort model (Gary Interview, May 7, 2022). Gary explained that he attempted to recruit teachers from the same schools in successive cohorts. In addition to the cohorts, at the end of each summer, Gary identified a participant as a teacher-leader, to return the following summer.

> All teachers participated only for one year, they were a member of one cohort. When that cohort ended, then I recruited my next cohort, but I usually invited one, at least one who was really a leader. I saw some leadership potential in a cohort and I invited them to come for a second year, and they all opted to do that. I read some literature about the importance of teacher leaders in professional development, so I used that, and that was very successful. (Gary Interview, May 7, 2022)

When I asked Gary how he decided who made a good teacher leader, he was unable to provide a clear definition, but suggested that his decision was based on instinct and how he felt the teachers conducted themselves during the RET.

Although Gary wanted to foster a community of practice between teachers and mentor scientists, an unintended consequence of the Biosphere RET, was the relationships developed between teacher and graduate student participants. After participating, teachers began inviting graduate students back to their classrooms to serve as role models for their students.

> Many of my graduate students have been LatinX, and many of the teachers in [county name] teach kids who are from Latino backgrounds, LatinX backgrounds, so they felt that they would be age-appropriate role models. So, we had this whole project of role model visits from my graduate students to go out to [county name], and that was something I hadn't even thought of, but it was teacher inspired and that was one of the one of the best benefits or outcomes. (Gary Interview, May 7, 2022)

Gary explained that some of the graduate students would visit teachers' classrooms because they were nearby to where their families lived. Others, however, were provided money by Gary for their travel expenses. Gary explained:

> The students would stay at the teachers houses, maybe become friends and colleagues, and then they would go into the schools with the teachers and help to implement curriculum that was developed as an outcome of their experiences in the [Biosphere RET]. And most of the time, the role model students were in the same cohort as the teachers, and they'd befriended one another in [South America]. (Gary Interview, May 7, 2022)

Teacher participants in the Biosphere RET spent two weeks in South America doing field work, and in the evenings, Gary would host "poolside chats."

> You go back to the hotel and we break out the rum or whatever you wanted to drink, and have all sorts of snacks. And we would drink and talk about what they learned, what they reflected on, and then, how they would begin to think about getting the curriculum, or what they learned back in the classroom. So, I would have the teacher leaders lead that, I'd just sit back and relax. (Gary Interview, May 7, 2022).

In the field, Gary would take a similar approach to the poolside chats, by allowing the teacher leaders to share their experiences from the year before as well as answer the newer teachers' questions. It was clear that Gary felt comfortable having teachers take the lead, stating: "I could have never done as good a job as he [the teacher leader] did, because he really understood what the teachers were thinking" (Gary Interview, May 7, 2022).

As we continued in our conversation regarding the relationships that developed during the RET, Gary explained:

> As far as I'm concerned, the [graduate] students, the scientists, who are professors of all different career stages, and postdocs, and even undergraduate interns, got as much out of the program as did the teachers — They learned a lot from the teachers about pedagogy in science, communication, and respect for the teaching profession. (Gary Interview, May 7, 2022)

This claim was substantiated by a survey Gary had conducted which asked the scientists about their experience in the Biosphere RET.

> If you asked me 10 years ago, I would say that most scientists who are doing the teachers have a favor to invite them in the lab, which I think is b.s. I never thought that! But it was

validated for me, based on some evaluation of [Biosphere RET] that the scientists got as much out of the experience as the teachers, so there was instead of a unidirectional flow, there was a mutually beneficial partnership among the scientists and the teachers. (Gary Interview, May 7, 2022)

When I asked Gary if he would provide me with the contact information for teachers that participated in his program, he was very clear that he felt teachers were being overworked and had little time to participate in a research study, though he acknowledged the importance of my work. Gary told me he would only give me the names of teachers who were no longer teaching in a K-12 setting. This represented for me a respect for teachers and how difficult their jobs can be, especially amidst the new protocols of the COVID-19 pandemic. Gary's respect for teachers and the teaching profession was corroborated by the conversations with the teacher participants with whom I spoke.

Biosphere's Vision of the NOS. In comparison to the program coordinators of the Neutron RET, the vision of the NOS for the Biosphere RET presented by Gary was much less detailed. From our conversation, it appeared Gary's biggest focus was providing teachers with "authentic research experiences," which he described as "teachers doing the same thing that the scientists are doing, it's not contrived" (Gary Interview, May 7, 2022). Gary also felt strongly that the field of paleontology was a gateway subject that highlighted a variety of different science disciplines such as geology, biology, anthropology, environmental science, and physics. Lastly, Gary felt that paleontology was a great field for teachers to participate in and bring back to their classrooms because "kids love fossils" (Gary Interview, May 7, 2022).

Storied Science Identities

The first three participants presented in this chapter participated in the Neutron RET: Oliver, Steven, and Helen, whereas the second three participants participated in the Biosphere RET: John, Denise, and Louise. In chapter five, I provide a cross-participant analysis, highlighting the shared science/teacher identities as well as common threads across participants' conceptions of their NOS and how their conceptions were shaped by their experiences with science, with particular attention to their experiences within the Neutron and Biosphere RETs.

Oliver

Oliver joined the zoom call for our first interview, eager to participate. Born in Ecuador, Oliver’s native language is Spanish, and he considers himself bilingual, fluent in both Spanish and English. Oliver moved to the United States at the age of six with his parents. His family moved back and forth between the U.S. and Ecuador, but the majority of Oliver’s middle and secondary education took place in the United States. Although his parents now reside in Ecuador, Oliver made the decision to remain in the U.S., because he felt he had more opportunities and was more comfortable here than in South America. I asked Oliver if he felt being bilingual impacted his experiences in science in any way. He felt that no matter where he was born or what language he spoke, he would always do something in the science field. Specifically, he said:

> I have so many arguments about the terms Hispanics, Latinos, LatinX. I don't like to go there. Yes, I was born in South America, but I have spent the past 35 years of my life in the U.S. I have my wife and kids from here. Take it as it is. I'm pretty sure you're familiar with that question about where you are from, right? And what it really means. So, you

know. It depends on my mood if I will answer it nicely or not, but I think it's a loaded question. (Oliver interview, June 28, 2022)

Here Oliver brought up his experience with microaggressions throughout his life, quite possibly throughout his figured worlds of science. While there is little work examining the impact of microaggressions in the field of science, there is evidence that microaggressions can impact an individuals' feelings of belonging within the science community (Harrison & Tanner, 2018) For Oliver, although he completed a degree in science and became a science teacher, it is possible that his experience of microaggressions contributed to his continued pursuit of recognition within the field.

In Oliver's figured world of middle and high school, he experienced social reproduction through tracking (Reichelt et al, 2019). At his school, students were encouraged to specialize in a particular track. Oliver explained, "some kids that went into a track in math and physics, some of the cohorts went into chemistry and biology, and there are some of the cohorts that kind of did a track in philosophy and history. I went into the chemistry and biology concentration." (Oliver interview, June 28, 2022). Evidenced in his figured world of middle and secondary schooling, Oliver began to see himself as someone who was good at science, and held what Carlone et al (2014) referred to as a "celebrated position identity" (p. 836) within science.

Currently, Oliver works as a Chemistry teacher, characterizing his district as urban and his students as mostly minority. According to Oliver, he only teaches honors courses and his students are motivated to learn. In addition to obtaining his certificate for teaching through an alternate route program, Oliver obtained an Ed.S. in curriculum and instruction and is heavily involved with the National Science Teachers Association (NSTA). He received an undergraduate degree in biochemistry and, prior to teaching, worked in several science-adjacent fields. He began working in the field of quality assurance and improvement, later moving on to work in a tissue bank. From there, he obtained a Master's degree in administration, leading to his work as an administrator in several hospitals and in different clinical departments, from gynecology to clinical engineering. Oliver pointed out that although his career in the hospital position may not be considered a chemistry position, he often applied his science background to administrative work. After being let go from his hospital administration job in the recession of 2008, Oliver's wife, also an educator, suggested teaching as a viable career option. When I asked Oliver if anything or anyone else contributed to his decision to pursue teaching, he replied:

> I guess everything converges right? Would I have preferred to stay in healthcare? I don't know. Life is all about making choices, right? And I always look back at this, and this may sound a little pretentious but, I had an opportunity to actually work at [major university] as an administrator. And for whatever reason I turned it down. And at that time, I think we had either our first kid or we already had two. You know, you start making decisions based on your surroundings, your environment, or your specific situation. . .But I have to say that I have found the teaching career very rewarding, very invigorating, and because of that I have become involved with a lot of other things. (Oliver Interview, June 28, 2022).

This excerpt from our conversation highlights how teaching was a backup option for Oliver, after feeling a level of success in his other jobs and then being let go. It also emphasizes that Oliver found teaching rewarding, not from being a science teacher, but rather as a result of the other activities he became involved with, referencing his many opportunities, accomplishments, awards, publications, and RET programs.

How Oliver Came to Participate in the Neutron RET

Oliver heard about RETs in general from a fellow teacher. He also heard about RETs through his networks at NSTA. Oliver explained that at the time of our interview, he had participated in three different RETs at three different universities, and said he would travel anywhere he had to if it meant he could participate in a research experience. For Oliver, participating in RETs was a much better way to spend his summer. He became somewhat of a research enthusiast, as he described below:

> For many years, I kept applying to another program, another program, and I was getting in, and I was getting in. But again, I think I've worked, I don't want to sound pretentious, but I have a decent dossier. My experience doing our RETs and doing all the things, so it came very easy for me to apply to a lot of these things and get accepted. (Oliver Interview, June 28, 2022)

Oliver laughed as he explained that his wife had to deal with his constant desire to participate in opportunities such as RETs, even when they took him away for weeks at a time. In addition to the support from his wife, he received support from his school administration, something he felt was unique. He explained, “Support from my district supervisor was key because you need letters of reference, that sort of thing, but I know from experience, some of the districts are not as supportive” (Oliver Interview, June 28, 2022). Oliver felt the support he received was in part due to his go getter personality as well as his ability to do things well, saying: “You know, if I’m going to do something, I'm going to do it right. I'm going to make you look good, so everybody wins. It's a win-win situation for everybody” (Oliver Interview, June 28, 2022). He could not understand why other teachers did not want to participate in RET programs. He felt RETs served as a resource for teachers to improve their teaching.

As Oliver and I talked about his reasons for pursuing a RET, he emphasized the value he placed on the recognition that came with authoring publications. Although he did not have any publications from the Neutron RET, he did have publications from the other two other RETs he participated in.

> Being published was a big, big determinant for me…I would have preferred to get a publication from every single one of the projects that I have been involved in, but that's obviously not the case. But I have worked enough that there's enough knowledge or something unique about my projects or the projects that I've been involved with that merits a publication. (Oliver Interview, June 28, 2022)

In addition to being published, Oliver liked the idea of spending time at what he referred to as “premier institutions.” He felt this was an opportunity he could not pass up, and “maybe some people may not be able to understand that,” alluding to the idea that he might be more knowledgeable about the value of participating at such prestigious facilities with such prestigious people (Oliver Interview, June 28, 2022). He expressed that many of the RETs offered participants the opportunity to come back for a second year, and he always went back. For two of the RET programs, he participated in, he went back for a third year, which he told me was uncommon.

Oliver’s Storied Science Identity

I present Oliver’s storied science identity in three storylines, all of which support an overarching identity story of wanting to be recognized as more than a science teacher, a science/teacher identity stabilized overtime through his experiences in his different figured worlds of science: Oliver’s stories as a science teacher, Oliver’s stories of being one of the few who understands fundamental content knowledge, and Oliver’s stories of wanting to have access and be recognized as an insider within the science community.

Oliver’s Identity as a Science Teacher. When I asked Oliver to describe himself as a teacher, he replied, “I’m the best.” He went on to say that his intention was not to sound “pretentious” but rather that because he had previous careers, he believed he offered a unique perspective to teaching. Oliver felt his teaching style was heavily influenced by his experiences in his previous careers: “A lot of the things that I bring from outside teaching, or at least from my professional experience, that I bring to the table, makes me a little unconventional” (Oliver interview, June 28, 2022). Oliver used real-life scenarios in his science teaching and placed his own teaching in contrast to teachers who may not have worked in other careers prior. He felt that the stories he told his classroom were those that he lived through, rather than being someone who talked about something they have not experienced**.** He remarked, “I know exactly what I'm talking about” (Oliver interview, June 28, 2022). He felt that another reason he was the best teacher was due to his deep understanding of the content, and presented himself as someone with high competency beliefs (Vincent-Ruz & Schunn, 2018)

When Oliver mentioned the phrase real-world, I asked if he could be explicit about what that phrase meant to him. He said, “to me, anything outside teaching is the real world, right?” (Oliver interview, June 28, 2022). He pointed out that tenure in the teaching profession allows individuals to maintain their job without necessarily performing. For Oliver, his use of the real-world here was not related to his conception of the nature of science, but rather to his view of teaching and the classroom as being something that existed outside of what he considered to be real. These segments of our conversation point to the idea that Oliver’s identity within science teaching was somehow different, or possibly subordinate to his identity while he worked outside of teaching and existed outside of what he considered the real-world to be.

Oliver's Stories of Being Someone who Understands the Foundational Content Knowledge of Science. Oliver recalled, from his figured world of high school, taking a lot of courses in both chemistry, anatomy, and physiology. He appreciated having good science teachers and specifically noted his chemistry and anatomy teachers as being very good. His assessment of 'very good' was rooted in their knowledge and credentials. Oliver said, "The guy who was my chemistry teacher held a doctorate in chemistry, so he knew what he was talking about . . . The anatomy and physiology person actually was a doctor, an MD" (Oliver Interview, June 28, 2022). I asked Oliver if he could elaborate on what a good teacher was. He explained that being a good teacher meant they had a strong knowledge of the content they were teaching. His science teachers came up a second time when I asked if there had been anyone that influenced his understanding of science in his younger years, and he responded:

> To this day, I thank my chemistry teacher in high school for teaching me nomenclature. It's a very hard subject. The way I see it, it's either you get it, or you don't get it. And for me, to look back at being so young, and I got it. And now I kind of compare that to when I'm trying to teach my students nomenclature and I'm trying all different things to see what works. I see how students may struggle with the concept itself. (Oliver Interview, June 28, 2022)

When I pressed Oliver to elaborate on what science meant to him, he suggested that science is the ability to understand phenomena, giving the example of day turning into night. He said the only way to understand phenomena is if you "have the knowledge." He continued:

> What is endothermic? What is exothermic? And that sort of thing. And what is pH? What is an acidic pH? What is basic pH? It's knowledge. I mean, because if you don't have the foundation, how will you be able to interpret any kind of information that comes your way? (Oliver Interview, June 28, 2022).

This part of our conversation provided evidence that Oliver believed in order to be successful in science, an individual must be well versed in their understanding of important concepts and facts foundational to a particular science discipline, once again emphasizing the competency beliefs component of identity. Oliver stated that understanding science was something that came naturally to him, especially in the content area of chemistry. He also expressed that chemistry provided a foundation in which to understand other science disciplines by providing the reasons behind something happening, not just that it was happening. This excerpt of our conversations highlights the importance Oliver placed on facts and content within his conception of the nature of science and science identity, but also each science discipline as discrete from one another. This view of the science disciplines stands in contrast to more modern conception of the NOS, as well as the vision of the Neutron RET, which presents science as interdisciplinary (Abd-El-Khalick, 2012).

Oliver's Stories of Wanting to Access and Recognition as an Insider Within Science. Oliver referenced that in order to understand scientific concepts and succeed in science, one needed to have adequate support along the way, which he shared he received from all of the RETs he participated in. However, for Oliver, his conception of support differed from other ideas of support found in the RET literature. For Oliver, his use of the word support was often related to the level of access he had to those in the science community. He relished the networking opportunities he received while participating in different RETs, including the Neutron RET, referencing them as an appealing factor that influenced his decision to continue to apply to RETs and other similar opportunities. He appreciated the professional courtesies he received during his participation in RETs and RET like programs. When I asked Oliver what he meant by professional courtesies, he replied, “I know I can reach out to them [the scientists], and in a moment's notice, I know they're gonna either have the answer to my question, or just to say hey happy holidays, or how you doing? That sort of thing” (Oliver interview, June 28, 2022). He emphasized how important it was for him that he stayed in touch with many of the scientists with whom he worked.

Oliver expressed that the reason he was able to learn so many things, such as gel electrophoresis, was due to the support he received from the researchers. He reflected, “They would say, let me show you how to do this” (Oliver interview, June 28, 2022). For Oliver, he explained that support in science was more than just a way to describe his own experience in the lab, but it was part of his “interpretation of science.” He explained, “You can have the knowledge, but if there is no support or someone who is willing to say, ‘Hey this is how you prepare an agar gel and that sort of thing, and this is what you do right?” (Oliver interview, June 28, 2922). However, as we continued this line of thinking, I could see Oliver begin to contemplate what he just told me, recognizing that when he was an undergraduate student, there was significantly less technology available. I observed in real time Oliver’s thinking change. Maybe if he was learning now what he learned back then, he could simply use a Google search or find a You-Tube video to watch. Perhaps Oliver was rethinking his own use of the word support. Rather than having support in learning a skill or scientific concept, or maybe in addition to that support, what Oliver really seemed to value was the connection to experts in the field, providing him with a sense of belonging or acceptance as an insider within the science community. When I say community here, I want to be clear that I am not necessarily referencing a community of practice, as discussed in length in my literature review, but rather a more general term used to represent groups of researchers working in the field of science. Carlone and Johnson (2007) referred to this feeling of being an insider as “recognition”, both self-recognizing and recognition by “meaningful scientific others” (p. 1195).

How did the Figured World of the Neutron RET Influence Oliver’s Science/Teacher Identity and/or His Conceptions of the NOS?

The Neutron RET was one of many RETs and other research experiences in which Oliver participated. During our conversations, he shared with me several opportunities he took part in related to research as professional development that took place within his figured world of science teaching. For Oliver, he saw opportunities such as RETs as pathways to publications and awards, something I was able to confirm through member checking. Therefore, by applying and being accepted into Neutron, as well as being recommended as someone with whom I should speak as being a successful program participant by the program coordinators, this only further stabilized his identity as a science person and not only as a teacher.

Additionally, Oliver came to the Neutron RET with a science/teacher identity and conception of the nature of science which suggested that only certain people understand the fundamental knowledge necessary to be good at science. This conception was supported within his figured worlds of middle and secondary science, where he felt his science teachers were good teachers because they knew their content well. His science teachers held advanced degrees in science fields, which to Oliver represented to him that they were not only knowledgeable, but better than the other teachers who held degrees in education. Oliver seemed to maintain this conception after participation in the RET program. Oliver also felt fundamental knowledge within science was content specific, emphasizing his conception that the science disciplines are discrete rather than interdisciplinary. This conception of science stands in contrast to more modern understandings of the NOS, as well as the goals laid out by the program coordinators of the Neutron RET. Finally, in regards to the Neutron RETs vision of the NOS that they wanted participants to take away, that science is messy, is a verb, and involves communication, it was difficult to determine what conceptions Oliver held prior to or after his participation, or if the RET impacted his perceptions in relation to this vision in any way at all.

Steven

Steven joined our zoom chat with a friendly greeting and smile on his face. He had dark brown hair and a goatee and described himself as a Caucasian male and a big guy, saying: “I’m six, three, but I’m also a large six, three” (Steven Interview, May 5, 2022). Steven also mentioned that he had sometimes been referred to as a hick or redneck, even though he would not describe himself as such. He attributed this description to his love for the outdoors: “I don't know if it's what I do socially or how I just love to be in the woods, and how my family tends to love to be in the woods, or exploring or climbing mountains or kayaking” (Steven Interview, May 5, 2022). Steven grew up in a farming region and worked on a dairy farm as a teenager, something he described as common for kids his age at the time. He attributed some of his early passion for physics as stemming from his experiences at the farm. He reflected, “I would bring those same life experiences, like simple farm hacks involving physics. They're everywhere because farmers are brilliant. They're trying to get something very, very difficult done in an efficient way” (Steven Interview, May 5, 2022). Steven eventually pursued an undergraduate degree in physics with a concentration in math, with the intention of becoming an engineering technician at one of the global technology companies in his home state. Steven decided to switch careers after working as an engineer for three years saying he felt strangled by it.

Steven described his upbringing as supportive, including in the context of engineering. He explained his mother was an analytical person, and both his father and grandfather modeled mechanical skills and how to work with tools. He explained that they taught him “skills needed to take an idea and try and make it a physical reality” (Steven Interview, May 5, 2022). He identified woodworking as a hobby, and explained that he was currently working on making a fiberglass canoe for an upcoming camping trip. Steven passed his woodworking skills to his own son, who was in the process of fashioning a B17 out of wood.

Currently, Steven is father to five kids, has a dog named Ranger, and teaches 8th-grade physical science. At the time of our interview, he had just completed his 14th year at his current school, and 17th year of teaching in total. Steven was chosen for this interview because he participated in the Neutron RET program. He mentioned, however, that he participated “in a lot of different research like teacher research related things,” but that he would do his best to focus the RET-focused questions on his experiences in the Neutron program. Steven participated in both the group and individual models of the Neutron RET, but not in consecutive years.

How Steven Came to Participate in the Neutron RET

Steven first heard about the Neutron RET from his father-in-law, who worked on a on the university campus and was friends with the Neutron RET program coordinator. In addition to having this connection, he also knew other physics teachers in his district who participated in the program. He explained what drew him to the program:

> It's the idea that we're going to travel around to different material science labs and we're going to learn what they do, we're going to learn about the equipment, we're going to be given the opportunity to like play with this stuff. (Steven Interview, May 5, 2022).

Although Steven was initially drawn to the program to play with fancy science equipment, like a scanning electron microscope, after participating he realized he got a lot more out of it than he anticipated.

Steven's Storied Science Identity

Steven's story is presented in three storylines related to his understanding of the nature of science and his science/teacher identity: 1) enthusiasm in science teaching; 2) the relationship between creativity and science; and 3) science is messier than a collection of facts in a textbook.

Steven's Stories of Enthusiasm in Science Teaching. When I asked Steven if any individuals supported his pursuit to become an engineer, he told a story situated within his figured world of middle school science. He explained that he found it interesting that his "most impactful science teacher" was his 8th grade science teacher Mr. Jackson, since the majority of Steven's students now are eighth graders. Mr. Jackson had a real passion for classroom demonstrations, which exemplified for Steven that Mr. Jackson enjoyed his work. As a middle schooler in the mid-1990s, and with only two working channels on his home television, he admitted that he had no idea who Bill Nye was: "So, when I first saw Bill Nye I think I was in high school, and I'm like 'Not only does Mr. Jackson behave like Bill Nye, but he physically looks like him too.' He could have been his doppelganger" (Steven Interview, May 5, 2022). Steven reminisced on the enthusiasm for teaching that both Mr. Jackson and Bill Nye possessed. Clearly, Steven valued highly any science teaching that included an element of entertainment because he felt that it strongly motivated his own science learning.

Steven told me about a memorable demonstration Mr. Jackson did for the class, called the barking experiment. He narrated, “You take a plexiglass and spray something inside like 90% isopropyl alcohol, just something that has really low vapor pressure, and you just kind of move it around, heat it up and then you light one end and it burns, from one end to the other and it makes like essentially a barking sound” (Steven Interview, May 5, 2022). However, for Steven it was not only the excitement of the demonstration that he recalled from that day, but the way Mr. Jackson presented it to the class, describing: “He stood up on a table and he was, you know, manipulating the tube and just talking and you know spinning it around a little bit acting” (Steven Interview, May 5, 2022). He remembered that although the class thought he was acting silly, he kept everyone’s attention.

According to Keller et al. (2014), “enthusiastic teachers provide cues during the act of teaching that allow students to deduce the teacher’s personal value and enjoyment” which can lead to students holding a level of “value and enjoyment themselves, reflective of elevated levels of interest” (p. 30). As a student, Steven felt that his best learning experiences took place with Mr. Jackson, who presented science with passion, something he would later bring into his own teaching methods. It was his enthusiasm for scientific ideas that rubbed off on Steven, and led to his own enthusiasm for science, eventually modeling Mr. Jackson’s enthusiasm in his own teaching.

Steven provided another story of his own enthusiastic teaching with one of the lessons he chose to share with me. It was his take on the egg drop challenge, typically done in physics classrooms giving students the opportunity to implement their understanding of momentum. This lesson used the question formulation technique. Steven described this technique:

> It's the idea of presenting a phenomenon and having people generate questions about what they see or observe, and then working those through to what's important, and creating an investigation, whether or not we go through the investigation. The idea of creating a thinking process where they're isolating what's important, and they have to think it through. (Steven Interview, May 5, 2022)

For Steven, he felt his enthusiastic flair sparked excitement in his students and their understanding of scientific concepts in his classroom (Keller et al., 2014). He began to describe the egg drop challenge, saying leading up to the day students would perform their experiment, he would walk huge, funny strides across the front of the classroom, asking me if I ever saw the Monty Python sketch, the *Ministry of Funny Walks*. He explained to me how he would explain the activity to his students:

> Okay, I'm going to be walking along the front of the school, and you and your teammates will be on the roof, three stories up with a vice principal, and you will have one hardboiled egg. I'm going to be walking at a set pace, and you need to deliver that egg to the target that I'm going to be wearing on my head. (Steven Interview, May 5, 2022)

Larkin (2020) noted that such pedagogy, which he referred to as “demonstratism,” has the potential for excitement, but may lack in scientific rigor:

> Science teachers often perform their demonstrations with a degree of showmanship. Done well, these can hook students’ interest and motivate them to want to know the answer to the mystery. But they can also take on the appearance of a magic show, placing the scientific understandings at arm’s length, even while kindling students’ sense of wonder. (Larkin, 2020, p. 42)

Steven reflected,

> I don't tell them anything, but at this point we have dropped things from the roof, and observed, and taken some measurements to distance they need to figure out all right. Well, we need the height of the roof. We need the height of the top of the bull's eye. Not necessarily the ground. But where the bull's eye is going to be on my head, we need to figure out how fast he's moving. These are all things they have to isolate and find a way to measure them. And eventually, they realized he must be walking funny like this, because that's how he's going to walk when and that is, I said, Yeah, you got it. So now you gotta figure out how fast that is so they, you know they must determine different things. So, I like to teach in a way where I present them with a challenge, and they have to really think about how they're even going to begin to fulfill it. (Steven Interview, May, 5, 2022)

In the case of Steven, it was evident that along with his inclusion of showmanship in his teaching, he also includes opportunities for his students to implement science and engineering practices (NGSS), such as making observations, developing questions, and collecting and analyzing data, as presented in the excerpt above.

Stories of Steven's Relationship Between Creativity and Science. A continuous storyline that spanned my conversations with Steven was creativity. Steven's conceptions of the nature of science were deeply entangled with his conceptions of creativity as well as what he envisioned as good science teaching. He emphasized that not only can creativity be infused into a physics lesson, but that physics itself is inherently creative. Steven identified this enthusiasm he infused within his teaching style as merely one aspect of his science/teacher identity and conception of the nature of science as creative.

Steven also loved to create things, and in particular, useful things. Steven described himself as curious with an appreciation for understanding the underlying mechanisms of how things work. He explained his curiosity was the reason why he loved physics. He described physics as a tool to provide "the underpinning understanding for pretty much every other branch [of science]" (Steven Interview, May 5, 2022). He tended to apply his knowledge of physics to other subjects, using physics as a method for making sense. For Steven, it was this relationship between creativity and science, manifested through his curiosity and his passion for creating, that most likely played a role in his pursuit of engineering. According to Steven:

> I enjoy creating, whether it's a functional piece of woodwork or it's some form of art or another, with friends, or with my wife, uh out of any medium. I think the creativity that I like to express outside the classroom. It's governed by scientific understanding and understanding the process. It's not like everything I do is geometric fractals and things like that, but I do feel that those artistic leanings or creative meetings impact how I practice science. (Steven Interview, May, 5, 2022)

When Steven talked about how creative he felt the process of science was, he brought up Richard Feynman, a name that would continue to come up throughout our discussions together. He went on to recapitulate Richard Feynman's ideas regarding the relationship between beauty and science:

> In science, we see a lot of things that are beautiful, because we have just an inkling of the order that's lying underneath. I think he was talking about who appreciates a rose more --- an artist or a botanist? They can both appreciate aesthetic beauty, maybe more terms can be used by the artist, but the depth of beauty can be better understood through science. So

> creative, beautiful, curious that's all in there in the process [of science] too. (Steven Interview, May 9, 2022)

This excerpt highlights the way Richard Feyman's ideas resonated with Steven, almost as if providing him with feelings of validation for his own linking of science and creativity.

Throughout our conversations, Steven mentioned various creative activities he participated in, from making comic books with his friends in his figured world of adolescence, to woodworking at home now as an adult. He reflected, "If you break people into stereotypes, weirdly enough, I played three sports all the way through [high school], but I would have been described as an art major because I took every class I could, I took all the art classes" (Steven Interview, May 5, 2022)

When I asked Steven to try and describe how creativity and science were connected, he shared a story situated in his figured world of secondary school science that illustrated this creativity in a somewhat unusual manner:

> We did this thing, where we went to the thrift store and we got basically whatever we could for a suit. Then we went to my place and we made a dye pack from corn syrup. And we shot the suit on a tree with a 12-gauge shotgun, so we got a decent spread. So, we did that and I got dressed up, and we waited till night. Then we took some of the construction lamps that my father had around the garage and we did some light blocking and then we took, like a block and tackle and a gimbal. Not like the gimbal that say a rocket engine swivels on but the one that you would put through the tendons in the back legs of a deer and we duct taped me by my ankles to the gimbal, and we pulled me up into the tree and I was, I was hanging there like well like a bit of urban prey that had been harvested. We took those pictures and we just thought it was weird and hilarious and we

> ended up getting into a photo contest. We won the photo contest and it got displayed at a college. (Steven Interview, May 5, 2022)

After he finished telling the story, Steven wondered why he told it to me. I reminded him that when he was asked how his creativity and his understanding of science were linked, this story made its way to the forefront of his mind. He thought for a minute, and realized that the story of urban prey was just one example of how through his art, he was able to bring things that at one time only existed in his mind, into reality. He came to the realization that his perspectives on the scientific process as well as the process of making art projects, like the urban prey, both involved problem-solving. The connections Steven made between his identities in art and science support the argument of Braund and Reiss (2019) when they discuss the use of art in Niels Bohr's innovative model of the atom, suggesting "the existence of new ways of looking at the world in the arts opens up spaces in which new thoughts about how the physical world works are more likely" (p. 223).

Stories of Science Being Messier Than Learning Facts in a Textbook. Steven's conceptions around the nature of science changed over time due to his experiences in different figured worlds. He articulated that his conceptions of the nature of science were destabilized, as he went from seeing science as a neat collection of facts in a textbook to something much messier. At one point in the interview, Steven said, "I'm trying to think back through my mind at what point did it [science] stop being the collection of facts in a book to a process of thinking that kind of branched over all the books" (Steven Interview, May 5, 2022).

When I asked him to try and identify an event or person in his life that led to this new conception of science as messy, he began talking about a professor he had during his figured world of science teacher preparation: "I had this professor—I don't know if she had mentioned what she thought science was, but I remember just discussing it with her" (Steven Interview, May 5, 2022). This professor taught in both the education program as well as the biological sciences department. He pointed out that although he may have heard that science was a process, it did not sink in for him until he worked with this professor. "I started to think how everything was in fact connected, built on something else, and it's just that slow progress towards more understanding or knowledge" (Steven Interview, May 5, 2022).

As he recounted his memories of this professor, he remembered she directed him toward the book, *Six Easy Pieces* (1963) by Richard Feynman. Steven described reading this book as diving "into the wormhole of Richard Feynman's life" (Steven Interview, May 5, 2022). Not only did his perspective on science shift after reading about Feynman's conceptions of science, but he also felt he could relate to him personally, since Feynman was a funny guy who loved the bongos.

In his book, Feynman presented science as a process of developing understanding rather than collecting facts. Instead of placing value on the names of things, Feynman's book emphasized "how things fit together" (Steven Interview, May 5, 2022). In the book, Feynman recounted stories of his childhood, where he would go on nature walks with his father. Feynman explained that his dad was less concerned about the individual names of birds, but rather, he wanted to understand bird behavior and what it is that makes one species of bird different from As Steven talked about Feynman's father, Steven had an aha moment. He realized Feynman's experience with his father was quite similar to the one Steven experienced with his own dad, as someone whose "way of doing things was trying to point out how things are connected, rather than just what they are" (Steven Interview, May 5, 2022).

I asked Steven why he decided to participate in a RET in the first place. His initial response was that he would be given "the opportunity to have an experience that would make more of the things I talked about with my students real" (Steven Interview, May 5, 2022). Steven used the phrase 'real science' to mean two different things. The first was to make science content relevant to students, while the second emphasized the dichotomy Steven perceived between real science and classroom science. Steven told me a story that emphasized his second meaning of the word real, taking place within his figured world of teaching.

> I was really fortunate when I came to this particular school. I came to a hollowed-out classroom and a hollowed-out physics program. There was no physics program left, there were no lab materials, there was nothing. I had a great teacher I observed under. When he found out, "you've got no written labs, you've got no textbooks to speak of, you've got nothing to teach from" he's like, "you should get this book, it's a book called thinking physics" (Steven Interview, May 5, 2022).

He suggested Steven use the book *Thinking Physics* (2002) by Lewis Epstein, to develop his Physics curriculum. Steven explained that this story came to mind because the organization of this book approached physics differently than most of the other physics textbooks Steven was familiar with. According to Steven, this book not only changed the way he presented physics to his students, but it changed his personal perception of physics as well. He explained that after reading the book, he moved away from what he labeled cookie cutter labs, and towards a view of science that involved uncertainty. He went on to say that real science involved doing and revising, and that, "If you are doing something that is real science, it will most likely not work out the way intended, your data won't be clean" (Steven Interview, May 5, 2022).

In addition to the idea of the messiness and need for revision of data collection, Steven felt that the book emphasized the importance of questioning as a part of real science. He said:

> Developing the question process is real science. Learning what's a better question to ask, or a better way to ask, or at least a way to ask it. As you know, when I'm investigating this, I'm at least going to learn something towards what I think my end goal is. And that's what I mean when I say real science, that basic foundational stuff. That may not be glorious science, but it's real because it lays the foundation for later understanding. (Steven Interview, May 9, 2022)

How Did the Figured World of the Neutron RET Influence Steven's Science Teacher/Identity and/or Conceptions of the Nature of Science?

It was evident from our conversations that Steven's experience in the figured world of RET impacted both his conceptions around the nature of science as well as his science/teacher identity. His experience provided opportunities to stabilize certain conceptions that Steven already held around dichotomy of real science and classroom science, which in turn influenced what he perceived his role as science teacher to be. Additionally, by participating in the Neutron RET, Steven began to identify himself, and be identified by those he worked with in the field of science, as an expert communicator. In the following section, I explore each of these impacts more fully.

Steven's Conceptions Around the Differences Between Real World vs. Classroom Science. Steven explained that the Neutron RET impacted his conceptions of what real science is and how may or may not be able to implement real science in his classroom. In terms of Steven's definition of real science as relevant, his experiences in the Neutron RET allowed Steven to make "the things I talked about with my students real" (Steven Interview, May 5, 2022). In regards to Steven's second way of defining real, his experience in the Neutron RET stabilized his conception that "real" science is messy, something he was exposed to in his laboratory work with graduate students, where they would share with him "where things fall apart" (Steven's Interview, May 5, 2022). However, the Neutron RET also further stabilized the dichotomy Steven perceived between classroom science and "real" science. Specifically, Steven explained that the experiences in the Team RET and the Independent RET were very different, one modeling more of the possibilities of what can be done in the classroom, and the latter providing him with an experience that he described as participating in real science.

Steven pointed out that his experience in the Team RET was limited: "There are still guardrails with the RET program because you're functioning within a lab setting for a shortened period of time, and it's not the fault of people running the lab it's just, sometimes your own comfort level" (Steven Interview, May 5, 2022). Steven described the Team RET as an opportunity where teachers rotated as a team through different material science labs on campus, the goal being for teachers to learn "about the process in that lab, what kind of work they do, what kind of tools or equipment they have, and getting some experience with those tools and equipment" (Steven Interview, May 5, 2022). He described one particular experience with a staff member from one of the labs, which I include below:

> He's like, "Hey, you guys ever watch that old show CSI? Would you like to do something like that?" "And the next day he showed up and he's like, "Here's a bloody T-shirt, whose blood is, well it's mine alright, whatever. And here's some shell casings, here's the skull of an animal.' And he just said, 'Alright, well you know, go to town, just you know, learn about that stuff.' So, he was very hands off and that idea of like, we're presented with something, maybe not an end question, but we're presented with material and we're

> presented with tools, and now we got to learn how to use the tools and pull whatever we can out of this that was just a fun experience. I wouldn't say that it was like, hey this is real science or this is real criminal investigative work that wasn't the goal. (Steven Interview, May 5, 2022)

Although the Team RET was not perceived by Steven as an example of real science, he felt that the independent version of the Neutron RET was "by far more what I think of when I think science" (Steven Interview, May 5, 2022).

This sense of real science for Steven related to his previous descriptions of what real science encompassed; however, he built upon that description during his time in the RET. He explained that real science involved "developing a protocol" as well as "doing the basic science for an end goal" (Steven Interview, May 5, 2022). During the Independent RET, Steven worked with gold nanoparticles. Steven gave a brief description of light behavior before going into his own experience with light behavior and the gold nanoparticles he worked with. He explained that by observing the color of the particles, he could tell how close or far off he was from the intended goal of his experiment.

> Even before I characterized things, I could already tell how far off the mark I was based on the color I was seeing. . . I could tell when my particles cooked up too stinking big! I'm like what? Like the absolute frustration, I could have sworn I did everything I did the last time. (Steven Interview, May 5, 2022)

During this second summer, he spent time "changing different aspects of the protocol, obviously with justification, experimentation, and developing data and evidence" (Steven Interview, May 5, 2022). Although this experience allowed Steven go back to his classroom and share with his students the realities of lab work, it would be difficult to replicate this aspect of real science in a classroom setting. He reflected, “You know, a six-day week, 10 hours of the day running a protocol over and over and over. Allowing things to cool and things to cook up to a certain temperature, then cleaning the lab equipment, and then signing up for a piece of equipment that I use at three in the morning” (Steven Interview, May 5, 2022).

For Steven, trying to develop the correct sized nanoparticles required hard work, as well as the process of trial and error. He shared, “The idea of working really hard and trying to be diligent on something and still just screwing up and having to try and isolate where that's happened, that's all part of the game you know. (Steven Interview, May 5, 2022). During the Independent version of the RET, Steven was working with a functional lab group who aimed to publish their results, and reliant on the piece of the puzzle Steven was working on. He elaborated on the nature of this work not only for publication, but also for application outside of the lab:

> We're building to something else, so like this past year that group published some work that basically said they're taking to human trial. The application to chemotherapy drugs through nanoparticles. And you know so I’m like, oh! I know for a fact like they're not using gold, they are however characterizing nanoparticles to a certain size. So, some of the work that I was doing . . . are all part of the puzzle, working towards a greater goal. (Steven Interview, May 9, 2022).

Although Steven wanted to model for his students what real science was, there was a tension between what he experienced during his experience in the independent model of the Neutron RET, what Steven defined as real science, and what could take place in a secondary classroom setting. For Steven, the true nature of science involved taking part in the tedious day to day aspects of scientific research with the intention to publish and produce something with some future application, something he positioned as different from what takes place in a classroom or what he experienced in the Team RET model.

Although Steven felt he was unable to replicate perfectly what real science was in his classroom, he thought his experiences in the Neutron RET impacted his teaching practice. Specifically, by participating in the RET, Steven further stabilized a conception of science based less upon individual content knowledge and more based in the scientific process. He explained that his experiences allowed him, “to accept the fact that I can throw a challenge out to my students and I can help them find success in their failure” (Steven Interview, May 9, 2022). Although he felt the curriculum he developed as a result of the RET was targeted towards college or an AP bio class, and therefore did not use it with his general education students, he still felt his teaching practice had been influenced by his experiences in the RET, especially in the way he emphasized the processes of science over individual facts. He said: “In general, I think my labs have become more open ended, more about the data produced and trying to understand the data, then, about like, this is how the second law of motion works . . . less based on definitive things that I can show you that are probably in bold someplace in a book I don't really want you to read anyways” (Steven Interview, May 9, 2022).

One of the practices that he felt he was able to implement more regularly in his teaching, as a result of his participation in the Neutron RET, was students generated questions. Steven felt that the process of questioning played a large role in the scientific process he observed during his time in the RET. He described the importance of questioning to the scientific process in the following way:

> There's a learning curve, because many come into it, not understanding that’s [asking questions] a big thing you need to know. How to question in order to devise, to go

> forward with a direction to take your research. And you're not answering a question somebody else posed, because typically, those questions are answered already. It's like you can't necessarily learn or extend at that level by looking at past work solely, because you're never pushing the bounds to something new, so it gives an opportunity to start generating their [scientists] own questions and their [scientists] own investigative avenues. (Steven Interview, May 5, 2022).

Steven explained that the RET helped him make connections between the process of asking questions and the interdisciplinary nature of scientific investigations.

> The more questions you have, it broadens your horizons, at the very least. And broadening their horizons, it also helped me see how more things were connected and how they all work towards the same goals. Goals is the wrong word, but they all work together. Maybe not harmoniously, but all these branches [of science], are working together in a way, where students or investigators or anybody involved in science, or science research, is having to pull from a lot of different areas to try and problem solve. (Steven Interview, May 5, 2022)

In addition to the importance of questioning in the process of science, Steven also thought of other ways he could implement what he learned into this teaching. Steven explained that a main goal of the RET was figuring out how to replicate the lab experience, while at the same emphasizing for students that the nature of science is “something that happens beyond high school sciences” (Steven Interview, May 5, 2022). He gave the example of having students investigate things that they “don't necessarily have answers for or that are already answered and can look up” (Steven Interview, May 5, 2022).

Steven highlighted that during his experience in the RET, he felt excited when he would look for something in a journal, and not be able to find what he was looking for. He explained:

> Which means what you're working on is very close to being untapped. So, the idea of doing something that's brand new and it being very creative because you're coming up with your own solution to a weird problem that you're not even sure how you ended up at this place. Like how who asked this initial question that led me to you know, helping someone 3D print basically a spatula that will hold the heart of something the size of a mouse, while we try and get some MATLAB timing photos with a little pre-photon laser to try and see what's going on inside the heart in between beats. That's just a weird place to end up, it had to start with a creative question. (Steven Interview, May 5, 2022).

Here, Steven emphasized how questioning in science is a creative process, however, he also used the term "untapped" to discuss things that are not present in scientific literature. Often, the word untapped refers to something being underutilized, often in relationship to non-human organisms and the environment, for the purpose of humans. Whether Steven was intentionally choosing to relate the investigation of unknown scientific endeavors to the exploitation of non-human animals and land, by using the term untapped to refer to science investigation, his language perpetuated a colonialist and capitalist view of science.

Steven's Science/Teacher Identity as Expert Communicator. During his time in the Neutron RET, Steven felt he was treated as part of the lab. The principal investigator (PI) treated Steven like any other member, even when it came to logistics, such as weekly group meetings. "Whether it was like I just got thrown the rotation, some people, you know you gotta do snacks this week, some people you're presenting literature" (Steven Interview, May 5, 2022).

He explained that although the PI was often busy, Steven developed relationships with the graduate students. Steven had the opportunity to learn the graduate student's personal backgrounds as well as participate in events outside of the lab, such as playing frisbee. However, Steven pointed out that by having children, he was less available to take part in these extracurricular activities with the graduate students. Additionally, Steven would talk with the graduate students about his experiences as a teacher and his knowledge of the education system, as he found they were interested in areas in which he held knowledge. The graduate students would ask Steven about his teaching methods, and how he approached different topics with his students. He explained that the graduate student's interest was partly driven by their roles as teaching assistants, hoping to elicit skills to better teach and work with undergraduate students, and partly by their need to receive funding. Steven explained:

> At some point, they [researchers] have to justify their work to people who are not in their lab. And they have to actually gain funding and they have to be able to communicate their goal, where they're at with their goal, and what they might possibly use this particular research for . . . because, again, you know funding is kind of key. (Steven Interview, May 5, 2022)

Steven began to see himself as valuable to the graduate students by helping them communicate in ways beyond scientific jargon. According to Steven, the graduate students respected "the experience of a teacher and someone who is more familiar with communicating to people that are different levels than they are" (Steven Interview, May 5, 2022). They were so deeply embedded in their topics that it was difficult for them to communicate in a way that those outside of their field could understand. "So, one of the things they said that they valued was how I would take what they said and communicate it back to them in a way that helped me understand what they were talking about" (Steven Interview, May 5, 2022).

After his participation in the RET, Steven remained in relationship with some of the graduate students, inviting them to visit his classroom and work with his students. He explained that while graduate students were in his classroom trying to communicate their work to Steven's students, he helped them with their "vernacular." Beyond words, Steven also helped graduate students recognize body language related to classroom learning, such as being able to identify what "someone's face looks like when you may have lost the attention of someone as well as strategies of what to do next" (Steven Interview, May 5, 2022). The experiences of having graduate students come into his classroom, emphasized for Steven the expertise he held as an educator, as well as the necessary skills of communication necessary for both teaching and the field of science.

Helen

Helen joined the zoom chat for our interview bubbly and upbeat. Helen began by saying that she was born outside of the United States, a detail of her identity that would come up throughout our conversation: "I came here when I was eight years old." Helen was born in Guyana, as were 4 of her five siblings. Only her youngest sibling was born in the United States. She labeled her country of birth as "third-world" and explained that her parents grew up very poor. Education was very important to Helen's father and was the reason why her family relocated to the United States. She explained, "You know my dad worked out of poverty, he spent four years here so that we could come here for education right, that's why everybody leaves their country to come to America for education, well, not everybody, but a lot of people" (Helen Interview, July 12, 2022). Her father placed high value on the fields of math and science, and considered those who worked in STEM careers as “elite,” influencing Helen and her sibling’s perception of careers in science as an achievement.

Helen pursued an undergraduate career in chemical engineering and a masters in pharmaceutical engineering and then worked for a pharmaceutical company as a validation engineer for a few years. Helen explained that as an engineer she worked in a cubicle, or “lonely little box” where she would spend her time “writing the protocols and looking at data and putting together the reports for the FDA” (Helen Interview, July 12, 2022). She felt confined in her position at the pharmaceutical company, something she described as influencing her decision to pursue science teaching. She admitted that her job as an engineer paid well, confessing that she took a pay cut when she became a teacher.

As mentioned above, Helen’s father valued education and particularly those who pursued math and science, so when Helen decided to switch careers from pharmaceutical engineer to science teacher, she said that her father, “damn near had a stroke. . . ‘The man, to this day, still has not forgiven me’ (Helen Interview, July 12, 2022). In addition to her father’s perception of teaching as holding less value than a career in a science field, she also found that other people in her life would make deficit comments about the field of teaching”

> Before, when I was working people would say, ‘Oh, what do you do?’ When I would say engineer at a pharmaceutical company it's like this automatic reaction of like, ‘Oh, you must be so smart and accomplished. And then, when I became a teacher, I was like, ‘I’m a teacher.’ It's more of like, I feel sorry for you, kind of reaction. (Helen Interview, July 12, 2022)

When I asked Helen why she decided to pursue teaching, she talked about how she missed “human interaction.” As Helen was searching for possible careers to switch into, she came across a teaching fellows' program and decided to apply. At the time of our interview, Helen was in her 14th year teaching physical science in a large urban school district, the same district she completed both middle and high school. Helen described herself as a dynamic science teacher, as opposed to someone simply going through the motions, and regurgitating information. Helen believed she learned more as a teacher than she ever did as a student.

How Helen Came to Participate in the Neutron RET

Helen expressed that the school in which she worked did not provide much science specific professional development, and that much of the PD offered was targeted towards English and history. In her experience, most of the administration consisted of former English and history teachers, and the environment in her district lacked in "support or encouragement for growth and learning and moving to the next level" (Helen Interview, July 12, 2022). Helen admitted that her desire to seek out opportunities may have been driven by her ego and her desire to be the best, stating: "If I am going to do something, it's going to be done right from top to bottom" (Helen Interview, July 12, 2022). Even as a novice science teacher, Helen consistently looked for ways to grow. She attended a professional development opportunity, and was impressed by one workshop in particular. The teacher who ran the workshop told her about his experience in an RET (not Neutron), and how impactful it was. This interaction began Helen's investigation into RET programs, where she eventually came across the Neutron RET. She also recalled other professional development opportunities, she attended being run by the University in which the Neutron RET was housed, and decided to apply.

Helen's Storied Science Identity

Helen's storied science identity is presented in two storylines related to her understanding of the nature of science and/or her science/teacher identity: 1) Helen's accessibility to science in her own figured world of high school science and 2) Helen's experience with students who were not allowed access to science. Each of Helen's stories included in this section support a conception of science and/or science/teacher identity related to both her own accessibility to science and the inaccessibility of science to others. Helen's storied science identity supports the idea that an individual's science/teacher identities are intertwined and cannot be teased apart from with their ideas of what matters to them, their sense of morality, and what they value, including values of equity and social justice (Helms & Carlone, 1999).

Helen's accessibility to science in her own figured world of high school science. For Helen, many of our conversations about her understanding of science centered around the idea that only certain individuals are provided pathways into science. Helen's stories with science portrayed a conception of the nature of science as interrelated with her identity as someone who had access to the science community. She recognized that others may not had have had the same level of access and opportunities in science that she did.

Helen shared a story which took place between the overlapping figured worlds of high school science and university science. According to Helen, this story was the first one that she could think of that led to her career in engineering, as well as one of her first memories of becoming passionate about science. She started the story off by saying that prior to high school she did not have many memories of school science, except for her eighth-grade earth science course, which she described as painful. However, in high school, she had the opportunity to attend a technical school with different majors. She was placed in the medical science major, which was considered one of the advanced programs in the school. In this program, Helen was part of a small cohort of students, something she contrasted with the typical high school experience in a large urban district.

In the medical science major, Helen navigated the high school landscape as a member of a small cohort focused on science, with the encouragement of teachers that guided students towards careers in biology and medicine. She described the teachers in the program as “experts in their different fields” (Helen Interview, July 12, 2022). She identified this group of teachers as experts because they worked in science fields prior to becoming teachers. She believed teachers who worked outside of teaching brought their expertise to their classrooms. She also mentioned that the school was well-funded, resulting in science classrooms equipped with what she defined as “real lab equipment,” as well as the ability to offered advanced science courses such as analytical chemistry (Helen Interview, July 12, 2022). Helen enjoyed being a part of what she described as a rich high school science program and having the opportunity to work with “experts.” Throughout our discussion, she continuously compared her unique high school experiences to the typical high school student in her district.

Helen described her high school labs as “cookbook,” something she held in contrast to the laboratory experience she had in a summer program she had the opportunity in which to participate. At Helen’s school, students were expected to participate in academic programs over the summer. Helen applied and was accepted to a program in chemical engineering at a university in a neighboring state, which specialized in STEM education (also the school Helen would later attend for her undergraduate degree). When she talked about the program Helen’s face lit up, especially when she reminisced about some of the amazing professors she worked with. One of the courses she recalled most vividly was one where the students worked with the professor to make a “superconductor.” She described the experience in this way:

> One of the courses that I did was with a physics professor and we actually made a superconductor, which was like one of the most grueling processes. We had to grind this

> material for hours. I mean we spent like an entire week, where we would come in and just sit there with a mortar and pestle making the superconductor. We had to read scientific literature, and we then used the conductor. It was a very rich experience. We then used this superconductor with liquid nitrogen, with lasers, and we put on this laser light show. And it was so impactful, like it really left an impression on me. I loved the work, even the reading. I didn't find it to be something overwhelming. So that actually pushed me towards a career in chemical engineering. . . So, I think it wasn't until high school that it was really like an opportunity and experience that made me fully realize that I love science and wanted to learn more. (Helen Interview, July 12, 2022)

Although this story could also have been used to show that Helen enjoyed working hands-on with science equipment, as well as how science can be fun, I chose to include this story in this storyline because I think it speaks to a larger theme I saw throughout my discussions with Helen. Helen highlighted here that it was because of the opportunities she had to engage in science, opportunities she had because of the school she was fortunate to attend, that opened her eyes up to the possibilities of pursuing a science career. It is hard to know whether or not Helen would have pursued a career in science if she did not have the experiences she had. From Helen's perspective, having experiences that not all students in high school have, laid the groundwork for her to later participate and feel welcomed within the scientific community.

Helen's Experience with Students Who Were Not Allowed Access to Science. In comparison to her own educational experience, Helen also told me a story where she witnessed students receiving unequal opportunities in a science classroom. During Helen's figured world of university, while she was completing her undergraduate degree, Helen worked with a program that sent her into middle school classrooms to assist science teachers in conducting labs with students. As she thought back to that experience, she said, “I actually really enjoyed it. It was a good experience, and it also had an impact because it just blew my mind” (Helen Interview, July 12, 2022). Helen then began to tell me a story about one of the times that she visited a classroom:

> There was this one school that I went to. The kids were probably in sixth grade and I showed up with this experiment. I can't remember what the experiment was, but there were some food items and the teacher had absolutely no control. The kids are just running everywhere. It was one of those old school buildings where you have the closets for them to hang the coats in, with the two doors, and these kids were circling through them. They were at her desk, and they started eating the experiment. (Helen Interview, July 12, 2022)

Helen laughed while telling this story, and I began laughing too. However, Helen stopped laughing and her demeanor changed to one of concern as she continued on with the story:

> What really like made me so sad . . . There were these two little boys and she told me, she's like, “Oh, they can't read so they're not going to participate.” And so, she put them at another table with books to color and I remembered walking out of there just floored. Even as I’m telling you right now, and I have goosebumps, because it floored me. That was a solution, right? Just because they can't read doesn't mean they can’t observe or try to understand or speak. And she literally put them at another table with coloring books. And these were kids that should be able to read a little bit, so that particular experience really shook me. (Helen Interview, July 12, 2022)

As I mentioned earlier, this story was told in response to why Helen became a teacher, however, I think it also speaks to a larger thread throughout my conversations with Helen that relate to both her conception of the nature of science as well as her science/teacher identity. In this story, Helen highlighted that the students “who couldn’t read” were not permitted by the teacher to participate in science. The teacher in the classroom made the decision that because these two students did not meet a certain criterion of what a student in science could be; they would not be allowed to be a part of the scientific community of the classroom that day. This story speaks to Helen's acknowledgement that all students should have the chance to participate in science, and by becoming a science teacher, she could possibly begin to change the narrative. This experience shifted Helen's conception of who gets to participate in science, as well as how she would eventually identify as a science teacher.

How Did the Figured World of the Neutron RET Influence Helen's Science Teacher/Identity and/or Conceptions of the Nature of Science?

Helen participated in the Team Model of the Neutron RET. When she talked about her experience, her face lit up: "It was definitely one of the nicest learning experiences I've ever had" (Helen Interview, July 12, 2022)! Helen described the campus where the RET took as a beautiful place, peaceful and serene, and her learning experience as balanced. She gave me a breakdown of her day-to-day experience while in the Team model of the Neutron RET:

> We had the days where we would meet in the morning, every week we went to a different team in their research facility, so we got to see different areas in their material science, research. It was three of us, me, and another gentleman. I think, if I remember correctly, he was from [the same urban district] and then there was another woman from somewhere [outside of the state]. It was just the three of us. So, we would go and it was very structured, and I think the structure helped to really bring clarity to what we were doing. (Helen Interview, July 12, 2022)

Helen continued,

> And so, we get this background knowledge, then we learn about how the equipment works and how it's used, and then they would guide us and help us develop a question to be tested and we would collect our data. And then, as a group, we would come together and do our weekly presentation. (Helen Interview, July 12, 2022)

Helen's Change in Conception About What Real-World Science. Helen used the phrase "real-world science" to describe her experience in the Neutron RET, so I asked if she could explain what she meant by that phrase. She explained that during her undergraduate degree she took several science courses, which she described as theoretical. Even though she did labs, that she characterized as typical, her undergraduate figured world of science consisted mostly of completing courses and taking exams, and less about research and investigation. Helen felt she was not pushed or encouraged by anyone to pursue research. She went on to say:

> Because doing research is different from when you're in a regular class where you have, 'read these chapters, answer these questions, take this test.' And that to me, just the culture of going in that direction, whether or not you end up being a researcher is a whole other question. But just the idea of pursuing scientific research and learning something on your own, where you're really . . . because in research you're in that driver's seat right, versus like you go to class you listen to a professor. (Helen Interview, July 12, 2022)

Helen felt she witnessed real-world science in the Neutron RET by observing graduate students apply their research to the real-world, asking questions like: "What's the application? How do I take this to the next step?" (Helen Interview, July 12, 2022). For Helen, by observing the graduate students' experiences in science during the Neutron RET, her conceptions of the nature of science were destabilized, shifting from a view of science centered almost solely on completing coursework and obtaining credits, to a view of science situated in research for future application.

Helen's Shift In Her Science/Teacher Identity as a Result of a Shift In Her Conception Around the Nature of Science as Interdisciplinary. At the point in which Helen participated in the Neutron RET, she mostly taught chemistry, sometimes biology, but never Physics. She emphasized that although she took a lot of physics courses for her engineering degrees, when faculty in the Neutron RET would go over background information for the lab work, she "really appreciated it, because there were things that I hadn't looked at in years" (Helen Interview, July 12, 2022). She described her experience in Neutron as fulfilling. Her experience made her realize both how much of the content she had forgotten as well as aspects of the content she never learned, so much so that it prompted her to begin teaching physics. Helen's experience awakened within her an understanding that science disciplines are interconnected, and how important it was for her to change the way she presented science content to her students. She said:

> In the real world of science there's no silo, it is interdisciplinary, and the RET program was completely interdisciplinary. They really stressed that, and it brought that to the forefront for teaching in my classroom, and I hope that that physics experience that they have, is like what's prompted them to want to pursue it and go further with it, which I think is just amazing. But then again, I feel all of that came about because of that experience, because that RET experience . . . It gave me that confidence, and that enthusiasm, and that drive to say, 'Let me push myself further.' I was hired for chemistry. And my principal was like, we could not find a single chemistry teacher that wanted to teach chemistry and physics. I was literally the only person that was like, 'yes, I'm going

to teach physics. And you know the RET made all the difference. (Helen Interview, July 12, 2022)

Through the figured world of the Neutron RET, Helen stabilized her conception of science as interdisciplinary. By providing Helen experiences that helped her develop a deeper understanding of the interdisciplinary nature of science, she became more confident in teaching science from that perspective. By seeing the overlap between the different contents, Helen experienced a shift in her identity as science/teacher, from being a teacher who was only capable of teaching chemistry, to a teacher who was able to teach physics as well.

John

John joined our conversation with a full white beard, a large smile on his face, and identified as an "old white guy" (John Interview, January 24, 2023). John was a retired science teacher of 37 years and his office, where he sat for our zoom conversation, was composed of wall-to-wall shelving, each filled with different artifacts from a lifetime career as a science educator and avid collector of specimen. He remarked, "I'm in right now what my wife calls my museum room. Because I have shelves full of fossils, I have a shelf full of skulls of all different kinds of animals, and I collect sand from every location that we've been" (John Interview, April 19, 2022). John had over 100 samples of sand in little spice bottles. He turned his computer camera around so I could have a better look at his sand collection. Even when John would travel for a personal vacation, he would try and make a connection with someone who he could work with on something science related.

John considered the idea of teaching in high school, but entered university with the intention of majoring in biology. Unfortunately, the university that John attended did not have a biology major, so he ended up majoring in zoology. He eventually decided to complete the health education program, which resulted in a K-12 certification, allowing him to teach both middle school and high school science. During his time in college, John volunteered with the college museum, eventually working as a docent, an experience that helped John realize how much he loved education. John said, “I was already in love with the science part, and then all of a sudden, I did this teaching, and I taught little kids, and I just thought, ‘This is just great fun!’ (John Interview, April 19, 2022).

When I asked John if he felt that his identity as a white male may have impacted his own understanding or experiences in science, he replied: “I'm a firm believer in white privilege and so, do I think I was privileged in a lot of ways because of it? Yeah, absolutely” (John Interview, January 24, 2023). As will be reflected in John's storied science identity, John is very outgoing and would ask to participate in a variety of science experiences. He recognized that as a white, male it most likely, “made it a lot easier for people to just say, yeah, come on —I can only imagine the doors were more open for me than they would be for other people” (John Interview, January 24, 2023).

How John Came to Participate in the Biosphere RET

Due to years of having a relationship with the local university and museum, John became close friends with Gary, the PI of the Biosphere RET: “He and I are buddies. I've known Gary for 20 years” (John Interview, April 19, 2022). When Gary was planning the Biosphere RET, he reached out to John telling him: “I have something you have to do” (John Interview, April 19, 2022)! At this point in time, John was only a few years away from retirement, and already participated in a large number of research opportunities, including research on sandhill cranes, mosquitoes, and many other things. He reflected, “I was like, ‘Gary, maybe another teacher should go and not me.’ And he's like, ‘I really want you to go to come, you'll love it.’ And I’m like, ‘I know I’ll love it. It's great.’ So, I went” (John Interview, April 19, 2022).

John described his experience in the Biosphere RET as ‘ridiculously wonderful” (John Interview, April 19, 2022). He felt that, especially for teachers with less research experience than he, it was an eye-opening experience. John came to the Biosphere RET with a significant amount of research experience under his belt, which made him “feel a little guilty doing it because it was such a wonderful experience you know, and I only had a couple years left [before retirement]” (John Interview, April 19, 2022). After participating for one year, Gary asked John if he would help him recruit teachers to participate in the upcoming iterations of the Biosphere RET, and he did. John expressed that he had a difficult time recruiting teachers to participate: “Honestly, it was so hard to get people to do it, which just floors me” (John Interview, April 19, 2022). He went on to say:

> Most science teachers didn't come from a background like you did or that I did. I don't think. At least most of my colleagues. There were several biology teachers that I worked with that rarely walked outside. I would be thinking, you're talking about life and you don't experience the living things that are out there. The number of teachers, that I suggested go do this [Biosphere RET] thing, most of them said no, they wouldn't. (John Interview, April 19, 2022)

John’s Storied Science Identity

John’s storied science identity is presented in two storylines: 1) John’s conception of the nature of science as situated within the context of animals and 2) John’s purpose as a science teacher to develop future citizens.

John's Conception of The Nature of Science as Situated Within the Context of Animals. From an early age, John had an interest in animals. Specifically, he told me a story that took place in his figured world of childhood, before turning six years old, describing it as one of his earliest recollections of science. His parents bought he and his brother a kiddie pool for swimming in the summer. Rather than using the pool for swimming, he and his brother would use dip nets to catch tadpoles, fish, and crayfish, and bring them back to the kiddie pool.

John mentioned his mother was not a scientist, so I asked if his parents still supported him on his journey into science. John said that his father loved nature shows and they would watch them together. However, since his both of his parents were born in a major metropolitan area in the northeast, they had little experience in nature. When John was 13, his family moved to a coastal state, in the southeast of the United States. He recalled it was after this move his interest grew even more in science. The following is a long excerpt from my conversation with John that highlights John's fascination with collecting animals in his figured world of adolescence.

> I mean there were snakes around and so I started collecting stuff and I remember the first snake my mother let me keep was a little corn snake, and it opened a door she didn't realize it would open. And there was a time in my house where I had like 17 snakes! I had caught a hog nose snake that laid eggs and I hatched out the eggs as a like a seventh or eighth grader and so now, I had these nine little baby hog nose snakes, I had corn snakes and other rat snakes and whatever I found, I kept. I remember a friend showing up in my garage one day, knocked on the garage door, he's standing in his underwear with his blue jeans in his hand like this [John holds his hands up to the computer camera as if he is holding something in his hands]. And I'm like, this is odd. You know it's a little

> middle school kid and he he's like, 'See what I caught.' So, we pull out one of my cages, I have many cages at that point, and he dumps in a big diamondback rattlesnake. An Eastern diamondback and puts it in this cage and we're like so excited about it, we attach it [the cage] to a lawn fertilizer spreader that was on wheels, because we want to walk around the neighborhood and show all of our friends. My father caught us as we're going down the driveway with it like, 'What are you doing?' And you know, 'Where are you going with my fertilizer spreader?' And we knew he would not be happy. When he saw he got really ticked off because he didn't like me keeping snakes at all, and the idea that I brought a venomous snake into the garage, he was not thrilled. So anyway, so that turned into a whole thing. He called the police, and the police came and shot it. It was crazy. (John Interview, April 19, 2022)

John also recollected another story from his childhood about a snowy owl. This story appeared to contrast his other stories about animals, emphasizing John's first conceptions of protecting animals in nature, rather than removing them from their habitats for purposes of collection. He said:

> I also have a recollection of a snowy owl that showed up in our neighborhood. Some people heard about it in the neighborhood and word kind of spread and it was up in this tree and everybody walked down to see it and I remember walking down there to see it and there were kids throwing rocks at it. And the adults were really mad, these are older kids you know, I was a little kid. I remember the parents were really mad at these kids and yelling at them. And that that's something I really remember. Seeing an owl, and seeing people upset that somebody was trying to hurt the owl. (John Interview, April 19, 2022)

From the stories included thus far in John's storied science identity, it is clear he was fascinated by animals, but what was less clear was exactly how he perceived animals in relation to his conceptions of science.

When I asked John if there were any individuals, outside of his parents, who supported his path into science, he talked about his biology teacher that he "just loved." At the time, AP courses did not exist, but the course John took was considered an advanced biology course. He described the course as one that "not many people took. It was more for kids that really loved biology" (John Interview, April 19, 2022). He remembered course consisted of, what he described as hands-on activities.

> I mean things that you just couldn't do now, we raised, we took eggs, we got we got farm fertilized eggs and every day we would open them and see what they looked like. They were all related basically the same. Each group would take an egg and open it up and see what the embryo looked like. And every couple of days, we would open up another one, so there were hundreds of eggs . . . And then we injected these little chicks with testosterone. We injected these chicks with testosterone and these little chicks grew big combs and wattles. (John Interview, April 19, 2022)

He described the classroom experience as bizarre, but interesting, and an experience in science that has stuck with him after so many years. I include this story because it represents not insight into John's fascination with animals, and his association of anything to do with animals with his conception of what science was, but also that science involved experimentation on animals, something he also became fascinated by. Here, from an ecofeminist perspective, John's story of experimentation with chickens in his middle school classroom portrays a human dominant perspective, where non-human organisms are considered as tools for exploitation rather than valuable contributors in scientific advancement. This is not to say that John advocated for animal exploitation in his pursuit of animals, but perhaps due to his own experience with science in and out of school, a conception of science in relation to animals was stabilized that presented animals as objects of science rather than contributors. This objectification of animals aligns with the dominant conception around animals in science and it would be unreasonable to suggest that John would conceive animals in science from an ecofeminist perspective (Merchant, 2006).

Along with collecting and experimenting with animals, John also collected books about animal identification. Since he was a little, John loved field guides. He told me, “My goal in life at one point was to get every Peterson field guide” (John Interview, April 19, 2022). He even wanted the field guides pertaining to the topics he was not that interested or know that much about, like rocks or astronomy. He tried to show me, but was unable to move his computer screen far enough, but he told me that his entire office was “covered in field guides” (John Interview, April 19, 2022). When I asked John if he ever reached his goal, he replied, with a resounding yes. He began to laugh a little and said: “I actually reached an even better one” (John Interview, April 19, 2022). John reached over and retrieved one of the field guides from his shelf. As he held the book he explained:

> This is a book, it's called the field guide to finding mammals. So, it's not just identifying mammals, but it's where to go in the United States to find mammals. I’m a really serious mammal watcher. And so, and I helped write this book, and so my name is, I'm not an author, but I’m acknowledged in this book. And this is the most recent Peterson field guide, it just came out maybe five or six years ago. So that's kind of like to me, that was

> like, 'Wow my name is in this!' You know, because I mean, I was a little kid when I got my first Peterson field guide. (John Interview, April 19, 2022)

Not only was John excited to have reached his goal, but more than simply collecting field guides, this emphasized John's desire for recognition as a contributor to the information presented in a field guide, what he considered as valuable scientific work (Carlone & Johnson, 2007).

John carried his fascination with animal collection into his classroom, in an effort to get his students excited about science. Most notably in his classroom zoo. The excerpt below emphasizes the ways in which he would use his zoo within his teaching practice as well as his emphasis on student led public engagement in his pedagogical practice:

> I had like 50 species of animals in my classroom, and one of the things that I would do, one of the many different things that we would do, is have my students educate the public. We would go to the museum at least once a month, sometimes twice a month, and I would bring like ten kids and ten animals. And my students would teach the public, and these are low level to regular level kids and I had taught a lot of minority kids that I would have at the museum teaching the public, and it was awesome. It was a great program and the museum loved it and they [his students] really appreciated it. (John Interview, April 19, 2022)

In addition to having his students teach about animals at the museum, he would also have his students teach the younger children within the district. John explained:

> I would load up a bus of 25 students and I would fill my car with 25 animals, and we would go across town to the underserved elementary schools. And my kids would teach the elementary school kids about their animals and that was an amazing thing to see. And I had a lot of minority kids go into these schools, filled with minority kids, and teaching

> them. And it was really cool to see these little kids looking up to these high school kids that are teaching them about these animals. And so, that was a really awesome experience. We had preschool kids that we would invite to my classroom. And they would come on their bus and they would sit in my students' seats and my students would be in my lab area with their animals, and they would come out one at a time and talk to the kids about each of their animals, and share with them. And they would get to hold some of them. (John Interview, April 19, 2022)

John also had his students write business letters to zoos all over the world, including Toronto, Australia, and China, and they would reply with little gifts and informative material for the students: "I had kids coming up to me and asking me, can I write another letter to a zoo because they were so excited" (John Interview, April 19, 2022). It was evident that the student's in John's classroom were impacted by the excitement for animals that John had, further supporting the idea that teachers own enjoyment in the classroom may lead to shared excitement from their students (Keller et al., 2014).

When he first introduced the zoo into his classroom, John found that every so often, one of the animal enclosures would have a piece of garbage in it, or that some of the students were disrespectful to the animals. He came to the realization that by making each student responsible for an individual animal, it fostered within them a greater sense of care for their own animal, as well as the other animals in the classroom. Below is a description of some of the activity's students would do with their animals:

> So, you might be responsible for the Emperor Scorpion or the Egyptian spiny mice or the whatever you know, whatever their animal was they had to learn. Not just how to take care of that animal, but the natural history of that animal and where it was from. I had a

> giant world map that the kids had to be able to find their animals on. And it got to a point where every kid almost knew where every animal was on the map, and these are kids that probably never looked at a world map. We did business stuff. I had them write poetry about their animals. I worked with some of our English teachers to help. Help them with business letters and help them with their poetry, so it was like this interdisciplinary thing that I did. But it took pretty much one day a week to do it. Every Friday we would do something that related to the zoo. (John Interview, April 19, 2022)

John provided opportunities with animals in the classroom zoo to his students regularly, until there was a significant increase in standardized testing. John explained, "Once you have to test and test and test and test and test, something's gotta give, and it was my classroom zoo" (John Interview, April 19, 2022).

For John, it was clear that he held a deep fascination for anything related to animals. Animals excited John and they acted as an entryway into science, something he would try to replicate for his own students in his teaching. Vincent-Ruz and Schunn (2018) posit that one component of a science identity is fascination. They define fascination in science as "interest and positive affect towards science [and] curiosity about the natural world" (Vincent-Ruz & Schunn, 2018, p. 5). For John, he was fascinated, not only by nature and animals, but more so about the process of collecting and identifying animals and his experiences with different animals and other living organisms in nature, as well as documenting his encounters.

In his figured worlds of adolescence and his home figured world, John's family supported his passion for animal collection and identification, and would over time, through his figured worlds of middle school and high school science stabilize his association between science and animals, by the use of animals for experimentation and tool for learning. This early fascination and the relationships he drew between animals and science, would eventually lead to his pursuit of a zoology degree in college. Ultimately, his fascination with animals would eventually become the cornerstone of John's classroom teaching and a method John used to engage his students in his figured world of science teaching. John's conception of the nature of science and his science/teacher identity were inextricably linked and stabilized overtime as John situated his understandings of science, the way he presented science to his students, as well as his own identity in relationship to animals. According to John, "My hobbies all relate to science—It's what I do" (John Interview, April 19, 2022).

John's Purposes as a Science Teacher to Present Science as Fun, to Develop Future Citizens, as well as Provide Representation for Those Students who May Pursue Science. John had a continuous stream of student teachers during his teaching career. He enjoyed taking on interns, unlike some of his colleagues who felt that it was chore. The same intern had students complete an evaluation of his performance. One intern had John's students complete an evaluation of his teaching at the end of his internship. The overwhelming response from the students was that he needed to learn how to tell stories like John did.

> The kid you know, this is a young college guy, he's 22 years old, he's like, 'I'm 22 I haven't done anything, I started high school, I went to college.' I told him, and I would tell all of my interns, 'Go do science when you have a chance! In the summers. There was one summer where I did genetics work on mosquitoes. It wasn't the most amazing thing, but there was fieldwork involved, where I had to go collect mosquitoes which doesn't sound that exciting, but it was in a lot of cool places, and it was wonderful! I loved it. I always tried to tell them go find somebody, find a scientist to hang out with. Even if it's only for one day. Do it and learn and see what science is really about, and

> once you learn, then you can bring it to your students and really understand what you know, help them to understand what science is all about. (John Interview, April 19, 2022)

When I asked John what he hoped the teacher interns would take away from going and doing science, he responded:

> A couple of things, number one is that these scientists are just human beings, they are not old black and white drawings of ancient white dudes, there are women in science, there are minorities in science. I think that's really important for these kids to see—To understand that science is always changing. I think that's really important for kids to realize, and that's not a good thing, it's not a bad thing. It's not that science was wrong, it's that science is constantly evolving and learning and that scientists question each other. (John Interview, April 19, 2022)

Here John's, when John used the phrase doing science, he presented a conception of the nature of science as changing, building upon what has come before. This conception of science was something he felt important for his students, but also something for the greater public to understand, especially in light of the misinformation surrounding the COVID-19 pandemic. This excerpt also emphasized the diversity of the individuals who participate in science. John tried to emphasize this idea of diversity in science in his classroom as well. He shared:

> My classroom was filled with specimens of all different kinds and cool posters on the walls, and you know, I had what I called the biology wall of fame. I would write letters to scientists and I ask them to send me a note to my students, and so I had them send me an autographed picture. (John Interview, April 19, 2022).

Some of the scientists that John received letters and photos back from included E.O. Wilson (whom John described as the Harvard ant guy), Norman Borlaug, who won a Nobel Peace Prize for developing dwarf wheat, and even Jane Goodall, known as the first researcher to document chimpanzees' creation and use of tools in the wild. I could not hide the look of awe from my face. He also wrote letters to individuals that he felt were examples of citizen science. This included Jimmy Buffet, who had done work with manatees. To John's delight, Buffet participated and sent his students a nice note along with his autographed picture.

Several of the individuals that would eventually end up on John's wall of fame were talked about in the textbook he used for his classes. John wanted to ensure that his wall of fame reflected the idea that not "all of the biologists and scientists are old white dudes" (John Interview, April 19, 2022). He felt that this was one way of making his classroom exciting and interesting for his students. His daughter, now a third-grade teacher, modeled her classroom after her father's, by installing her own version of the wall of scientists, hers called the wall of fame, since it included more than just scientists. "I'm not sure there's a white guy on it at this point" (John Interview, April 19, 2022). John joked. By having a diverse wall of scientists, John hoped that both he and his daughter were providing students an opportunity to see themselves in the scientists up on the wall. He felt representation was particularly important, especially "for the kids that you think might actually go into science" (John Interview, April 19, 2022).

John held to the philosophy that his role as a science educator, especially to students in a general education setting, was less about developing future scientists and more about preparing students to become better citizens. He explained:

> I think if you're teaching AP students, AP physics, AP biology, and AP chemistry, and that kind of stuff, it's a different focus than what I was doing. Not that I haven't had

> plenty of students that ended up being biologists and scientists, and I’ve had plenty that have become educators. But you know, it's not like that's what most of them are going to be, you know they’re going to be citizens, and I think that's really important, that's a big push that I have, to try to make better citizens as far as their relationship with science. (John Interview, April 19, 2022)

When I asked John to elaborate on what he meant by better citizens, he replied: “As far as it related to science and health, I thought that's really important to make them better voters” (John Interview, April 19, 2022).

In addition to making students more informed as citizens, another goal he had as a science teacher was ensuring his students were having fun in his classroom. According to John:

> I had many, many students who would come into my classroom saying they hated science. And my mission was, at the end of it, to ask them that same question, ‘What do you think about science now?’ And they didn't hate it anymore! I mean, I felt really good about that! I wanted to be the fun teacher. I wasn't going to be abused, I wasn't going to be pushed around, but I wanted to have fun. I want to have fun in whatever I’m doing, I want to have fun and if it's part of my job I would have fun at my job. (John Interview, April 19, 2022)

At one point in our conversation, John made a comparison of what he considered to be actual science to classroom science. When I asked him if classroom science was different than actual science, he replied:

> Well, I mean I think they're very they're similar except of course, you’re providing kids that opportunity to introduce them to a lot of subjects and science and a lot of information about science, even though you know, like I said before, my major goal was not to jam

> their heads full of scientific knowledge, as much as it was to get them to appreciate it and enjoy it, and you know, love science, and want to learn about it. (John Interview, April 19, 2022)

As a science teacher, John valued a conception of science teaching centered around having fun as well as the development of students to knowledgeable citizens in the world, not necessarily to become future citizens. John's science/teacher identity and conception of the nature of science was much situated within his personal values related to science and the purposes of science education. Evidenced in his stories, John was successful in shifting his student's views on science from a subject they hated to one they enjoyed and some even loved. Additionally, based on his story about the chicks in the earlier section, as well as his stories regarding related to getting students excited about science, a conception of science that John would carry with him from his figured world of high school science to his future conceptions of science and science teaching.

Based on John's stories, it appears that his conception of science is similar to one of the descriptions of hands-on teaching presented in Larkin (2019). "To the general public, the phrase "hands-on" serves as a conceptual marker that divides the exciting type of science teaching from the boring one (p. 1297). However, his ability to excite his students in science class should not be diminished. By presenting science as exciting and as accessible, as a field where more than white men can contribute, John provided pathways for his students to engage with science content.

During our member check meeting, I asked John if he felt I captured his stories and his conceptions of the nature of science. He said I did. I also asked him, since so many of his stories were centered around animals, what he felt that told us about his understandings of the nature of science. He replied:

> It was more a matter of how excited I got learning about animals—It’s like everybody in the whole county is supposed to be talking about the same subject on the same day, and I think it's so much more important to bring out your excitement of it, however, that happens to work, and that will get the students excited. And I felt, get them excited about part of it and that increases their excitement about the rest of it and about science in general. (John Interview, April 19, 2022)

When I asked John if there were ways, other than having the classroom zoo, where he used animals to teach students about science or as an entryway into loving science. He told me he would tell stories about them, especially “stories about animals that I thought would excite kids.” John prided himself on his use of stories as a tool for teaching science, having a science/teacher identity as a storyteller both within and outside of the classroom. “It’s, you know, kind of who I am, more so than how I was trained to teach” (John Interview, April 19, 2022).

How Did the Figured World of the Neutron RET Influence John’s Science Teacher/Identity and/or Conceptions of the Nature of Science?

Although John participated in a wide variety of research experiences, I asked if he could pinpoint how or if the Biosphere RET, in particular, impacted the way he viewed the process of science. According to John, it reinforced things he already learned, and gave him “lots of ideas on how to communicate with [his] students” (John Interview, April 19, 2022). John often showed his students photos he took during his research experiences, saying that any photos he used in his PowerPoints were his own. The Biosphere RET was just one more opportunity to share exciting photos and experiences with his students.

John explained that throughout his career in science education, he worked with paleontologists and participated in fossil digs, similar to what he did in the Biosphere RET”

“Whenever I get to learn something new from some amazing person, that's like the best thing” (John Interview, April 19, 2022). Although it was clear he valued the scientists, I wanted to know if he felt valued in return. I asked John if he felt that the teachers were valued for having expertise by the researchers.

> I mean he [Gary] was really great at making you feel like you were a scientist. I mean he always expressed how you are doing science. This isn't play, this is research that we are doing together, right now you are a science researcher. And so, he definitely felt like we were part of the research. (John Interview, April 19, 2022)

I also asked what he thought “doing science” meant to Gary.

> We would be involved with the whole process of science and I think there were people that actually got acknowledged in some of the research. I have some photographs in a book that he wrote about it, he definitely felt like we were part of this full science process. (John Interview, April 19, 2022)

Here, although John mentioned the idea of science as a process, he also presented a conception of the nature of science that involves recognition for one’s contributions. In addition to recognition in the form of contributions, John also felt that Gary and the other scientists recognized the teachers as being “part of the team” (John Interview, April 19, 2022).

Although the majority of John’s reflections on his participation in the Biosphere RET and other similar programs pointed to his ability to bring experiences back to the classroom to share with his students, it appeared they did not provide opportunities for John to destabilize his conceptions around the nature of science or his science/teacher identity, but rather stabilize a conception of science centered around fascination, excitement, and collection.

Denise

Denise had a calm, yet upbeat demeanor, which provided me with a sense of ease, like I knew her for years. Denise was a mother of three adopted children, and currently works at the university level in science teacher professional development, specifically involving collaborations between scientists and teachers.

Denise received an undergraduate degree in human biology and went on to pursue her graduate degree in microbiology. After a few years, she decided to leave the program, prior to completion, and pursue a career in the field of orthopedic surgical sales, which she continued to do for 14 years. After adopting her children, Denise decided that she needed a job that was more compatible with her new role as a mom, looking for something less stressful and with less travel. She also felt that by becoming a teacher she could "follow and monitor her own kids' learning" (Denise Interview, March 15, 2022). Denise joined a teaching program targeted towards second career seekers which focused largely on pedagogy and classroom management and less on the content side. Conveniently, Denise applied and was hired as a middle school science teacher at a school directly across the street from where she lived, and remained in that position for six years. She felt successful as a middle school science teacher, attributing some of that success to her experience in previous careers: "I think my former experience in the business world really, and in the field, and having a science background helped me see teaching through different lenses and it was a great natural fit" (Denise Interview, March 15, 2022).

Denise described her science teaching experience as being on an adventure:

> You know when you're in the classroom, there's certainly days that are a struggle, and certainly kids that are a struggle, but the ones that have these light bulb moments, are the ones that do these amazing projects, that are stretched beyond your expectations of what

> you expected from them, I think that's really exciting. (Denise Interview, March 15, 2022)

She laughed and told me that on her taxes each year, her CPA guy would put her title as molder of young minds, a title she felt was very suitable: “I felt you could open these doors and gateways for these kids and let them explore things that they wouldn't have otherwise been exposed to, and I loved that” (Denise Interview, March 15, 2022).

When I asked Denise how her students would describe her, she responded, “She's really fun, it's a fun class, there's a lot of excitement and things happening in there” (Denise Interview, March 15, 2022). She felt that as a teacher she was dynamic and innovative, and would do her best to think outside the box, attributing these aspects of her teaching style to experiences she had prior to teaching. She described herself as curious and inquisitive. “If I saw something online or something in the news, it would start a whole project” (Denise Interview, March 15, 2022).

Denise described her student population as mainly Hispanic, with the majority of students receiving free and reduced lunch:

> Its overall an excellent group of kids. You’ve got a few rowdy, bad ones, and I think that's with any school but, generally speaking, the kids are great. The parents are, you know, some invested, some not. You've got kids that are homeless, you've got kids that are in trouble, it happens. (Denise Interview, March 13, 2022)

She went on to describe the demographics of the local community:

> Generally speaking, it's probably like a lower middle class, and there are some pockets of historic neighborhoods around which are a little more expensive and kinder of fancy and other areas which are very low income and kind of in the hood. (Denise Interview, March 13, 2022).

Denise explained that although she taught a few, what she described as regular education classes, the majority of the classes she taught were “advanced and gifted, which is, of course, the greatest group ever to work with” (Denise Interview, March 13, 2022). She went on to say:

> The kids were amazing and some of them are so smart, they are a lot of fun and just always asking questions and always pushing buttons and you know if they'd ask a question or want to try something, they're like okay, let's try it, let's just see what happens (Denise Interview, March 13, 2022).

How Denise Came to Participate in the Biosphere RET

During Denise’s first year as a teacher, she felt she would benefit from enhancing her knowledge in regards to both the content she taught as well as the education system she was teaching in (she lived in a different state than the one she completed her own education in). She decided to enroll in a course in order “to kind of brush up on some of that content that I was teaching and — learn some really cute lessons or something to do in the classroom” (Denise Interview, March 13, 2022). During her time in the course, she was introduced to Gary, the PI of the Biosphere RET program, who was planning on taking a group of teachers on a research trip in a few weeks. She remembered him saying:

> I have a program that I'm running in two weeks — I'm taking a bunch of teachers to collect fossils and I've got a few openings; would you be interested in going? It's in two weeks, and you know you'd be gone for a couple weeks in [name of state]. I said, “Yeah I'll go.” So, I ended up going a couple weeks later. (Denise Interview, March 13, 2022)

Although this first trip with Gary was not the Biosphere RET, it led her to developing a relationship with him, and an awareness for the professional development programs he ran for science teachers. She later applied and was accepted into the Biosphere RET.

Denise's Storied Science Identity

The story of Denise is presented in two storylines related to her understanding of the nature of science as well as the way she presents science in her classroom: 1) Science is fascinating and 2) Denise's Support/Lack of Support in the Field of Science.

Science is Fascinating. It was clear from the stories Denise told, but also from her facial expressions and tone in her voice, that Denise was fascinated by science. Throughout her figured worlds of childhood to her figured world of RET, Denise's conception of the nature of science was linked to her fascination with what she considered scientific activities, such as exploring, collecting, investigating, and experimenting (Vincent-Ruz & Schunn, 2018). She would later use her fascination for science as a method for engaging the students in her classroom.

Denise's intonation was one of excitement as she reminisced about her childhood memories. Her first memories of "doing something science" consisted of investigating the local creek behind her house:

> I think some of my first memories, I would say, as a child — I grew up in St. Louis, and behind my house was a creek. And the kids would always go back there, and play in the creek, you know, splash around, and run up and down the creek, and collect rocks and things. And in that creek was actually a ton of fossils! (Denise Interview, March 13, 2022)

Denise wanted to know more about where things came from. She explained that in addition to her memories of the creek, her family would go on a yearly vacation to the beach. She described her experiences at the beach as observing "nature and finding organisms and collecting things, leaves and seeds and little crabs, and you know, sand dollars and shells and things like that, and just being fascinated with nature, animals, life, ecosystems" (Denise Interview, March 13, 2022).

Another story that Denise told me took place within her figured world of university science. During her undergraduate degree, Denise was pre-med, and had, and still has, what she described as a morbid love of bones. “I love anthropology, I love archaeology, I love bones” (Denise Interview, March 13, 2022). This led Denise to eventually pursue a career in orthopedics. She originally thought that she might go into the field of forensics, explaining that when she was in college, forensic TV shows were practically non-existent, compared to shows like CSI that are so common today. Denise decided to enroll in an anthropology course at her university.

> Ironically, while I was in that class, there was an old house in the downtown area of [name of university town] that someone had purchased and they were renovating and they found bones in the basement. And they were human bones, and so the teacher couldn't talk about a lot of the stuff because it was an open investigation, but it was kind of fascinating to be in his classroom when all this was happening, you know, live in the moment. And I got really interested in a lot of that. So that anthropology class was one that I was like this is really, really fascinating. (Denise Interview, March 15, 2022)

Denise pursued this passion for forensics by accepting an unpaid internship with the bureau of investigation, during which she became friends with a homicide detective. Denise credited this experience in the field of forensic with increasing her interest in science.

Denise’s Support/Lack of Support in the Field of Science. Denise identified her fifth-grade teacher as someone who impacted her early understanding of what science was. She looked back at the class with feelings of fondness. Denise recalled that it was during this class where she “truly did experiments and hands-on type things” for the first time (Denise Interview, March 15, 2022). She performed dissections of crayfish, built cat skeletons, and learned about light and wavelengths.

> You know, just like what you would hope, a teacher would have just a really charismatic personality, he [Mr. Joseph] was funny, he had nicknames for every kid, he made you feel like you're more important, that you could do science. And it was a class I would look forward to going to. So that's my first memory of a science teacher who I thought was inspiring, or fun and engaging, and I liked the content (Denise Interview, March 13, 2022).

Denise was drawn to Mr. Joseph's enthusiastic style of teaching (Keller et al., 2014). In addition to enthusiasm, Mr. Joseph made Denise feel important. Carlone et al. (2014) put forth those feelings of importance in the figured worlds of school science, especially when students feel important enough to be recognized by their science teacher, are related to the development of a student's science identity. Particularly important is the support of young woman's identities within science. Vincent-Ruz and Schunn (2018) found "at this age [middle and early high school], developing a strong science identity is especially critical for girls" (p. 11).

Denise valued the experiences she had in Mr. Joseph's class so much that she held on to her notebooks from his course, what might be considered as identity artifacts from her figured world of middle school science (Barton et al., 2013; Holland & Leander, 2004) The notebooks, as identity artifacts, provided insight to a time and space where she felt supported in science and a part of the process of authoring her own identity within science (Barton et al, 2013).

Not only did Mr. Joseph make the student's feel important, but he made the work they were doing in his class feel important, as if the students were contributing to something greater than their individual science class. Denise explained one example of how Mr. Joseph did this:

> I remember, and I really thought this was real at the time, there is a letter from the President. And I forget the context of the letter, but we were really made to think that the President had written our class and we were doing this particular experiment, on behalf of the United States of America, and I still have that letter in my notebook and I really thought that was real at the time, now I realize it's just an assignment. But he was great. So that memory definitely sits with me. (Denise Interview, March 13, 2022)

In contrast to her experience in Mr. Joseph's class, during the completion of her science degree in university and while working in certain professions in science, her experiences were different than her male counterparts. She felt this difference most starkly in the field of orthopedic sales. Denise explained that after leaving her graduate program in microbiology, she went into orthopedic medicine to work for a sales company. One component of her job required her to go into hospital operating rooms, she shared her experience with me:

> I mean, there are people on the table, you know, under anesthesia, being cut open, and I am in charge of some of this. And I'm not an MD, but I am setting up the back table with the surgical tech and telling the doctor, 'This is what you need to do now,' or 'this is the part you need to put in,' and 'this screw is better than that screw', and 'this is why.' (Denise Interview, March 13, 2022)

She explained that in her role she felt "really important" (Denise Interview, March 13, 2022). Denise would be "helping them [doctors] through cases and building this kind of partnership and collaboration with these doctors, where they trusted me" (Denise Interview, March 15, 2022). She went on to tell me that she felt she "was with people that were way above my skill level, " but she "could still hang with the big dogs [referencing the doctors]" (Denise Interview, March 15, 2022). Here, Denise held within her two conflicting identities, one where she felt valued enough to be trusted by the medical professionals, and another where she felt inferior to them, referencing them as big dogs. The term big dog is often used to represent those in powerful positions, defined by Merriam Webster (2023) as “a notably prominent, important, or powerful person, organization.” Colloquially, the term big dog also connotes a male in power. Whether Denise intentionally or inadvertently used the term big dogs in this story is unclear, but it does signify the way in which she identified as a woman in a science field, when she was with mostly male medical doctors.

Denise continued by telling me that the field of orthopedic surgery is “probably 97% male now” (Denise Interview, March 13, 2022). She described her experience as one where she was very aware of being the only female present, which limited her ability to network. She explained that there was even a particular area at work where only the males could go, it was the room where they would change in and out of their scrubs. Her experiences in her figured world of orthopedic sales resulted in feelings of inadequacy for Denise, where she felt she “didn't have the same abilities” as her male colleagues (Denise Interview, March 13, 2022).

Although today the field of science is more accessible, Denise expressed that many of the same barriers still exist for women. Denise connected her experiences in the field of orthopedic surgery to the passion she had for her role as a science educator as well as the position she currently holds in science teacher professional development saying, “And that's why I love the program I'm doing now, and that's why I think teaching is so important, and teaching science and exposing kids to different areas of science and fields and doing it in a way that makes it engaging” (Denise Interview, March 13, 2022).

When I met with Denise for member checking, I asked if I represented her experience of science as male dominated accurately. She replied, “I mean glaringly so, orthopedic sales were definitely the dominant thing where I noticed being in the minority as a woman" (Denise Interview, January 5, 2023). Urrieta (2007) suggested that within figured worlds, "people encounter narratives borne out of historical significance (both oppressive and liberating) as well as a distribution of power, rank, and prestige (or the lack thereof) that they either accept, reject, or negotiate to varying degrees" (p.111). For Denise, although her figured world of orthopedic sales perpetuated narratives of hegemony and sexism, perhaps by having a science identity which was supported early on in her science education she was better able to reject those oppressive narratives.

Denise contrasted her experience in orthopedic sales with her experience now as a graduate student in Geology, and level of accessibility she now sees in the field:

> When I look at my cohort of students, we're pretty mixed. We're 50/50, male/female. We've got people from all different nationalities, gay, lesbian, straight. It's everything . . . In decades past, which I would venture to say, that's not the case. It was probably way more male dominated in geology than it is today, but I think our department is doing a fair job at trying to level the playing field, so to speak. They encourage women in science and women in geology for sure and even people with disabilities. There's a great course there where they're bringing folks that have disabilities out into the field, which in the past has been an obstacle. They couldn't do field work necessarily. And there is a lot of technology and things that they're implementing to make that [geology research] more accessible and inclusive. (Denise Interview, January 5, 2023)

This conception of the field of science as inclusive is something she echoed in her visual narrative, presented in a later section.

How Did the Figured World of the Neutron RET Influence Denise's Science Teacher/Identity and/or Conceptions of the Nature of Science?

As Denise and I talked about her experiences in the Biosphere RET, her face lit up. It was clear she had so many things she wanted to share with me. She asked me if I only wanted to hear about events specifically related to science, and I told her she could tell me anything that she felt stood out. She described her time in South America, particularly in the Amazon Forest as both surreal and bizarre. "You'd turn around, someone was talking, and there in the tree is a ginormous, tarantula. You know, crocodiles on the water and just all kinds of crazy cool wildlife and you're in the jungle, you're in the Amazon" (Denise Interview, March 15, 2022).

She described her experiences bartering with local children that her group would barter with the children to provide them transportation on their canoes. She explained how exciting the experience was for her:

> And we'd ride out on the canoes into the middle of these great huge lakes to those little small islands, where we would collect samples. I remember seeing a colonial pipe and some archaeology pieces on one of the islands. We couldn't touch them because our permit was for fossils, and not archaeological artifacts. But it was really cool because you'd be like, 'Wow, who's this? and 'How did it get here?' I remember, we hiked up on these kind of huge limestone cliffs and Sally, one of the graduate students fell off the rock, it gave way and she fell, and another guy grabbed her by the arm before she went into the river system with crocs. Like it was an adventure, and I was thinking the whole time like, I'm too old for this. What am I doing?' 'I am not a seasoned climber, but we were doing it, and it was so fun, and so invigorating. (Denise Interview, March 15, 2022)

Denise recalled from her experience in the Biosphere RET as being wild and interesting and was excited to share her experiences with her students when she returned to the classroom. I could see the excitement in her eyes as she reminisced over the various wildlife she encountered, such as cranes, toucans, and sloths. She also enjoyed the lecture series that she attended, saying that she always loved to learn. “I could sit in lectures all day. I'm probably the only kid that would say that I like to take notes” (Denise Interview, March 15, 2022). Often individuals associate note-taking and the ability to pay attention during direct instruction as characteristics of a good science student, positioning individuals capable of these tasks as being good at science. Carlone et al. (2014) referred to this positioning as “celebrated subject positions,” suggesting that to become scientific means “positioning oneself (deliberately or not) and/or getting positioned as a “good” science participant and therefore aligned with, being able to fit into and/or see oneself inhabiting the classroom’s celebrated subject positions” (p. 839). The celebrated subject positions do not infer that someone is actually good or not good at science, but rather that they are able to easily navigate classroom norms, such as note-taking and listening.

One of Denise’s biggest takeaways from the Biosphere RET was related to the scientists themselves. Denise had the opportunity to spend time with scientists in the field, listen to their talks, and go into their labs, saying:

> You’re meeting all these people and you're like wow, this is big. Like this is an important person, I’ve got pictures with people that if you pull up their publications, they’ve got hundreds and hundreds of books and publications, it's quite impressive. I'm like, yeah, I was with her, or I've got a picture with him. I sat and talked to him for a long time at dinner one night. It's pretty cool. Especially when you realize that in these different professions of science, it really is kind of a small community. Like you know the who's

> who, you know who is a bigwig in that field. And it's just fascinating to see these people do what they do. (Denise Interview, March 13, 2022)

Here Denise used a similar phrase as one she used earlier, ‘big wig,’ a term deriving from the “large wigs formerly worn by distinguished men” in the 18th century. Although Denise had experienced her identity as a female in science undergo several iterations throughout her figured worlds, eventually leading her to feel accepted within the science community, her language choices elicited that somewhere in her identity she was unable to fully destabilize an idea that men are the ones that hold positions of power in science.

When I asked Denise if she could speak a little more about her role in the research during the Biosphere RET, she talked about how good Gary was at making everyone feel like they fit in.

> It could be something as silly, as you know, this group of teachers will be in charge of making breakfast on Monday, or this group of teachers will be responsible for bringing the fossils back to the vehicle, you know, whatever it might be. This group is going to set up all the fossils on the table in the evening. (Denise Interview, March 15, 2022).

According to Kim and Sinatra (2018) “studies focus on how the individual feels s/he belongs in the science environment without sufficient examination of how the culture and context of the science environment is welcoming (or not welcoming) the individual into the field” (p. 2). By involving teachers in the mundane aspects of the research process as well as the excitement, teachers gained a deeper sense of belonging. For Denise, she felt she was participating in a community of science as well as a community of teachers, where she was able to reflect upon how her learning might translate into the classroom.

In contrast however, one of Denise’s descriptions of the role of the teachers during the RET included being “an extension of the scientist” (Denise Interview, March 15, 2022). This description positioned teachers as lacking in identity, and solely existing for the purpose of the one they are extended from. When looking for literature regarding the phrase, “to be an extension of someone,” I located literature in the field of narcissistic behavior, suggesting that narcissistic individuals think that “everyone and everything is an extension of the self, exists to serve the self, and is under the control of the self” (Brown, 1996, p. 264). Applying this conception of the phrase “to be an extension of someone,” one could argue that in the RET relationship, the teachers existed to meet the needs of the scientists. Although Denise discussed her experience as one that positively impacted her identity in science, her use of the phrase being an extension of the scientists could be interpreted as supporting a narcissistic positioning, as seen in the description below:

> An important role because you're expanding their [the scientists] capability of collecting. You only have so many eyes and so many hands and so much time, but if you can, you know branch that out, now you're going to be able to collect much more and be able to do much more with that and, as we know, data and the amount of data that you have is super relevant and important for purposes of accuracy and what have you. I think that that was our role. (Denise Interview, March 15, 2022)

Additionally, Denise felt that during the RET, she experienced “real-science,” which she characterized by collecting specimens and being included in the scientists’ publications. She clarified:

> I mean the things we were collecting were specimens that would be going into collections at the museums, they were in people's research in publications, and if you collect a specimen that's used, your name is on the specimen in perpetuity you know, like you are the collector. (Denise Interview, March 15, 2022)

I return to this conception of real-science in chapter five, where I provide a deeper analysis of the collection of specimen.

As we talked, Denise explained that her experience working with scientists in the Biosphere RET was different than what she had predicted, saying that she initially “thought it was going to be a one-way street, they were going to be explaining to us and we were going to be taking it in and maybe asking some questions” (Denise Interview, March 15, 2022). However, through her experience, she was exposed to the role broader impacts plays in the nature of science and research. She explained what she meant by broader impacts as well as the scientist’s perspective on the expertise of teachers:

> That a lot of them [scientists] have a true interest or desire to do outreach and that's to adults or to students . . . They treated us as the experts for teaching, so they were the content experts, but we were the teaching experts, and so, how can we blend those things together? And how can they communicate science better? We were able to provide insight into those aspects and different teaching strategies, different nuances within schools. (Denise Interview, March 15, 2022).

Denise was surprised at how little the scientists knew regarding the role politics play in the K–12 education system, “how the process works with units or lessons and testing, we were able to kind of explain that and put a little meat on the bones of those processes to them that they didn't otherwise understand or know” (Denise Interview, March 15, 2022). Gary, the PI of the Biosphere RET, was very intentional in his desire to understand the various impacts the program had on the scientists, rather than only focusing on the teachers, and provided them with end of program evaluations and surveys. The survey results were very similar across the board with the scientists, who agreed that having teachers in the RET program was “extremely meaningful for them and helped hone their teaching skills” (Denise Interview, March 15, 2022). Denise mentioned that after the trip, many of the scientists’ published articles related to their experiences with teachers, how they “honed their communication skills” and “done outreach” (Denise Interview, March 15, 2022). According to Denise, the fact that scientists valued their work with teachers, and made them feel important by exposing them to the work that they do, spoke back to the often-devalued positioning of teachers in our current society. Denise said:

> A lot of times I feel like people don't value teachers in many instances, and I feel like people don't think teachers are smart or important. I mean it goes both ways, there are people that do, but generally speaking teachers are underappreciated. And the fact that these scientists feel it's important to expose the teachers to these different fields and science areas and the research happening, it's important that they're doing that. And it's great that they're doing that, considering the skill level and the skill set and how busy they are. That they take the time to do that, that they want to share that with kids. Because that's what's going to influence the next generation, that's what's going to inspire someone to want to do science, and that anybody can do it. (Denise Interview, March 15, 2022).

Denise recalled a story of one graduate student with whom she worked, who was so impacted by their experience with teachers and the idea of making a difference in K–12 science students, decided to change her career path and begin working as a high school science teacher.

> She did outreach through the program that I work for and did one of our teacher professional developments, so she was very involved in that. She liked it so much that she ended up moving to [name of state] becoming a high school anatomy teacher, which she still is. She just did her dissertation and got her PhD —She's teaching school now as a

> high school teacher because she was so fascinated with the interaction. (Denise Interview, March 15, 2022)

Denise pointed out that this graduate student was one of many to transition from practicing scientist to a position in science outreach, either working fulltime in a museum or as a K–12 science education, as a result of participating with teachers in the Biosphere RET or other programs like it. This represented to Denise that being actively involved in the nature of science encompasses something greater than research, but also the importance of public awareness and the broader impacts of science. This aspect of the RET experience made an indelible impression on Denise and impacted her future teaching practice.

The Ways in Which the RET Impacted Denise's Teaching Practices. Denise spoke highly of her experience in the Biosphere RET, designating it as one of the "highlights of her teaching career" (Denise Interview, March 15, 2022). Not only did she value the experiences she had in the science field, but she also valued the relationships she had made with like-minded teachers, those with whom she collaborated, discussed, debriefed, and reflected. In addition to working with scientists and fellow science teachers, Denise also connected her experience in the RET with the parents of her students. She described one of the experiences she had with her students and their parents:

> I took my kids up to a river and we fossil hunted with their parents and the scientists met us there and we collected fossils along the river. We talked about the geologic history of [the state] and looked to identify the specimens we collected and their significance and how they all fit in with the Biosphere RET. You know, because there's grass loss that you can find there, you know dugong and mammoth and all of these things that were traversing back and forth. (Denise Interview, March 15, 2022).

This experience with the parents of her students highlights the content knowledge she was able to bring back with her from the RET. Not only did she return to the classroom with increased understanding of the geology, she brought back with her the importance of broader impacts in science. The following story of Denise’s teaching took place after he participation in the RET. When I asked Denise if she attributed her India trip to her experience in the RET, she said it may have “inadvertently” impacted her classroom practices (Denise Email, March 2, 2023).

Denise’s school was an International Baccalaureate (IB) school, where it was expected for students to participate in thematic projects. One year her principal attended lecture at a conference where they were talking about “upcoming countries” such as China and India. She said when he returned from the conference, he wanted to do something related to what the lecture: “He said, ‘What am I supposed to do with India and math you know, like what are we supposed to do with India and science?’ So, I was like, ‘I could come up with something’ (Denise Interview, March 15, 2019).

Denise and her class talked about it together, and they came up with a project related to their unit on human impacts. She explained the project in more depth:

> And we looked at resources, and specifically the kids fell on water. So, we ended up working with a nonprofit. We worked with hydrogeologists and engineers and different folks in the country that were part of [name of the nonprofit] that were working in India for them. And we raised over $10,000 and we built a reverse osmosis facility. (Denise Interview, March 15, 2022)

Denise’s students became so invested in the project that they wanted to get a booth at a local annual Indian Festival to raise even more money. Denise told me about the experience for her and her students with so much excitement:

> The booths were 1,200 dollars and the kids are like, ‘We want to do a booth and sell stuff and raise money for the [name of the non-profit]. And I said I will contact them, tell them who you are, and let's see if they'll give us a discount or maybe they'll gratis a booth. And they did! For two years! The kids had a booth. They made handmade soaps and T-shirts that had an elephant on it —They designed everything and it was kind of a student run project and, in addition to raising the $10,000 and building this reverse osmosis plant — the next year they're like well, can we go and see it and I’m like, “I would love to, let's figure out how to do that. I don't know if we can, but let's investigate.’ We ended up going to risk management at the district and got approval for a school sponsored international field trip. Never happened before! They've done non-school sponsored international trips, but never a school sponsored one, so we can raise money. Because it was like $4,000 a kid to go. And we did! I took 22 kids to India with me and we saw the plant, we toured all of India. They saw the Taj Mahal and you know they went to Agra Fort and all kinds of stuff. And it was a lot of fun. And from that the kids ended up creating a nonprofit called [name of non-profit] and it runs to this day. It's all student run, and I’m a silent board member of the nonprofit, but it is all student run to this day. (Denise Interview, March 13, 2022)

Denise explained that one of the reasons she was able to accomplish as much as she did was due to the support she received from her principal, who often referred to go getter teachers like Denise as “work horses.” She recognized that not all teachers would be supported in taking on such a large project. She explained that if she wanted something, he would help make it happen.

Although Denise is no longer in the classroom, she attributes much of the work she is now doing in science teacher professional development as, “A reflection of working with a scientist [who was involved with the Biosphere RET]. I’m taking on scientist projects and continuing those projects on another layer” (Denise Interview, March 15, 2022). In her current work, Denise is doing her best to replicate the experience she had in the RET for other science teachers.

Louise

Louise joined our chat from her home office, filled with artifacts from her travels and her walls draped with maps. Not long into our conversation, Louise casually walked with her computer from her office to a space outside, providing our zoom call with a backdrop of birdsong. I learned very early into our conversation that nature was important to Louise, in all aspects of her life: “As you can see behind me, my room is surrounded by maps. I love being outdoors, I'm a big hiker.” I slowly shifted my camera towards my own office wall, where I had a map on display. Louise was filled with excitement. “A map, great!” This provided Louise and I with an immediate connection as we were able to relate to each other and entry point for the remainder of our conversation.

When I asked her what it was about nature that she loved, she replied: “I just love being outdoors, and long hikes give me lots of time to think. When I’m walking through, what kinds of rocks I'm walking through, where'd they come from? Where are they going?” (Louie Interview, March 25, 2022). As we continued our conversation, and as I listened to Louise tell me her stories, I was engaged by her voice, which was calm yet filled with inflection, and I would often become immersed in her storytelling. One might describe her as having a voice made for radio.

Louise identified as being Western European, white, middle class, and female. Louise was a recently retired high school science teacher of 20 years, and is currently employed at a local university working with novice science teachers. In her current position she supervises new teachers, teaches a seminar course, as well as a science methods course for undergraduates. The science methods course is targeted towards math and science majors who are considering pursuing education programs. In addition to her work at the university, Louise serves as a mentor teacher for the state that she lives in. Louise felt that her career path was a straight trajectory, explaining her current role as a culmination of her time in the classroom.

While Louise was a teacher, she pursued an Ed.D. at the local university, conveniently located very close to her home. Louise felt that she was in constant pursuit of understanding, whether it related to her sixth-grade students, how she made sense of her own “teacher identity” (Louise Interview, March 25, 2022). She expressed that she did not receive much mentorship as a new teacher, something that influenced her decision to pursue her role as a mentor.

Louise described her early education, from kindergarten through the eighth grade, as poor and that her earliest memories of science centered around her father. Louise’s father was a science writer who began his college career as a chemistry major at MIT but transferred to a school on the west coast, earning a degree in English. Louise described her father as scientifically literate. After moving, Louise’s father began working in a research laboratory at a nuclear radiation facility. Louise felt that one of her first memories of science was seeing her father leave for work every day wearing a dosimeter to monitor his radiation exposure:

> I remember seeing that on his shirt from probably the age of four or five. And I never thought of the nuclear radiation research facility as being a threat to my life or my health. In fact, our community swimming pool was there, because it was their emergency water

> supply, and that's where I had my swimming lessons—Oh, and one day my whole family was there swimming and my father said, “Oh there's Edward Teller.” He was swimming in the pool with us and dad explained to me that he was one of the fathers of the atomic bomb. So, my first science memories are probably connected to living in [name of town] where there's a big research facility for nuclear radiation power type stuff. (Louise Interview, March 25, 2022)

Although this quote does not appear to directly relate to Louise’s conceptions of the nature of science presented throughout the rest of her storied identity, it may represent an early introduction to access within the science community. However, it may also have initiated a stabilization for Denise that the world of physical science is a male one.

How Louise Came to Participate in the Biosphere RET

When I asked Louise how she came to participate in the Biosphere RET, she explained that she “had never done any work in paleontology, that was literally in the field” and she was “relishing the opportunity” (Louise Interview, March 25, 2022). Louise had a friend who recommended the program to her, and who wanted to do the experience together. She also explained that during junior year of high school she was supposed to take part in an exchange program in Central America, but due to civil unrest at the time, it was canceled. Louise felt that if she participated in the Biosphere RET program, she could coordinate to stay a few extra weeks in the country she was originally supposed to visit in high school, which she ended up doing.

Louise expressed that the idea of working with a university paleontology program on a current research question, was really exciting. She explained that the Biosphere RET was working on a geological question that had no clear answers, so it was something that she could not turn down. She felt that as a science teacher, she would be able to bring back new knowledge to her classroom.

Louise pointed out that taking trips like the Biosphere RET, and other similar programs that she has participated in, required approval from district administration. She recognized that not every school would be willing to do that: “They are in effect, partly paying for these trips, because they have to pay for a substitute to take over [her] classes” (Louise Interview, March 25, 2022). However, in order to get approval, she made the argument that “these trips have to be specific to [her] teaching and [she would] have to be able to advocate for their value for the school as a whole for the approval to be given” (Louise Interview, March 25, 2022).

Louise’s Journey to Becoming a Science Teacher

I chose to include this section, unique to Louise, because it was evident from our conversations that her journey into teaching highlighted aspects of her figured world of teaching relevant to her science/teacher identity. When I asked Louise how she came to be a science teacher, she responded: “I never saw myself as a teacher, I never really had a teacher identity growing up” (Louise Interview, March 25, 2022). Louise described her decision as purely logical. After she graduated in the 1980s with her degree in geography, she needed to find a job, and “there was just this crippling nationwide teacher shortage for science” (Louise Interview, March 25, 2022). She furthered:

> There was a series in the New York Times around this time just chronicling the lows of public education and what schools are having to do to make up for the lack of qualified science teachers, and I couldn't believe how dire it was. — So that was one reason, I knew that there would always be a job if I went into science education. (Louise Interview, March 25, 2022)

A second reason for Louise's career in teaching was as a result of her ex-husband working on his doctorate in astronomy. Louise explained that once he completed his degree he could potentially get hired anywhere, so she needed something portable. Her third reason for becoming a science teacher was because she liked the "possibility of being a positive person in somebody's life at some point in their life. That really drew me to teaching science" (Louise Interview, March 25, 2022). When I asked her if she would elaborate on what she meant by being a positive person, she explained she wanted to do for students what her favorite teachers did for her. She expressed that there are a lot of "kids who might not have a whole lot of positive influence at home" (Louise Interview, March 25, 2022), something she knew not all children had. Lastly, Louise felt becoming a teacher was simply a better option that other jobs. She enrolled in a teaching program at a nearby university and received her teaching credentials in life science. That year was a tumultuous time for Louise and her family. She was pregnant with her first child, and her mother passed on the baby's due date.

> Newly married starting a family but ready to work, so I got a few job offers that fall, I now had a six month old and I took the worst one, and this is something that I think about a lot now, 30 years after the fact of how little guidance advice, or mentoring in any kind of program that I was involved in back then, this was in the late 80s. I was really a free agent at the time I didn't think about that, but now looking back. It was not supportive to building someone's identity as a teacher and we've got better programs in place now, and I'm part of them. And I'm always on the lookout for my student teachers and Grad students, that they have a sounding board for thought decisions they're going to make as they are starting to develop as their own teacher. (Louise Interview, March 25, 2022)

Her first teaching position was extremely difficult. She was working in a high school and a junior high, housed in two different buildings throughout the day and teaching four different subjects. Her position was not renewed, which although she is grateful for now, at the time left Louise with a sense of personal failure.

> There was no mentoring in the classroom. I would ask the admin of both schools, I would ask teachers, ‘Can you come and visit my classroom to give me some feedback?’ And the answer is always no. And the only feedback I got was just boilerplate tinged with criticism. (Louise Interview, March 25, 2022)

Louise recalled a particular day during that first year of teaching, when her principal came in for unannounced observation, and instead of noting the student engagement in the rich lesson, wrote only about how long it took him to be noticed by her at the classroom door.

Louise made the decision not to return to teaching the following year and “stayed home for 10 years” (Louise Interview, March 25, 2022). During that time, she had a second child, moved internationally for some time, and eventually landed about 50 miles from Louise’s home town. After Louise and her husband divorced, she made the decision to look back into teaching, so that she could have an income. “And through a connection of friends, I heard about a music offering a music opening at a nearby middle school and I'm also a professional musician, I play the piano” (Louise Interview, March 25, 2022). Louise was able to work on an emergency certification while she worked towards obtaining her teaching credentials in music, leading to Louise holding teaching credentials in both music and science.

> And so, I stayed at the middle school and all my initial fears about coming into the classroom completely were true. I had a really rough time but I needed the income, and this was what my training was in, and I still love the idea of public education. I'm

> extremely committed to it, I see myself as a 100% product of public education, so it means a lot to me. My K–12, my undergrad, my credential, my masters, and Ed doctorate are all from public institutions, so that says so much to me about the strength of our system and what it can do. So, I stuck with it and little by little, life got better and after five years of teaching music, the principal came over to me and said at the end of one year, he said it really does look like we're going to get our funding next year for the music program—Anyway, he said, there was going to be an opening in the science department, would I like that, and I said, 'You bet!' I taught seventh grade science for a couple of years and then switched to sixth grade where there was an opening and that's where I lasted for the next 12 or 13 years. And the nice thing about teaching one grade, year after year is that I was able to really, really specialize in the 11- and 12-year-old thinker. (Louise Interview, March 25, 2022)

Louise's Storied Science Identity

Louise's storied science identity is presented largely as a movement back and forth between stabilizing and destabilizing her identities within science. In Louise's figured worlds of high school and university science, Louise felt excluded by the physical science community, but welcomed by those in the life sciences, stabilizing an identity as not a physics person. As a science teacher, teaching a combination of physical and life science to her middle school students, Louise made every effort to ensure her students did not have a similar experience of seeing the physical sciences as foreign languages, incorporating art as a tool to provide opportunities for sense-making in addition to an emphasis on providing tools to increase their fluency in the "language of science." By doing so, Louise felt that she became more confident in her own understanding of physical science. Louise's identity journey supports the argument by

Braund and Reiss (2019) when they suggested that the arts can do more than engage students, but "that using the arts as a language to help learners understand scientific concepts can be a powerful way of enabling such learning" (p. 232). In Louise's efforts to disrupt historical patterns of marginalization and elitism in the physical sciences in her classroom, and support positive science identity formation of her students, she stabilized her own deficit identity in physical science.

Louise's Story of Feeling at Home in the Life Sciences. A constant storyline throughout my conversations with Louise was the idea of language. Louise felt that as a student in both her high school and college figure worlds, she did not understand the language of math and the math heavy sciences. These feeling of inadequacy began stabilizing an identity for Louise that she was more of a life science's person, a place she felt welcomed and at home, and not a physical science person. Louise described her middle school science teachers as being esoteric, lacking focus on their science teaching, and felt disconnected from them. She contrasted her middle school experience with the one she had in high school, describing her teachers as "warm and encouraging and friendly and so smart" (Louise Interview, May 24, 2022). She continued:

> I was in the hiking club and the supervisor was the physiology teacher and one of the biology teachers, and he became a mentor for me all four years. He was the one to organize all of our hiking club trips. I became the hiking club President, so he and I were always working together, planning the next backpacking trip, and I can't imagine a kinder, gentler, thoughtful person than him. But then the other three biology teachers that I worked with during those four years were just like that! They really stood out to me as

> being, there's no sarcasm like I would find with a lot of the other male teachers. Just such a great spirit of welcoming you where you were. (Louise Interview. May 24, 2022)

Louise did not take chemistry, physics, or upper-level math classes in high school, so she was unable to compare the dispositions of the teachers of those classes to the teachers in the life sciences. However, Louise felt that her experience was perfect for her because, she felt “so at home and very, very, very capable” (Louise Interview, May 24, 2022). For Louise she experienced a sense of belonging, which contributed to a positive identity in the life sciences (Hazari et al., 2020).

According to Hazari et al. (2020), “Sense of belonging refers to a students' perceptions of fitting into and not being alienated from their community” (p. 1589). Additionally, Hazari et al. (2020) contrasted their construct of sense of belonging with Carlone et al. (2014) description of recognition, saying that although the two may be related, they are “theoretically distinguishable” (p. 1589). They suggested that “individuals may feel recognized as a ‘physics person’ (by educators, classmates, etc.) while still feeling like they do not fit in with peers and others in their disciplinary community possibly because they hold other identities that are exceptional and unique from others in the community (e.g., gender, race, or ethnicity)” (Hazari et al., 2020, p. 1589).

In college, Louise struggled to declare a major. As a geology major, Louise was often frustrated, stating she “didn't feel very fluent in physics and chemistry and higher-level math” (Louise Interview, March 24, 2022). Her mom suggested she try geography as a major. Louise let out a little laugh, “I had never even heard of it as a department or subject, I thought it was the state capitals” (Louise Interview, May 24, 2022). After looking into geography as a possible major, Louise fell in love with the department, and declared her major at the end of her junior year. Louise felt the geography major combined everything she loved, saying:

> I studied linguistics, a lot of languages, I studied anthropology, biology, and botany, and geography just seemed to put it all together, plus my love of maps. I did quite a bit of cartography at [University] and I do a lot of backpacking and hiking, so it just seemed to be just a perfect mix. (Louise Interview, May 24, 2022)

However, as a geography major, Louise still needed to take some chemistry and physics courses, expressing she felt as though she could not “think independently in those fields” (Louise Interview, May 24, 2022). She reflected:

> As an undergrad, I would see my colleagues and my friends, who were in those programs, the way they spoke about chemistry and physics just didn't, it seemed almost like a different language to me, and I couldn't recognize that. I just felt too much like an outsider. Of all the courses I’ve taken over my lifetime, chemistry and physics were the most personally challenging for me. (Louise Interview, May 24, 2022)

The excerpt above highlights a stereotype that still persists is the idea that men are better than women in the fields of math and math-laden science fields, such as geology (Kim & Sinatra, 2018). Unfortunately, the lack of women in these fields, compared to the life sciences, contributes to the perpetuation of such stereotypes (Eren, 2021). Further, by only making efforts to recruit females into math-laden sciences, rather than making changes to the field itself, I argue the field will remain disproportionally male.

Louise’s Use of Verbal and Non-Verbal Language as an Entryway into Understanding Science for Herself as Well As Her Students. As a child, Louise enjoyed making maps with her father. As mentioned in Louise’s introduction, she had maps lining the walls of her office and expressed to me that she has been a lover of maps since childhood. When I asked her where this love came from, she explained:

> Well, probably my father, we did a lot of camping and backpacking. When I was a little kid we did a lot of traveling, with my mother as well, but my father and I would pour over maps together. My parents gave me a big huge beautiful atlas as my graduation present from [university]. Whenever I had to do a country report when I was growing up, it was all about the map. I just loved making the map. So, I think it was a great visual display of information for a kid because it's like entering another world in a way, so I'm assuming that's what started me on my appreciation for a map, as a diagram I can walk through. (Louise Interview, May 24, 2022)

This quote demonstrates that maps represent more than just a thing that she loved, but a way for her to interpret the world around her. Louise also incorporated map-making into her teaching. As a middle school science teacher, she taught a mixture of life and physical sciences, so she was able to infuse material from her undergraduate degree into the course. She explained:

> I would give a group activity every year. I would do it at some point after we were learning about erosional features, but also topographic features as well. In our map analysis I would give the kids a final exam question that one of my Geomorphology professors gave us at [university]. Which was, I would take a hand towel and scrunch it up, so all of a sudden, you've got valleys and mountains and all kinds of creases that make interesting patterns and we would have to then map it, but in an explanation of why these things could have happened geologically. (Louise Interview, March 24, 2022)

Louise's brand of teaching, supported the argument that 3D representations can enhance a learner's understanding of structures, processes, and concepts in science (Braund & Reiss, p. 229).

One of the ways that Louise characterized her science teaching was by the use of student developed models of scientific concepts:

> The kids will draw a lot of iterative models through the course of a unit, and then they'll come back to their model, share it with partners, and then come back after sharing. And by the end of the unit, let's say weather, and let's say the question was something that I've had them do when we've learned about weather. What is making the leaf on the tree shake? What's going on to make the leaf on the tree shake? Draw everything you can to help explain to me and to your neighbor what's causing the leaf to shake. And some kids will say, 'it's just what the tree does when enough leaves are shaking.' Then we start to see these patterns, and so it's just fascinating how kids make sense of the things that they've been familiar with since birth. (Louise Interview, March 24, 2022)

Louise paused and explained that it was not just about making models but more importantly about having students place "themselves within a context in scale, like as a part, of let's say you're one of the particles. What's happening?" (Louise Interview, March 24, 2022). She took the idea of placing oneself within a system as a method of sense-making from a biography she had read about a Nobel Prize winner in physics who imagined he was a subatomic particle, "he would move from this part of the atom to that part of the atom with all of these things happening, all these fields in place. When I was reading that, I was thinking of course, that's how you can make sense of how some process is working, by putting yourself right in the middle of it" (Louise Interview, March 24, 2022).

She explained that her classroom would be full of artwork that students made. “All of the artwork is to explain they're thinking of a particular concept, and sixth graders love to draw, everybody loves to draw” (Louise Interview, May 24, 2022). In addition to modeling and other visual artwork, Louise taught earth’s composition to her students by reading aloud a book to them. The book was entitled, *How to Dig a Hole to the Other Side of the World* (1979), a book that she read to her own children when they were little, and a book which Louise described as “quite scientific.” She described:

> I’d have them draw what they imagined as we read through the book. And I'll show them the pictures that they want to see, but I want to see how they're making sense of all this new information that's coming to them through the framework of a children's bedtime book. . . I love the opportunity to let them use nonverbal ways to make their understanding visible to me. It's really perfect for sixth grade, but I would do that even in high school, I'm sure. (Louise Interview, May 24, 2022)

Louise’s standpoint on teaching science through artistic mediums mirrored that of Braund and Reiss (2019) who suggested, “communication through a variety of visual, spoken, and alternative written language modes (alternatives to written, expository texts), drawn from the arts, offers ways of breaking down the barriers that students find hard to cross” (p. 229).

In addition to teaching students through alternatives to academic language, Louise also ensured her students could participate in the traditional language of the scientific community as it presently stands. She said:

> Even from day one of the school year, and because of how much I value conversation and the social aspects of constructing knowledge, the fluency of our contextual language is very, very important to me. I make a point of giving the sixth graders one new word a

> day. And that word is often a central theme of what we're going to be working on that day. (Louise Interview, May 24, 2022)

She shared that in one particular instance, the word of the day was not only central to their lesson, but to the actual events taking place outside of the classroom: "One day that word was aftershock and we had an aftershock that day, so that was unbelievably central" (Louise Interview, March 25, 2022). Louise felt that if she was going to be teaching science to her students, there should be a mutual understanding between them, something that could only be achieved through a common understanding of the words used in the classroom. Louise explained:

> Every class period in my sixth-grade classroom, we would spend at least 10 minutes of the 50-minute class time talking about that word in context, maybe in different contexts if they've seen it elsewhere. We'd break it down into its roots. I would even teach them how to write in Cyrillic if it's a Russian word or if it's a Japanese word like tsunami, we would write it in Karachi. I had a student teacher who was fluent in Japanese and he taught them how to write tsunami in two different versions, he even brought his ink and pens. (Louise Interview, March 25, 2022)

Louise described the understanding of scientific words as "a way of entering into science" (Louise Interview, May 24, 2022). While Louise was completing her EdD, she described her classroom as her laboratory. Her research question centered around how "sixth graders refine their sense making abilities, from the beginning of the year to the end of the year" (Louise Interview, May 24, 2022). She was particularly interested in her students' sense-making around the topics of mass, volume, and density, demonstrated by how student talk changed over the period of one school year:

> I was really curious to see how language, how diagramming, how any kind of communication changes from year to the end of the year with these kids who were right at the bridge between concrete and abstract thinking. And in a science context, where none of them have had a science classroom until sixth grade. It's a really interesting point to start looking at how people think, and how they make sense of phenomena that, in a way, they're familiar with. From being in a bathtub with things that float in the water, to having to grapple with questions like, why are continents moving, which is also a function of, well it's basically a density question. (Louise Interview, May 24, 2022)

This particular interest in the concept of density originated from a conversation Louise had with one of the eighth-grade teachers, years before she began her EdD. One day, while she was chatting about a lab she was doing on density, he said:

> ‘Oh, I wouldn't bother with that because kids don't get density until high school. And I thought that was a really interesting thing to say, especially for an eighth-grade science teacher where you've got some pretty sophisticated brains in eighth grade, you've got their sophisticated brains all throughout, but it was it was a comment that really stuck with me and I was really wondering, ‘What can I learn from that thinking about students’ capabilities when they're looking at something?’ (Louise Interview, May 24, 2022)

Years later, when Louise needed to develop a research study, she decided to focus on density. Her study compared students taught from a state adopted curriculum as a control group, and an intervention group which used a curriculum she created from a variety of different resources other than the standard text book. She compared the results of each group of students on the end of year chapter test. She explained the findings of her study to me:

> And my intervention kids hadn't used it so they weren't familiar with the language that the textbook used around density. They weren't familiar with the style of anything. They hadn't had any sort of multiple-choice assessment, whereas the control groups had been doing everything that the textbook offered on density. Which meant that they already had some pre-tests that were multiple choice—What I found was that the intervention groups didn't need prep for the end of the chapter test. They were really good at reading the questions, understanding what the question was asking for, solving the question, and they did, really, really well. As opposed to the kids who had followed the book, it was the typical bell curve of grades. I had a whole bunch of different assessments and I also had a pre and posttest, so I had all kinds of data sources to be looking at, to see if there were patterns and uniformly the intervention group became so much more fluent in talking about their understanding of a question and how they would go about solving it, whereas the other kids tended to look at how can I apply density equals mass divided by volume. So, they were always looking at where to plug it in. (Louise Interview, May 24, 2022)

Louise hypothesized that she would see this in her findings because of how programmed students become in what Louise called procedural fluency. She described this term as the privileged form of language used in academic settings, “it's sort of privileged in our kind of conveyor belt model of math and science education. Learn the procedure, practice it, practice it, practice it, and you’ll do fine on the test” (Louise Interview, May 24, 2022).

I felt that I was beginning to make a connection between Louise’s own feelings of not being fluent in the language of physical science, to her emphasis of different forms of communication in her classroom, such as artwork and storytelling, as well as her efforts to support her students in academic language. I asked Louise if I was right in making this connection, she responded:

> Oh, absolutely. That's absolutely right. I try to keep my language as consistent as I possibly can, so the kids are hearing the descriptions in a very, very similar way. I'm not trying to throw new words at them. I'm trying to keep our vocabulary very predictable and consistent. Definitely. Oh, my! I think a huge part of science education is a common language where both the teacher and the kids can understand each other. (Louise Interview, May 24, 2022)

In addition to supporting her own students' identities in science, Louise believed that her experience as a middle school science teacher resulted in her having a greater understanding in chemistry and physics, resulting in her ability to now identify herself as someone who understand physical science. "Now that I've been teaching it, I love chemistry and physics units in middle school" (Louise Interview, May 24, 2022).

Louise's storied identity presents an identity journey through academic sciences, where she moved through their figured worlds searching for a way to make meaning and to be welcomed in a version of science that felt so unwelcoming. Rather than simply being satisfied with the version of physical science she felt she could never understand the language of, Louise pushed back and infused arts into her science teaching, to strengthen her student's identity within science, and inadvertently, her own. According to Varelas et al. (2021) regarding the false dichotomy that continues to be perpetuated between the arts and the sciences:

> The arts celebrate the body—and the ways in which bodies are sites of knowledge—and identity exploration by shifting one's perspective from objective to an embodied, first-person imagining and experiencing phenomena, events, and situations. In this way, arts-

> based ways of knowing align with indigenous pedagogies that celebrate holistic ways of experiencing the world instead of privileging disembodied explanations of reality (p. 495).

Whether Louise was aware of it or not, she demonstrated an act of rebellion against heteronormative and colonial versions of science she encountered in her figured worlds of science by positioning the arts and sciences as more than mutually exclusive, but rather as entangled, symbiotic, and filled with opportunity, what Haraway (2016) refers to as "art science worldings" (p. 67).

How Did the Figured World of the Neutron RET Influence Louise's Science Teacher/Identity and/or Conceptions of the Nature of Science?

Much of Louise's associations with science centered around how she taught science to her students, including those related to the Biosphere RET. Louise described herself as an "ambassador" for her students. She reflected:

> I'm bringing back what I learned. I come back and it's like I've just been away for years sailing around the world solo, like she survived it, she's back, I always bring candy from the area that I've been traveling to — they never know that I'm about to do that (Louise Interview, May 24, 2022)

As we discussed Louise's experience in the Biosphere RET, she expressed one of her most memorable moments were participating in the research nights, because she felt everyone was positioned as a valued member of the community:

> So, every night after dinner, we would gather around the hotel swimming pool and we all had been either assigned or we had chosen research topics that we would lead a discussion on various nights. I absolutely loved those. And everybody had the same

> assignment, whether you are a classroom teacher or a Grad student or a faculty member, we all had the same assignment. So being able to be part of a literature group with presentations every night was so much fun. Oh my gosh I loved that. (Louise Interview, May 24, 2022)

Louise referred to her role in the RET as an interested observer, but also having the opportunity to work “alongside” professors. Often the term alongside refers to individuals working to complete the same task, rather than one having power over the other, as opposed to other terms like apprenticeship, used throughout the RET literature. When I asked Louise if the learning was mutual between the teachers and the scientists, she replied:

> Oh yes, they were interested in hearing us talk about classroom life because they were interested in how I would interpret my findings to a sixth-grade science classroom, for example: How would you present this? How would you break it down? I felt like I had a role as a practitioner of teaching. (Louise Interview, May 24, 2022)

Louise felt the scientists valued the teachers for their expertise as educators, and that the relationship was collegial. She expressed how grateful and privileged she was to participate in the RET, and that she “never felt talked down to” (Louise Interview, May 24, 2022). She described scientists as being truly concerned with the fact that they were working with a science teacher who would be going back to their classroom and translating what they learned to their students. In contrast to feeling appreciated as an educator, as a contributor to science, Louise described herself as a “neophyte,” saying her role was that of a “a citizen scientist” (Louise Interview, May 24, 202). Supporting the work of Shanahan and Bechtel (2019) who found teachers were more likely to be valued for their expertise as teachers than as a contributor to science. Not only did Louise infuse what she learned into her teaching, but she reported back to the scientists on how the students responded. Louise felt that her experience in the Biosphere RET reinforced her "thinking that there's lots of great things that teachers can be doing to keep them in teaching" (Louise Interview, May 24, 2022). This link between RET is rarely mentioned in the RET literature, and something I return to my discussion chapter (Baker & Keller, 2010).

According to Louise, participation in the Biosphere RET, and similar programs, led her to becoming a better teacher, as she was able to share her experiences with her students when she returned. She also felt that by having teachers participate in RETs, teachers might find a renewed sense of teaching and increase teacher retention. Working with scientists in the field, Louise felt welcomed and valued by the scientists for her expertise as educator, stabilizing her identity as someone able to communicate scientific material, something she placed so much emphasis on in her classroom.

> And coming back after these trips, my students seem relieved that I survived and just on the edge of their seats to hear about all the crazy adventures that I had. What a great way to teach science, so I don't know that it changed things [her conceptions of science] so much, but it clearly made me a better teacher every single time because I could talk from some experience. (Louise Interview, May 24, 2022)

However, it was unclear from the stories Louise shared how her experience in the figured world of the RET impacted her conceptions of the nature of science.

In the following section I present what I refer to as participant's visual narratives, which includes the visuals teachers drew in response to visual prompt I provided at the start of our interview, as well as my analysis of their visuals based on their verbal descriptions. For Helen, because she did not provide her visual after our interview, I only include an analysis.

Participant's Visual Narratives

In this section I present the participant's visual narratives they drew and explained in response to my prompt asking them to visually convey how they personally connected to science (see Appendix A). Prior to generating their storied science identities, it seemed as though the visuals were just an additional method for teachers to convey their understandings of science. However, after constructing the storied science identities, it became evident that teachers' visuals emphasized different aspects of how they related to science than their stories did. Where participant stories were rooted in the different experience's teachers had with science and science teaching, their visuals centered around what science was. More specifically, most participant's visuals presented at least two themes as it related to the nature of science: 1) characteristics of scientific knowledge or how knowledge is developed; and 2) the purposes of science. In addition to/instead of these two major themes, some participants included additional components in their visuals such as the process of science, the different disciplines of science, as well as discrimination in science, which I include in their particular visual narrative.

Therefore, in this section, I present each teachers visual drawing as well as the way in which they described their visual. Teacher's descriptions of their visuals are organized within tables to clearly present what they drew, how they described what they drew, and how I categorized each description. By presenting this portion of the findings in table form, it makes it easy to look across participants descriptions as well as to compare their descriptions to their storied science identities. Lastly, although I have presented teachers visuals as separate from their storied identities for purposes of organizing this paper, I want to acknowledge that their visuals are part of their storied science identities and serve as additional layers in the participant's stories, whereby I am able to enhance the "three-dimensional narrative inquiry space" (Clandinin & Connelly, 2000, p. 50). I end each visual narrative by describing how the teachers' visuals and descriptions of their visuals served as a way to support the findings presented in science teachers storied science identities as well as in some instances, to offer additional insight into their science/teacher identities and/or conceptions of the nature of science.

Oliver

In Oliver's visual narrative, certain aspects of his science/teacher identity and/or conceptions of the nature of science reflect his storied science identity. Oliver was the only participant to discuss his own research in his narrative, further stabilizing his science/teacher identity as someone who desires to be recognized for his work in science and the awards he has received. Similarly, just as Oliver presented science as composed of fundamental content knowledge in his stories, knowledge of which he was well versed, this was reflected in his visual narrative by including images related to the discipline of chemistry.

Most interestingly, I would argue, in Oliver's storied science identity, I presented his discussion around experiencing microaggressions, but chose not to elaborate on how he situated himself in terms of demographics within science. More specifically, Oliver did not clearly identity as White or a person of color. However, in his visual narrative, he did make sure to emphasize the discrimination that still exists within science, choosing to visually depict racial and gender gaps pervasive in science research. It is possible that for Oliver, it was easier to verbally present the issue of discrimination in his image, rather than discuss his own personal experiences with discrimination within the field of science.

Figure 4.1

Oliver's Visual (part 1)

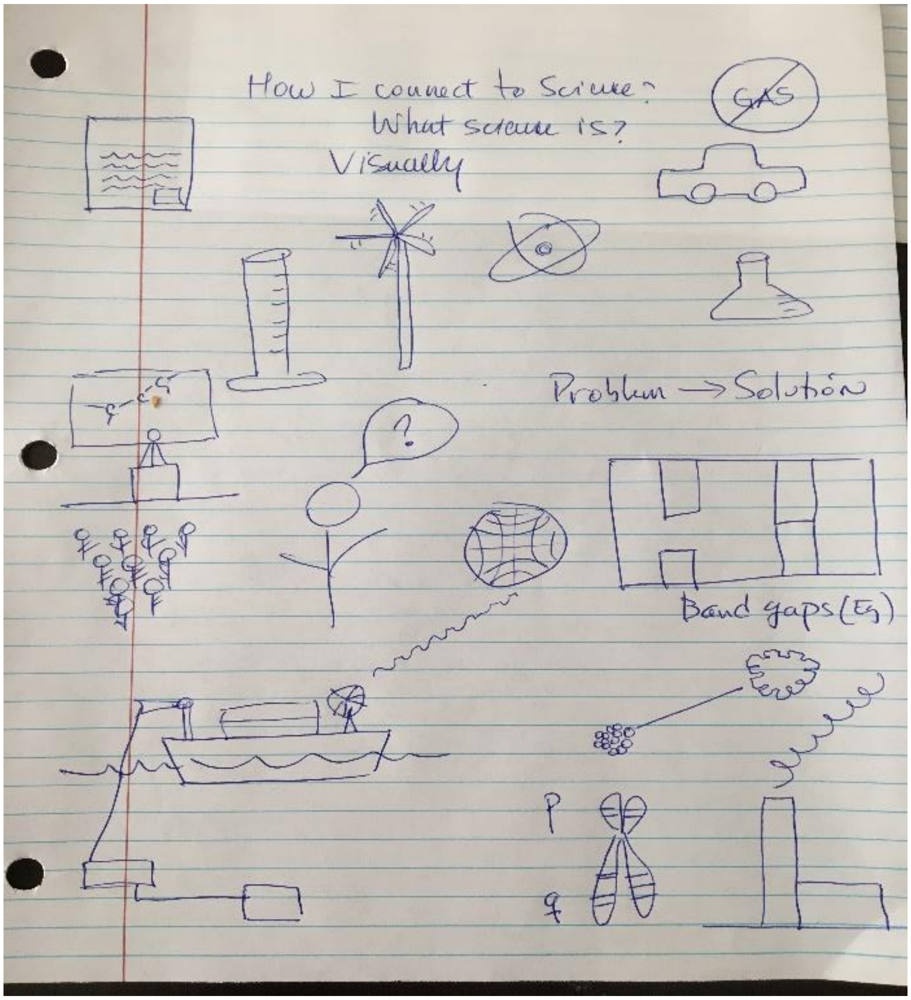


Figure 4.2

Oliver's Visual (part 2)

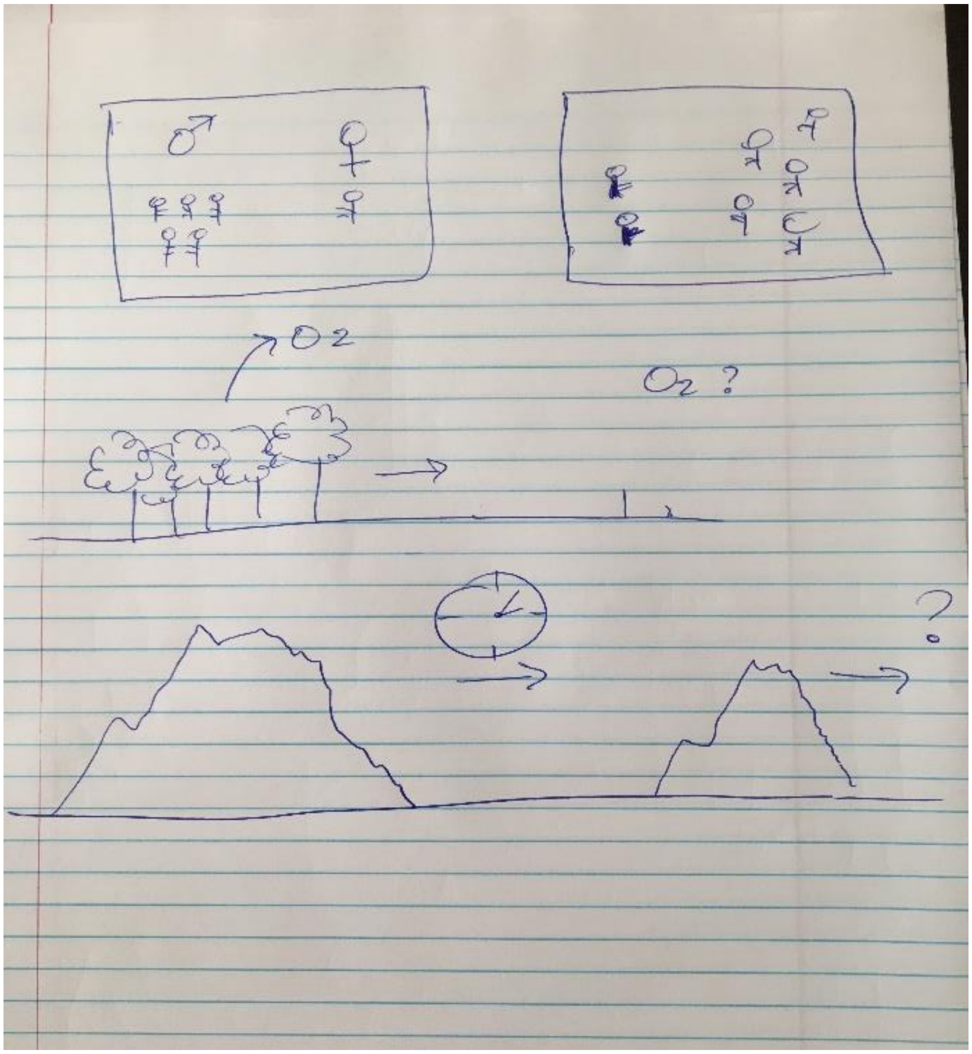


Table 4.2

Oliver's Visual Narrative

Components of Science	Description	Drawing
Characteristics of scientific knowledge or how knowledge is developed	Science involves communicating scientific ideas is one of the main goals of scientists or anyone involved in research, example publications; scientists presenting research, example a conference	Scribbles; stick figure using a projector specifically in the field of organic chemistry to individuals in an audience)
Purpose of science	Science involves problem solving; science involves solving environmental problems	Words problem and solution with an arrow between them; stick figure of a person thinking about solving a problem; windmill, electric car, industry making pollution, deforestation, mountain with erosion
Disciplines of science	Chemistry equipment and symbols	Graduated cylinders, flask; atom symbol
Personal experiences in research (recognition)	Olivers personal research experience, as well as having the knowledge to use particular tools in science, such as ocean exploration	Boat with a person on it, chromosome, band gap
Discrimination in science	Racial and gender gaps in science	Two boxes, one representing more males than females, the other representing more White people than "minorities")

Steven

When I introduced the visual narrative portion of the interview to Steven, he responded positively saying, "I love to sketch" and that he was going to be listening to heavy metal music while he drew. However, Steven's visual appeared as if it did not relate to his storied science identity. When he talked about his visual included aspects of creativity. I told Steven that I struggled to see how his image reflected what he was talking about. He went on to say:

> I built a very boxy geometric structure, but I feel that science is one of the most creative endeavors people can have, I mean I drew an uncreative thing. I drew what looks like a barn with the door. Oh man! So, it's a barn that can only hold so many things of a certain size. But science is creative and involves asking questions which were not really put in the picture very well at all really. This looks like somebody had a plan in mind and it's making order out of chaos. But science is a creative endeavor. In order to actually find new things, you have to start with the curiosity question and then you're not only, you know, going after new knowledge, you're going after ways that never existed before. (Steven Interview, May 9, 2022).

It seemed as though although Steven wanted to depict science as creative, his drawing included components of science he held prior to his participation in the RET, perhaps emphasizing how hard it is to destabilize certain positivist perspectives around the nature of science.

Figure 4.3

Steven's Visual

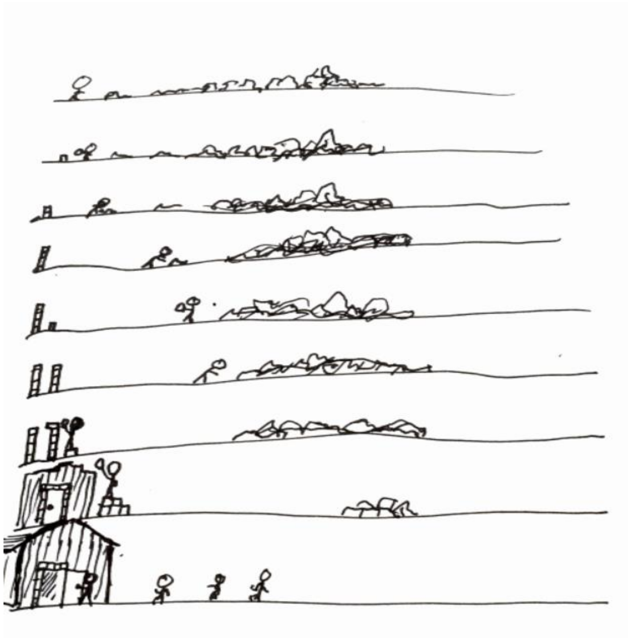


Table 4.3

Steven's Visual Narrative

Component of Science	Description	Drawing
Characteristics of scientific knowledge or how knowledge is developed	Science builds on previous work/knowledge, we shouldn't have to start from scratch, "history class;" science is fallible and involves revision; science is creative	Series of images that show someone building a house from starting materials
Purpose of science	Making sense out of things; working towards an end product	Series of images that show someone building a house from starting materials
Process of science	Gathering evidence; using evidence to support ideas; testing ideas	No image

Helen

In the case of Helen, although she did not share her visual with me, she still provided me with an explanation of her visual. Her visual reflected certain conceptions around the stabilized after her participation in the RET, such as the collaborative and interdisciplinary nature of science. Nevertheless, there was an aspect of Helen's visual narrative that she discussed that were not evidenced in her storylines. In her drawing, Helen drew images to reflect the purposes of science, and in her description, she conveyed science research served to make "our work and world better," while at the same time acknowledging her uncertainty of "how much better" (Helen Interview, July 12, 2022). Although this sentiment was not reflected in her stories about science, it does align with her conception of science situated within the construct of social justice. Her lens of social justice reflects the possibility that Helen would hold a more critical conception of science than other participants. In her stories she presented a conception of science as well as a science/teacher identity concerned about who has the opportunity to participate in science, whereas in her narrative she began to address who it is science benefits.

Table 4.4

Helen's Visual Narrative

Component of Science	Description	Drawing
Characteristics of scientific knowledge/ how knowledge is developed	Science is cyclical rather as opposed to a linear scientific method; science does not start from scratch; science is collaborative and interdisciplinary	Circle; books and person sitting and thinking; two stick figures talking to one another
Purpose of science	Understanding the universe/the world we live in; development of "vaccines and other pharmaceuticals."	The earth; chemical bottles
Process of science	Observe the world around you; record observations and data	Magnifying glass; lab book

John

After constructing John's storied science identity, I was surprised to return to his visual and not see animals reflected to the same capacity. What was more strongly emphasized in his visual than in his storylines was the emphasis on how scientific knowledge is constructed as well as the purpose of science. Although he mentioned these ideas on the margins of his stories, it was more central to what he chose to depict with his drawing. Such a stark contrast between a participant's visual and their stories presented two possibilities. First, there was a possibility that for John, there was a disconnect between his conceptions of science and his enactment of science. Second, it may have highlighted a limitation of this study and the amount of data collected from interviews via zoom rather than observing the participant in the RET program and/or in their classroom, something I discuss more in chapter five.

Figure 4.4

John's Visual

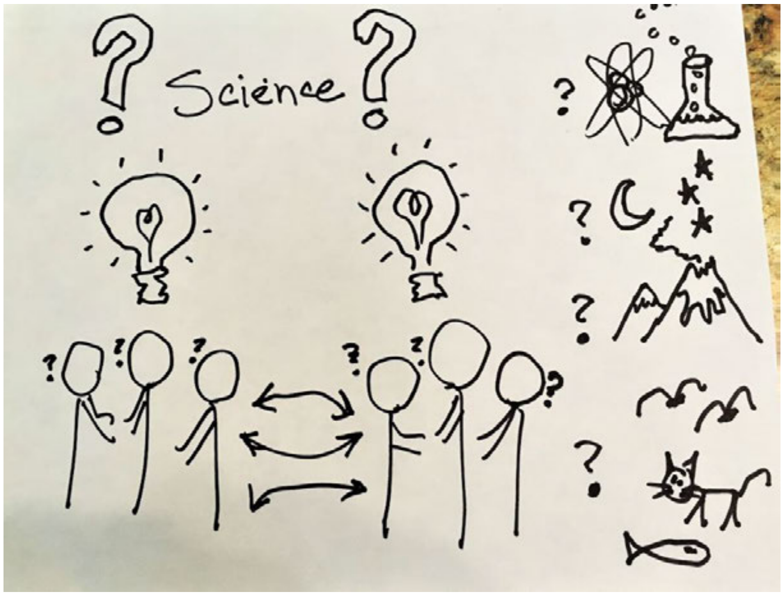


Table 4.5

John's Visual Narrative

Component of Science	Description	Drawing
Characteristics of scientific knowledge/how knowledge is developed	Science is collaborative and interdisciplinary	Two groups of stick figures talking to one another
Purpose of science	Understanding the universe/the world we live in; development of vaccines and other pharmaceuticals	Lots of questions marks
Science disciplines	Chemistry; astronomy; earth science; biology	Atom and flask; night sky; volcano; bird and other animals

Denise

In contrast to John, it appeared that Denise's visual depicted similar conceptions of the nature of science as her stories did. In her stories she emphasized a desire to investigate the world around her, even in her figured world of childhood. Just as she would be exploring her local creek, she emphasized looking at bugs under a magnifying glass. In addition to her conception of science involving learning about the natural environment, I would argue that she emphasized a conception of science related to her experiences as being marginalized within the science community.

In her drawing, Denise emphasized the sociocultural aspects of science. Although Oliver mentioned discrimination within science, Denise seemed to push further and talk about such discrimination as inherent to the way in which science knowledge was/is/should be constructed. Denise described that the symbols she used in her drawing were meant to represent that "science is about health, science is about the economy, science is about governments, science is male, female and anything in between, it is K through gray, so basically life lifelong learning" (Denise Interview, March 13, 2022). It was clear from both her stories and her visual that because of her own experiences of feeling unwelcomed in science, she was engaged in identity work to stabilize a science/teacher identity of inclusion. She continued by saying that in addition to holding a more inclusive conception who can participate in science, she also felt that inclusion should be reflected in where science takes place, saying "I think that science isn't just the lab setting, it involves outside, and you know it has a lot more than I think what standardly people think of, like Einstein in a white lab coat. That it involves all races, colors, genders, ages, anybody can be a scientist" (Denise Interview, March 13, 2022).

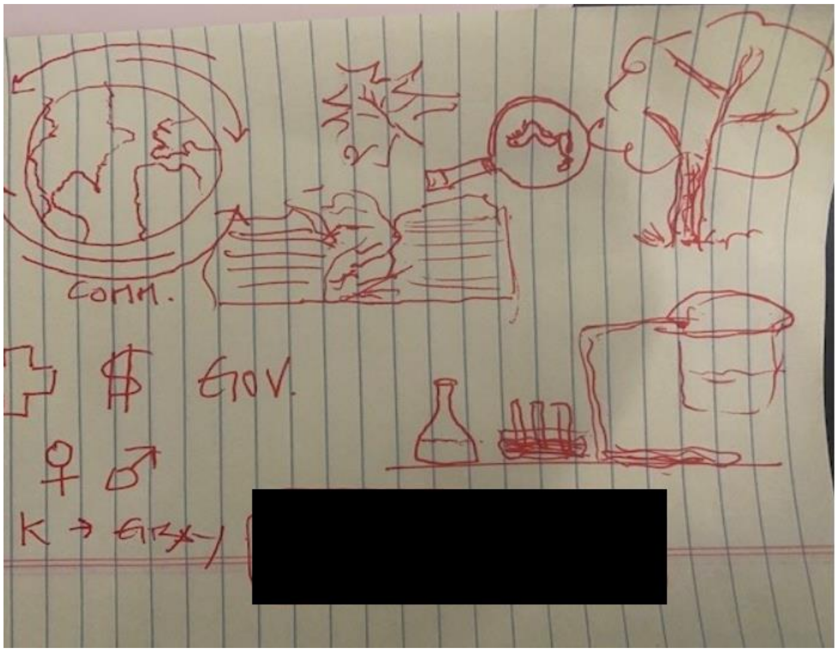
In addition to presenting science as inclusive, her image reflected an additional element of the sociocultural aspect of science that was not present in her stories. Denise explained that her drawing also represented science involving:

> All kinds of different facets of the inner workings of society, whether it's the economy, the government, politics, culture, some of which I couldn't really figure out how to draw." "I mean, I even think sadly, just with the wars and the things that are going on, some of that science related, right? I mean it seems like a lot of wars are initiated, either because of religious beliefs or some kind of resource that we want, which has a scientific element to it, you know or space, which again, you know, ecosystems and resources and space to live, all have this underlying science element to it in a way. (Denise Interview, March 13, 2022)

It was interesting to see that out of the six participants in this study, only two acknowledged the idea that science may lead to negative consequences, and those two participants were female.

Figure 4.5

Denise's Visual



Note: a black square was used to cover names of participants Denise had included in her visual

Table 4.6

Denise's Visual Narrative

Component of Science	Description	Drawing
Characteristics of scientific knowledge	Science is sociocultural; science is continuous, changes, involves communication/sharing knowledge, and multidisciplinary	Several symbols; arrows in different directions
Purpose of science	Inventions; science involves learning about the natural environment; understanding our planet	No image; bugs and magnifying glass; canyon and river

Louise

Similar to John, it was hard to see the connection between Louise's visual and her storylines. For Louise, the majority of her storied science identity was organized around the use of non-verbal ways of learning in order to provide her students with a sense of belonging within the physical sciences, something she felt she did not have throughout her own figured worlds of science. However, in her visual, Louise depicted a singular idea around science: Science is about understanding phenomenon. Although this is considered by those in science and science education as a major component of scientific research and science learning, it seemed to present a very limited perspective on Louise's conceptions around science and the aspects of her science/teacher identity. Once again, this may highlight similar aspects of the visual narrative component of the research I discussed in relation to John. However, it may also be reflective of a need to explain with greater clarity the intention of the visual narrative within the research in order to elicit richer drawings from participants.

Figure 4.6

Louise's Visual

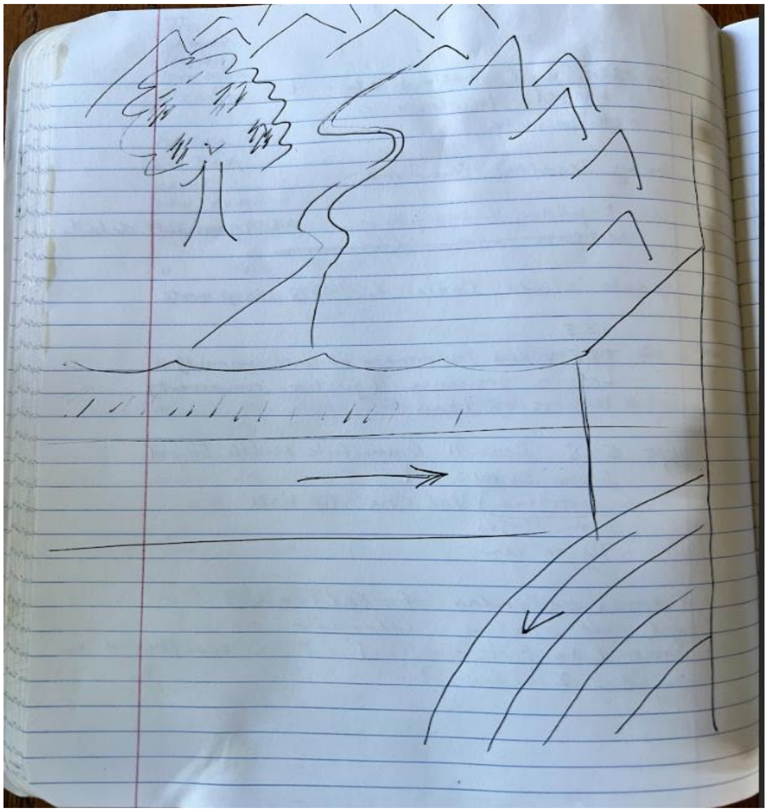


Table 4.7

Louise's Visual Narrative

Component of Science	Description	Drawing
Purpose of science/science education	Learning to interpret what we observe; using experimentation and evidence to explain phenomena	Diagram involving a tree, river, and subducting plate going into the ocean

Chapter 5: Discussion and Implications

I came to this dissertation study as someone who participated in several figured worlds of science, from the figured worlds of elementary and secondary science, to university science, RET science, as well as my figured world of science teacher, where my own conceptions of the nature of science as well as my science/teacher identity stabilized and destabilized. As a female, I participated in figured worlds of science where I felt valued and others where I felt I did not belong. As a researcher in this study, I shared similar experiences with my participants, realizing that my stories were similar to theirs and took place in similar figured worlds, while at the same time were uniquely my own.

By using the conceptual framework of figured worlds and the analytical framework of storied identities, I worked with middle and secondary science teachers who participated in a RET, to catch a glimpse of some of the ways in which their experiences in science, through the telling and retelling of their stories, impacted their understanding of science and shaped their identities within science and as science teachers. As a reminder, I am modeling my use of the term figured worlds after the work of Urrieta (2007) who described figured worlds as a way to examine identity within the different “worlds” in which individuals “Come to figure” who they are (p. 107). Additionally, I used the construction of figured worlds by Holland et al. (1998) to describe identity formation as situated within sociocultural and historical contexts. By using teacher stories within their figured worlds of science as both my methodology and the analysis of my data, I referred to the presentation of my findings in chapter four as science teachers’ storied science identities. In doing so I attempted to answer my first two research questions:

1. How do individual teachers conceptualize the nature of science after participating in research experiences for teachers (RETs) and other experiences with science?

2. How do research experiences for teachers (RETs) and other experiences with science influence the ways in which teachers conceptualize the nature of science?

It is important to recognize that the storied identities constructed in chapter four are neither comprehensive nor precise, nor could they ever be. No one person's experiences or figured worlds are the same, and no one person's storied science identity is the same. No storied identity is ever finalized or fixed, rather, it is more useful to conceive of identities as being in a constant state of change, becoming stabilized and destabilized in the different figured worlds in which we participate and interact. No one figured world is discrete, but rather figured worlds are always overlapping and interconnected. Further supporting how complex identity work is, through the construction of my participants storied science identities, I came to the realization that my participant's identities in science could not be held as distinct from their conceptions around the nature of science (Helm, 1998). Likewise, my participant's science identities could not be held distinct from their teacher identities. Therefore, within this chapter I maintain the use of the phrase science/teacher identity when discussing my participant's identities.

While acknowledging the complexity of participant's storied identities, I want to also point out the usefulness of the figured worlds framework as a tool to help enable the construction of the storied science identities presented in chapter four. Figured worlds provided a mechanism by which I was able elicit stories across space and time which impacted my participant's science/teacher identities and conceptions of the nature of science. By using questions centered around figured worlds of science, rather than simply asking my participants to tell me how they identify in, relate to, or have been impacted by science, their stories situated in experiences and with people, spaces, and time, provided access for myself as well as for the participant's themselves to engage with their identities in and with their conceptions of science. At the same time, by using the framework of figured worlds to generate my findings in the form of storylines, I located shared storylines/findings across participants, which I argue may not have otherwise been realized.

In the remainder of this chapter, I attempt to address my final research question, where I ask, "How does the portrayal of the nature of science in research experiences for teachers (RETs) and other experiences with science influence their individual and collective storied identities as secondary school science teachers?" In order to answer this question, I looked across my participants and across RETs, examining shared conceptions around the nature of science and science/teacher identities as a result of their figured worlds in science, including the figured worlds of the Neutron and Biosphere RETs, looking for shared storylines. Finally, I ended this chapter with a section dedicated to the implications of my work for the field of science teacher education and professional development, with special attention given to RET programs, as well as recommendations for science education more broadly.

Participant's Shared Storylines

Using the framework of figured worlds as a conceptual guide, when looking across my participants, across both RETs, I identified the following four shared storylines related to their science/teacher identities and/or their conceptions around the nature of sciences: (1) the impact of elementary and middle school science figured worlds on science/teacher identity; (2) the roles of recognition and sense of belonging in the development of science/teacher identity; (3) science/teacher's identity informing pedagogical practice and commitments; and (4) science teachers feeling valued for their role as expert communicators in RETs. Although there are some storylines that feature all six participants, not all participants will be discussed in each section, rather I chose to include only participants whose stories were relevant to a particular storyline.

A clear storyline that cut across all participants storied science identities was the impact of their figured worlds of elementary, middle, or secondary school science on their identities as science/teachers and/or their conceptions of the nature of science. In our discussion, I asked participants to recall individuals, times, and places they felt influenced their understanding of science and how they personally related to science now. In response, each teacher brought up a story of a particular experience, sometimes a specific person, that was not only memorable but which/whom shaped the way they viewed and interacted with science. However, the ways in which individuals or experiences shaped identities was not necessarily consistent. Though it was outside the scope of the study to examine why and how the individuals, and experiences, that participants chose to share influenced their conceptions of science and identities within science, through the act of remembering and retelling their different stories, participants and I were provided a pathway to "interpret their past in terms of these stories" (Connelly & Clandinin, 2006, p. 479). Therefore, rather than asking why or how, the stories shared by participants held within them both context and meaning of who the participants were, who they are, and who they are becoming in science and as science teachers (Avraamidou, 2019b).

Storyline #1: The Impact of Elementary and Middle School Science Figured Worlds on Science/Teacher Identity

Within this storyline, there were common threads, one of which being stories related to a particular science teacher. Often participants identified this teacher as being memorable, as either someone they liked, valued for their expert knowledge, or as someone who provided participants a sense of recognition for being a student who was good at science. Participants used words such as love, fondness, bizarre, and interesting to describe the experience they had in these teachers' classrooms, and sometimes the teachers themselves.

For Steven, John, and Denise, their experiences with their memorable teacher often stemmed from being excited. Steven was drawn to the entertaining and enthusiastic qualities of Mr. Jackson, eventually emulating his style in his own classroom. He felt not only did Mr. Jackson's demonstrations draw students in and keep them engaged, they were evidence of Mr. Jackson's own passion for his profession. Both John and Denise described their memorable teachers as being the first time they really did something related to science and hands-on learning, such as dissections. These experiences in middle and high school science classes were not only memorable, but began stabilizing a conception of science as fascinating.

For Helen and Oliver, rather than identifying one particular teacher, they felt they had good science teachers throughout their high school career because their teachers held terminal degrees in the science content they were teaching. To Helen and Oliver, teachers having degrees in the content rather than/or as a substitute for a teaching degree, served as an indicator of their intelligence and increased ability to teach. They both used the word expert to describe their science teachers. It is possible that this early designation of scientists as experts was maintained throughout their careers in science and eventually into their identities as science/teachers, making participation in an RET an attractive option of science teacher professional development.

Lastly, for several of the teachers, their experience in middle, and secondary school situated participants as "celebrated subject positions" (Carlone et al., 2014). According to Carlone et al., (2014), celebrated subject positions are situated within a cultural model of identity, where an individual may be positioned as a science person, or not, based on how they interact with and are positioned by others within that figured world. Both Helen and Oliver were supported in their schooling by being placed in science specific cohorts or tracks. From an early age, they were recognized as a part of a select group of students who had the potential to pursue science. Similarly, John referenced the class of his memorable teacher as being advanced, and one that “not many people took” (John Interview, April 19, 2022), supporting an identity as one of the few who was able to take an advanced science course.

In contrast, Denise and Louise, rather than simply be recognized as science people, their stories support an identity of science situated within sense of belonging. Although the construct of science identity presented by Carlone and Johnson (2007) suggested recognition within science is defined by feelings of belonging, according to Hazari et al. (2020), although related, the constructs of recognition and sense of belonging are distinguishable. Hazari et al. (2020), in their work with female identities of physics students, defined recognition as “one's perception of how others view them in relation to the subject” whereas “sense of belonging is defined as one's perception of fitting in (or not feeling excluded) in their physics community” (p. 1588). By using this definition, recognition focuses on what the individual can do, whereas sense of belonging concerns feelings of mattering and being included within a community.

For Denise, she shared a story of Mr. Joseph, a teacher who made her and the other students feel important. The term important here connotes more than simply being recognized as a science student, but as mattering within her classroom science community. In the stories presented by Louise, she presented two different identities within her figured world of high school science. One of her science identities was within the life sciences, where she was welcomed, “at home, and very, very, very capable,” and another in the physical sciences, where she felt like an outsider who did not know the language (Louise Interview, May 24, 2022).

Throughout chapter four, I discuss the constructs of recognition and sense of belonging in relationship to my participants identities in science throughout their figured worlds. According to Carlone and Johnson (2007), recognition is being recognized by oneself and recognized by others as a science person. For many of my participants, recognition played a role in their science/teacher identities. When looking back at Helen, Oliver, and John, by being placed in science focused cohorts in school or by taking an advanced science course, they were positioned by their teachers as being good at science. In contrast, the stories of Denise and Louise emphasized how important it was for them to feel included and matter in the science communities of their middle and secondary school science figured worlds. According to Hazari et al. (2020) a "sense of belonging is strongly influenced by characteristics of the community which surrounds young women," something they argue is potentially crucial to the success and persistence of women in science, particularly in physics (p. 1601).

Storyline #2: The Role of Recognition and Sense of Belonging in the Development of Participant's Science/Teacher Identities

In the previous section, I discussed the constructs of recognition and sense of belonging as they related to my participants experiences in middle and high school science. In this storyline, I build upon the constructs of recognition and sense of belonging evidenced throughout the storied science identities of my participants, beyond their figured worlds of middle and secondary schooling, and extending into their experiences in their respective RETs.

From the stories Oliver shared, it was evident that his science/teacher identity was very much situated in the recognition he received for his achievements, such as awards and publications. Oliver recognized himself and felt recognized by scientific others. This recognition was the driving factor in his participation in organizations like the NSTA as well as the many RETs in which he participated, including the Neutron RET.

John's stories also emphasized the importance of recognition to his identity in science. From his stories about his wide-ranging participation in research experiences, including the

Biosphere RET, John was not only fascinated by animals, but also admired the scientists who worked in the field with animals, and tended to refer back to how often he worked with scientists in the field. John felt recognized for his achievements by meaningful scientific others when he was listed as a contributor in a field guide, after spending much of his life collecting and using field guides. In the Biosphere RET, John emphasized that part of his conception of the nature of science included recognition within the field of science, in the form of publications. In the contexts of Oliver and John, recognition was tied to what the participant did rather than who the participant was.

Although the RET literature does use the term recognition, there are few articles that reference the idea of providing teachers with a sense of prestige or elevated status within their goals and/or outcomes, often related to a teacher's sense of self within the teaching profession (Baker & Keller, 2010; Cattadori et al., 2011; Dresner & Worley, 2006b). Similarly, to recognition, prestige can be described as what someone does, rather than who they are. However, prestige often is discussed in relationship to positions of power. The RETs, as represented in the literature and the stories of my participants, regularly make attempts to provide their teacher participants with opportunities of recognition and prestige for the contributions they make in the field with scientists. I would argue however, of greater interest and perhaps more pertinent, is understanding how participation in an RET may lead to teachers developing a sense of belonging as a science person rather than perpetuate elitism in the field of science, through words associated with power like recognition and prestige.

As discussed in chapter two, the RET literature had very little to say about science identity, with even less focused on the construct of sense of belonging. For example, Faber et al. (2014) described a teacher's sense of belonging in the context of their experience in the laboratory as feeling welcomed and "like they were part of the group" (p. 797). Similarly, Baker and Keller (2010) stated their program aimed to create "a sense of belonging to a larger community of scientists, teachers, and educators" (p. 21). However, in both studies, researchers failed to elaborate on how this sense of belonging was fostered or how teachers' identities in science were impacted by these feelings. They also neglected to discuss teachers' feelings of belonging leading up to their experience in the RET.

In the previous section, I discussed the importance of belonging in science for Denise and Louise in middle and high school. However, their struggle to belong continued into their university experiences and careers. For Denise, she described countless moments of being aware that she was the only woman present during her geology degree and then later in her career in orthopedic sales. According to Kim et al. (2018), "the current STEM prototype tends to be White, male, socially awkward, and singularly obsessed with their chosen STEM field," a prototype still popularized by TV shows such as the Big Bang Theory and other forms of media (p. 593). Although the number of women graduating with degrees in the life sciences has increased dramatically, so much so that there are nearing equal numbers of women and men in those fields, the number of women continues to remain significantly lower than their male counterparts in the physical sciences and engineering (Pew Research Center, 2021).

Later, Denise went into the field of orthopedic sales, a field she described as requiring engineering and construction skills. Despite Denise's confidence in the skills required for the job, she still felt like an outsider, as a woman in rooms filled with men, even referencing the male doctors with whom she worked as "big dogs." Barton (1998) writes about the relationship between representation and science identity, defining them respectively as "what science is made to be" and "who we think we must be to engage in that science" (p. 379). On the basis of this definition, by having only male counterparts in her figured worlds of science in college and in her careers, it became easy to see how Denise would struggle to identify as a science person.

Not unlike Denise, Louise originally wanted to pursue a bachelor's degree in geology, but felt the math and physics requirements would be too difficult for her. She referenced several times throughout our interviews how she believed she was not a physics person, perceiving the language of physics and math as foreign. Perceptions of inadequacy led Louise to pursue a degree in geography where she could infuse her passions for art and the life sciences. It was not until she began teaching physical science to her students, in an attempt to prevent her students from developing a similar identity as "not a physics person," that Louise strengthened her own identity in physics. In the stories of Denise and Louise, it was evident that rather than feeling a need to be recognized through awards and publications, both of these female participants, unlike their male counterparts John and Oliver, wanted to feel like they belonged as science people, especially as physical science people.

In their descriptions of their experiences in the RETs, Denise and Louise expressed feeling valued as expert educators, which was similar to the majority of my participants and a theme I discuss in greater detail in the next section, whilst still maintaining aspects of a deficit science identity. Although Louise described her experience in the RET as working "alongside" scientists and that she "never felt talked down to," she still referenced herself as a "neophyte" and a "citizen scientist," both terms carrying the implication that she was not an expert in science (Louise Interview, May 24, 2022).

Similarly, although Denise described feelings of fitting in when working with the PI of the RET, Denise also used the phrase "being an extension of," when describing her identity in relation to that of the scientists, language that implied teachers' roles as inferior to the role of the scientists. Denise also referred to the scientists as being “big wigs,” similar to the way she described the male doctors she worked with in her previous career as “big dogs.” The use of these terms not only suggested that the individuals held positions of power, but that they were also male. Urrieta (2007) suggested “in figured worlds people encounter narratives borne out of historical significance (both oppressive and liberating) as well as a distribution of power, rank, and prestige (or the lack thereof) that they either accept, reject, or negotiate to varying degrees” (p. 111). Here, it appeared that although Denise felt she fit in during her experience in the Biosphere RET, she still maintained historical narratives that support a patriarchal conception of who holds the power in science.

In chapter two, I discussed in detail the use of language across the RET literature describing the relationship between mentor scientists and teachers, positioning scientists in roles of power over teachers, such language including the terms “apprentice” and “master,” as well as the phrase “at the elbow.” According to Brown (2017), although figured worlds can be sites of possibility, they can also be “a site of constrained social reality that is situated within and mediated by relations of power, meaning that sometimes individuals act out the script given to them” (p. 84). While Denise and Louise refrained from overtly saying that they felt less than, in fact they said the opposite and may have felt the opposite, they still ‘acted out’ through their language choices that the mentor scientists were the ones that held the knowledge and authority when it came to science.

Storyline #3: Science Teachers Feeling Valued for Their Role as Expert Communicators in RETs

Despite teachers' different experiences related to the constructs of recognition and sense of belonging, female and male teachers, in both the Neutron and Biosphere RETs, walked away from their experiences as feeling valued as educators for their expertise in communicating.
For three of the teachers in particular, pertinent to their experiences in their figured worlds of the RET, was being valued as an expert communicator. In Steven's stories, although he felt valued as a contributor to the scientific work being done in his lab, and his role in the publications of the graduate students, he emphasized his value in being an expert communicator. Steven talked in depth about the relationships he developed with graduate students he with whom he worked in the lab. He shared how the graduate students showed interest in the knowledge he held as an educator, including knowledge of the education system as a whole, but more importantly, his ability to communicate information to a broader audience. The graduate students recognized the expert teaching knowledge Steven possessed as valuable, particularly in their roles as teaching assistants and in their need to gain funding for their research projects. Steven was able to communicate scientific information clearly, less as scientific jargon that only those in science might understand. When the graduate students visited Steven's classroom, he also shared his expert understanding of body language related to student learning, something the graduate students held limited knowledge of.

In Denise's stories of her experiences in the Biosphere RET, she stated that the teachers were treated as experts of teaching, while the scientists were experts of the science content. The scientists valued the teacher's expertise as it related broader impacts, and their need to communicate science to the public. She also was valued for her understanding of the education system, outside of communicating content to students, including the administrative and political components of being a teacher, such as testing requirements and the need to create lesson plans. Unique to the Biosphere RET program, the PI was intentional in investigating how the scientists perceived their experiences with teachers, providing scientists with a survey at the end of the program. According to Denise, scientists across the board emphasized in the survey how meaningful it was to work with teachers as a way to hone their teaching skills. Denise also shared that in general, the teaching profession is often undervalued, and teachers are presented as not being smart or important. Denise expressed that she felt a renewed sense of importance to the profession because the scientists, individuals whom she valued for their expertise in science, felt it was important to work with them.

Louise described the relationship between scientist and teacher as mutual. However, when I pressed her about what that relationship looked like, it was evident she felt the teachers were valued for the expertise in education and the scientists were valued for their knowledge of the science content. She described the scientists as interested in her expert knowledge of how to break down complex scientific material in a way that a middle school student could understand, identifying her role in the partnership as a practitioner of teaching. She also used the words grateful and privileged when talking about her time in the Biosphere RET, terms that emphasized a feeling similar to Denise, an idea that science experts were taking the time away from their high-status professions to work with teachers.

In chapter two, I discussed the limited RET literature which positions teachers as experts (Faber et al., 2014; Rushton & Reiss, 2019; Shanahan & Bechtel, 2019). These studies presented different findings when it came to teachers being valued as experts. Rushton and Reiss (2019) found that by the end of their participation, teachers felt recognized for both their expertise in teaching as well as their expert knowledge in science. In contrast however, the work by Shanahan and Bechtel (2019) suggested that although teachers were somewhat valued by scientists for their expert teaching knowledge, the scientists received more value for their knowledge in science. Specifically, Shanahan found that teacher's expertise in education was "downplayed" and "undervalued" by the scientists, as well as the by the teachers themselves, whereas the expertise of the scientists was "foregrounded" and considered as holding higher status, reinforcing a hierarchy of science over teaching (Shanahan, 2019, p. 380–381). By maintaining this hierarchy, participants did not receive equal value for the contributions they brought to the RET collaboration. In the present study, findings support the work of Shanahan and Bechtel (2019), where three of the teachers, Steven, Denise, and Louise, felt viewed as expert communicators because of their expertise in education, but less so in terms of their contribution to the science component of the science/teacher partnership. This finding was even more stark for the two female teachers, Denise and Louise.

Storyline #4: Participant's Science/Teacher Identities and Conceptions of The Nature of Science Reflected in Their Pedagogical Commitments

In this study, participant's science/teacher identities and conceptions of the nature of science were reflected in their pedagogical commitments, reinforcing the work of Helms (1998) who found that teachers actively attempted to connect their discipline to other aspects of their lives, and connect other aspects of their lives to their discipline. In this storyline, I highlight the ways in which participants' science/teacher identities permeated every aspect of their storied lives, like threads weaved between each of their figured worlds. I want to be clear that in this section I am not presenting shared pedagogical commitments across my participants but rather a shared phenomenon of their pedagogical commitments reflecting aspects of their individual identities, and conceptions of science. Additionally, based on the stories teachers shared with me, I would argue for the female participants, not only did they infuse into their pedagogy aspects of what they were personally passionate about, but they also implemented a feminist ethic of care. I want to be clear in saying that I am not suggesting the female teachers in this study did or did not infuse topics related to a feminist view of science, but rather in response to experiences of marginalization, they made deliberate pedagogical choices pushing back against exclusivity in science.

Steven's stories emphasized the importance of creativity in his personal and professional identities, throughout his figured worlds of high school and home-life, from his art projects to woodworking hobbies he shared with his son and his father. He embraced conceptions of the nature of science that aligned to creativity such as the work of Richard Feynman, who emphasized the creative and artistic elements in science rather than a conception of science as prescriptive and unimaginative. His middle school science teacher's enthusiasm represented to Steven a way to bring creativity into science teaching, something he later emulated in his own classroom.

Steven's teaching style was reflective of his passion for creativity, by infusing aspects of his favorite movies into teaching as well as in the lesson plans he chose to share with me. In one of the lessons in particular, Steven provided his students with an engineering design notebook, where students were asked to design engineering equipment. This lesson incorporated opportunities for students to be creative by asking them to imagine and create and also included aspects of storytelling.

Oliver described himself as being the best in everything that he did, including teaching. Rather than situated in a characteristic of science, Oliver's science/teacher identity was situated in his own achievements and being recognized for those achievements. Specifically, Oliver wanted to be recognized as being more than a science teacher, often referencing his previous career positions in his stories as well as the many research experiences he participated in since becoming a teacher. He strongly identified with his status as second career teacher, describing himself as a teacher who could offer more to his students than his first-career science teacher colleagues. This identity of science was reflected in aspects of his conception of the nature of science as well as how he presented science to his students. Oliver viewed the nature of science as something only certain individuals, perhaps the best individuals, could be good at it, and therefore not an avenue for all of his students to go down. However, because of his experiences outside of teaching, he felt he brought the real-world science to his students through the stories he shared with them.

Oliver positioned himself as someone who understood the fundamental knowledge necessary to be successful in science. The value he placed on content knowledge was also relevant in his teaching, as he described presenting this knowledge to his students, like in the example of nomenclature, and many of his students struggling to understand it. Even after his participation in the Neutron RET, where the program goals were to emphasize a conception of the nature of science as interdisciplinary rather than as an accumulation of discrete bits of content, it appeared that such a view of science had not yet made it into his lessons. When I asked him to share a lesson that best exemplified the presentation of the nature of science to students, the objectives centered around students comparing and contrasting the different properties of polymers.

A constant theme across all of John’s stories, both in and outside of science teaching, was a deep sense of wonder and excitement about the animal kingdom and all of the biodiversity within it. When I asked John to share stories that reflected his conceptions of the nature of science, he began by sharing memories from his childhood where he would find and collect different animals near his home, with the numerous stories of doing research related to animals with scientists. John's conception of the nature of science as well as his science/teacher identity revolved around animals, specifically collection and identification of animals. Therefore, it did not come as a surprise when John shared stories from his figured world of teaching, that he embedded animal collection and identification into his science lessons as well as very structure of his classroom.

John had a classroom zoo and found numerous ways of imbuing the zoo into his pedagogical practice. He would assign each student an animal to have responsibility over and to learn about. His students would share their knowledge with visitors at the local museum as well as with the elementary students in the district. Additionally, the majority of lessons and student work John shared with me centered around collection, identification, and classification.

Helen began her interview with stories related to where she was born and the ways in which her parents worked hard to ensure she and her brothers had a better life. From an early age, Helen was aware of the opportunities that might be afforded to her in relation to her education here in the United States, as opposed to her home country of Guyana. This appeared to be the beginning of an identity shaped around the question of who receives certain opportunities and who does not. As Helen described her figured world of high school science, she often compared her privileged science opportunities in her small cohort of students to the experiences of most other students in her public education system, realizing she was afforded opportunities in relation to science education, such as resources and facilities, that other students in her district did not.

Her social justice identity was further stabilized during her experience in the science classroom where she witnessed the marginalization of students based on their disability. Helen referenced this story when I asked her why she made the decision to become a teacher. Maulucci Rivera (2013) wrote, when examining teacher identities in relationship to social justice, "emotions influence the goals teachers set and indicate the intensity of their relationships to ideas, to their beliefs about science, to others, and to science teaching" (p. 137). Based on the stories she shared, as well as the fact that Helen did not share lesson plans with me, it was difficult to identify the ways in which social justice impacted her teaching practice. However, related to the findings of Maulucci Rivera (2013), what was evident, was how clearly a sense of social justice informed Helen's decision to leave her position as an engineer and pursue a career in teaching, which I would argue reflects one component of her pedagogical commitment.

For Denise, her stories about her conception of the nature of science and science/teacher were tied to two larger storylines. The first storyline revolved around finding science fascinating and adventurous, where she shared stories from her early adventures in the local creek to what she described as her morbid love of bones developed in her anthropology course. When I asked Denise how her students would describe her as a teacher, she said fun and exciting, likening her classroom to an adventure. She described her teaching practices as innovative and out of the box, attributing these characteristics to her experiences prior to teaching.

Along with her conceptions of science as fun and exciting to the classroom, she also shared stories related to her science/teacher identity and conception of the nature of science situated within marginalization. From her own experiences, she implemented pedagogy grounded in the belief that all students deserved the opportunity to pursue degrees and careers in science, fostering a sense of belonging rather than feeling like outsiders. She felt her experiences of being othered influenced the way she taught science, by exposing students to different science careers, and doing it in ways that were engaging. Although Denise is no longer in the middle school science classroom, she expressed that she brings the same aspects of her science/teacher identity described above to her current position in science teacher professional development.

When I asked Denise to share classroom materials reflecting her conception of the nature of science, the materials more closely aligned to her first storyline. Denise provided lesson plans and other materials where students participated in paleontology activities, going out to a nearby fossil rich location, providing students with experiences similar to the one she had in the Biosphere RET. Although her beliefs about inclusive teaching were clearly emphasized in her stories about science and science teaching, they were harder to locate within her actual classroom materials.

For Louise, every aspect of her storied identity was intertwined with her love of art and nature. She described having a love of maps from an early age, which combined both of these passions as a way to understand the world. Over the course of her teaching career, Louise taught both music and science, since she was equally qualified in both areas. More than simply infusing what she loved into her pedagogy, Louise brought into her teaching a deep belief that science must be presented in languages that everyone can understand. Much of Louise’s science/teacher identity was centered around being an outsider in the physical sciences, feeling as though she did not understand the language being used to access the content of the courses. In contrast, Louise felt welcomed and very capable in the life sciences, a branch of science she felt she understood the language of. Prior to teaching, she was able to make connections between her other passions and the life sciences, allowing her to recognize herself in subjects such as geography.

Louise infused her passions of art and non-verbal ways of knowing into the lessons she developed for her students, providing the space for her students to stabilize positive identities in the physical sciences, a space she felt she did not have. She used storybooks, modelling, and other artistic forms of expression as ways for students understand and represent their understanding of science in her classroom. Through this process of supporting a positive identity formation in her students through non-traditional ways of knowing in a science class, she worked to destabilize her own deficit identity in the physical sciences. In addition to the in-depth description of several of her lessons in the stories she shared with me, in the actual classroom materials Louise provided, students were asked to develop a 3D printed human fossils, which also reflected her passion for marrying art and science into her pedagogical practices.

The findings presented in this storyline support the work of Helms (1998), who suggested that “understanding the relationship between subject matter and a teacher’s sense of self can inform teacher educators and researchers about a teacher’s pedagogical commitments” (p. 832). However, this study expands upon this work by highlighting the ways in which teachers who have experienced marginalization may be more inclined to implement aspects of feminist pedagogy in their teaching, as opposed to teachers who always felt welcomed within their figured worlds of science.

Discussion

As a theoretical framework, ecofeminism is evidenced in every facet of this study, including the findings presented in chapters four and five. Ecofeminism served as the lens by which I viewed my participants’ stories about their science/teacher identities, as well as their conceptions around the nature of science and the language they used to share those stories with me. Given the findings in chapters four and five, and using the theoretical framework of ecofeminism as a guide, my discussion is organized around the following two questions*: Who participates in RET programs? And what is considered real-world science?*

The first question is guided by ecofeminism, and feminism more broadly, as it asks not only who participates, but who is afforded an opportunity to participate. According to Gaventa and Cornwall (2001):

> Knowledge, as much as any resource, determines definitions of what is conceived as important, as possible, for and by whom. Through access to knowledge, and participation in its production, use and dissemination, actors can affect the boundaries and indeed the conceptualization of the possible. In some situations, the asymmetrical control of knowledge productions of others can severely limit the possibilities which can either be imagined or acted upon; in other situations, agency in the process of knowledge production, or co-production with others, can broaden these boundaries enormously (p. 72)

As RETs provide opportunities for knowledge generation both within the field of science and science education, by looking at who is afforded certain opportunities within RETs, the questions of who participates addresses issues of power and equity. Although the categories of who participates may not each depict a clear connection to ecofeminism, I would argue it is the process of questioning that is a ecofeminist/feminist act.

The second question is also representative of the lens of ecofeminism. As discussed in a previous chapter, ecofeminism, and other forms of feminism, are greatly concerned with the way language is employed. According to Patel (2015), “all language is, to a certain extent, metaphorical and therefore representative, a signifier of something else and all texts and textual practices are socially and culturally situated” (p. 26). The term “real” is used often, and I would, argue, too casually. It is used metaphorically as a place-holder of what is hoped to be achieved in science classrooms, the golden standard of school science. However, across the literature on RETs, as well as in policy documents, I would argue it is never actually defined, but rather left open-ended, suggesting that it is doing what the scientists do. This leads to the assumption that there is only one real way to do science. However, the word science inherently implies knowledge production, as the very word means, "to know." Therefore, by suggesting only a singular version of science, there is also a suggestion that there is only a singular way to know. Therefore, we are left asking the questions about the knowledge generated by this so called 'real-world' science: "Whose knowledges? Where and how obtained, by whom, from whom, and for what purposes" (Olesen, 2011, p. 129)?

Who Participates in RETs?

When looking across my participants there were several ways in which they held shared science/teacher identities. In this section I discuss these shared identities as well as provide a critical examination of who has the opportunity to participate in RET programs. Although I recognize my findings are limited due to the number of teachers in the study as well as how the teachers were selected to participate, something which I discuss later in my section on limitations, the following three shared science/teacher identities are included in this section: (1) identities as second-career science teachers; (2) identities as go-getters, science prototypes, and research enthusiasts; and (3) identities as representative of the dominant demographic in science. I do not claim the identities in this section are exhaustive of ways in which my participants were similar, rather it is representative of the stories they shared with me as well as the lenses by which I analyzed those stories.

Identities as Second-Career Science Teachers.[4] Only one of my participants chose teaching as their first career. For the remainder of the participants selected for this study, teaching science was not their first option. In fact, only one teacher received an undergraduate degree in teaching before entering the classroom. The remaining teachers in this study came to teaching after first pursuing careers in science or what some may characterize as science adjacent fields, some due to social factors and others due to personal factors (Vaidya & Thompson, 2020). I refer to social factors and personal factors as described in the work of Vaidya and Thompson (2020):

> Social factors include a changing economy, losing one's job, or changing location and being unable to find an alternative job in the same field. Personal factors include being dissatisfied with one's previous job, looking for a challenge, the desire to make a difference, having a long-standing desire to be a teacher, desiring a sociable environment, wanting a work/life balance, perceiving a career fit based on personal ability and prior career and personal experience (p. 108).

For Oliver, teaching was not his first option, and may not have been an option at all if he had not lost his job due to the 2008 recession. For Helen and Steven, teaching offered an attractive alternative to their current positions as engineers, which they found strangling and isolating. Denise and Louise both stated that the teaching career offered them positions that aligned to their figured world as moms. In the literature around second-career teachers, researchers have found that the teaching profession offers more time with family when compared

[4] I use the term second-career science teach to represent anyone whose first career was not science teaching, even if science teaching was a third, fourth, fifth, etc. career

to other career options, making teaching an attractive alternative for some with families (Watt et al., 2007).

The second-career science teachers in my study often emphasized that since teaching was not their first career, they could offer more to their students. This is not a unique finding as it relates to science teachers who have switched into the field from a previous career. Looking across the literature on the induction of second career science teachers, Ruitenburg and Tigchelaar (2021) found that second career teachers desired recognition for their previous work and what they have to offer because of it. They found this limited how effective teachers found their professional development to be, and possibly decreased retention of second career teachers. Therefore, they suggested that induction programs, and professional development more generally, recognize “what second-career teachers need and have to offer” which in turn “may foster teacher quantity, teacher quality, and school development” (p. 12). My findings support the ability of RETs to provide this type of professional development for second career science teachers, by offering them a sense of recognition.

Identities as Go-Getters, Being Science Prototypes, and Research Enthusiasts. A general pattern across my participants was their goal of being go-getters. Their desire for continuous self-improvement often related to why they applied to an RET in the first place. Helen described herself as someone who is only going to do something if its “going to be done right” (Helen Interview, July 12, 2022). Other participants recognized themselves and were recognized by their administrators for being ambitious and effective science teachers. In Oliver’s stories, he often referenced that he was the best and constantly looked for ways to keep being the best, and felt his administrator recognized him for his efforts because it made them both look good. Denise described herself as a go getter, being recognized by her principal as a "workhorse."

In addition to being self-motivated, participants often identified as what I am referring to as being a science prototype.[5] This description is based on who is often typecast as a science person by popular media and other forms of representation, similar to that of the celebrated subject position (Carlone et al., 2014). By saying my participants were science prototypes, I am referencing them as individuals with certain qualities, like loving to learn, being curious about their science content, and liking things that are typically associated with science, such as but not limited to nature, animals, lab work, listening to lectures, or taking notes.

In addition to being science prototypes, all but one participant in this study took part in more than one RET, or other RET like programs, leading me to refer to them as research enthusiasts. It seemed they were individuals drawn to programs like RETs where they could engage in science related things. Oliver touted the many RET and RET type programs as a way to receive publications and recognition, but also as a better alternative for work than summer school. He also mentioned that he could not seem to understand why other science teachers did not choose to participate in RETs. John found himself engaging in RETs and RET like programs even prior to his teaching tenure and even pursuing such experiences on his personal vacation time. He referenced doing RET-type experiences as being a part of who he was.

Similar to Oliver, John expressed that when he was working with Gary, the PI of the Biosphere RET, to recruit participants into the program, he was amazed at how difficult it was.

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[5] According to Merriam-Webster, the word prototype is defined as "an original model on which something is patterned"

He characterized some teachers as being like him, sharing an excitement to participate in science research, but the majority as teachers who barely go outside. Although Helen did not participate in other RETs, she did mention doing shorter science research-based workshops as opportunities to gain professional development hours. Therefore, all but one teacher included in this study had applied and been accepted to more than one RET or RET-type program at the time of their participation in this study.

Identities as Representative of the Dominant Demographic in Science. As mentioned throughout this paper, individuals who tend to fulfill the RET archetype, tend to also mirror the dominant demographic in science, as being white, and often male. Although half of my study participants identified as male and half as female, four out of six identified as white or Caucasian. Despite the majority of RET participants reported as identifying as white, very few studies on RETs discussed the race or ethnicity of the participating teachers with respect to participation and outcomes. In the few cases where researchers specifically reported that their pool of participants was “diverse,” evidential ethnicity data was often left out (Baker & Kelly, 2010; Dresner & Worley, 2006; Enderle et al., 2014; Grove et al., 2009). Although many papers include only a subsample of RET participants, as was the case in this study, this not only presents a discrepancy in those who tend to apply and get accepted into RET programs, but also in the way RET programs are researched. If programs are indeed recruiting and admitting more diverse pools of applicants into their programs, but are only reporting out on a majority of white applicants, measures of success and future implications for programs are being skewed in favor of meeting the needs of white teachers.

Not only does the literature on RETs lack details on teacher demographic, but it reported even less on the demographics of the participating teachers’ student populations, the types of communities (i.e., urban, suburban, or rural) in which they worked, the type of school system (i.e., public, private, or charter) their schools were in, or the particular level of classes teachers taught (i.e., general education, honors, advanced placement, or international baccalaureate). As I discussed in my review, although the NSF intended to "to increase the participation of underrepresented groups" in research experiences, the literature rarely indicates diversity as a priority in the student populations those teachers serve (NSF, 2021, para. 3).

Despite the fact that my interview questions did not aim to uncover specific demographic statistics of participants' students, I was able to examine their district demographics using public databases. In the following paragraphs, I present the demographic data for my participants, based on the data provided by NCES, and other public data sources, as well as the participants own descriptions of their students. Although my study was limited in the number of teachers and RETs I examined, I argue my findings may still present valuable contributions to the conversation around which students are benefiting from teachers participating in RET programs at large, something I discuss in more detail in the implications section that follows.

For four out of six of the teachers in this study, the student demographics of the districts in which they taught were comprised of a majority of white students. However, I recognize that looking at databases may not always capture the most accurate description of a student population. Although the district data present her district as predominantly white, Denise described her student population as mainly Hispanic, and her school as "Title I," where the majority of students received free and reduced lunch, and located in a low-income neighborhood. However, despite Denise's students fitting the description of a population less inclined to pursue the field of science, she also explained that the majority of classes she taught were for the advanced and gifted students in her school. Similarly, although Olivers district is comprised of nearly 80% Hispanic students, he told me that he only teaches honors courses. Although this only represents two of my participants, it is an aspect of RET recruitment that I personally can speak to. During my own application to a RET program, I encountered individuals involved in recruitment who felt that because I taught predominantly special needs students, my participation in the RET would be providing valuable resources to a population less inclined to pursue science. Although I highlight this aspect in my findings, I do not want to suggest that teachers of honor or advanced students should not participate in RET programs. However, it does raise questions of access and inclusion regarding the student populations whose teachers participate in RET programs.

When speaking with my participants, they recognized that although the graduate students they worked with in the lab and field were diverse in terms of ethnicity and biological sex, the principal investigators of the labs tended to be white males. This finding in my study mirrored what was found in my review of the literature, where the majority of science mentors, when demographics were provided, were male, unfortunately perpetuating the idea that men are more inclined to be science people. (Barnes et al, 2006; Blanchard et al, 2009; Dixon & Wilke, 2007; Hughes et al, 2012; Mirando & D’Amico, 2013). This finding also harkens back to the patriarchal language used by Denise and Louise when talking about the scientists in the fields, as I discussed in an earlier section of this chapter. According to the framework of ecofeminism, and feminism more broadly, by having mostly white males as mentors to science teachers, and particularly to female science teachers and science teachers of color, RETs are perpetuating the idea that it is white men who hold the power in science.

What Is Considered Real-World Science?

One major finding of my literature review was the wide-ranging use of the terms real-world and authentic as they related to science. Throughout the RET literature, these two terms are used ubiquitously, often being touted as a goal of RET programs, while almost always going undefined. This presents a dilemma for the practical implications that teachers implement real-world science in their classrooms. By using these terms without clarity, researchers often reflect positivist and/or anthropocentric views, resulting in a lack of clarity and an overly simplistic view of what real-world science might mean (Blanchard et al., 2009; Dresner & Worley, 2006b; McLaughlin & MacFadden, 2014). In this section, I discuss the different ways my participants used the terms real-world/real science.

Helen went through her science career with an understanding that being good at science meant taking discipline specific science courses and passing discipline specific science exams. Helen's own science learning placed little emphasis on the role of investigation in science and science as interdisciplinary. Even after working as an engineer, her perceptions of how science should be taught in the classroom stayed the same. It was not until Helen's experience in the Neutron RET that her conception of the nature of science began to shift. By participating in scientific research, Helen's conceptions of science broadened to encompass more about investigation and less about answering questions on a test. By participating in the RET, she was exposed to how interdisciplinary scientific research actually is, an aspect of the nature of science reported as a result of participating in RETs in other RET studies (McLaughlin & MacFadden, 2014). This broadened conception of science as interdisciplinary allowed Helen to see how much overlap there was between the discipline of chemistry, which she had taught prior to the RET, and the discipline of physics, which she would go on to teach afterwards.

Helen was not alone in her shift in seeing science as interdisciplinary after participating in an RET. As mentioned above, Steven also began to perceive science as interdisciplinary while working in research in the Neutron RET. Denise also took away a conception that science disciplines intersect. However, beyond simply seeing the relationship between different science disciplines, Denise saw an even broader conception of the interdisciplinary nature of science. In her visual she used different symbols to represent that “Science is about health, science is about the economy, science is about governments” (Denise Interview, March 13, 2022). She went on to say:

> It [science] can help us in all kinds of areas because a lot of the inventions that happen or the things that we're using are because of science and the reason why we have those things. I mean, I even think sadly, just with the wars and the things that are going on, some of that is science related, right? I mean it seems like a lot of wars are initiated, either because of religious beliefs or some kind of resource that we want, which has a scientific element to it, you know or space, which again, you know, ecosystems and resources and space to live, all have this underlying science element to it in a way. (Denise Interview, March 13, 2022)

Denise’s visual representation of science pushed further than the other two participants conceptions of science as interdisciplinary, and I would argue aligned more closely to critical conceptions of interdisciplinary science. Erduran (2014) described science as “inherently interdisciplinary” including aspects of “history, philosophy, psychology and economics” (p. 98). However, I would suggest that Denise’s conception of science as interdisciplinary included components of an ecofeminist conception as well.

At the same time, when Denise used the term “real-world science,” it was not in reference to interdisciplinarity, but rather concerning the way scientists become known for their work. Her discussion pertained particularly to the field of paleontology; the field of science emphasized in the Biosphere RET. She expressed real-world science as collecting specimens that might make their way into a museum or get mentioned in a publication. She placed extra emphasis on the fact that if you are the one to find that specimen, then your name, as the collector, becomes the name of the specimen. For Denise, this was one aspect of real-world science and this highlights two important features of Denise’s conception around the nature of science. The first is that real-science results in publications and being recognized for your work, a conception similar to that of Steven and John. The second is that popular conceptions of real-science are often situated within anthropocentric norms, a view that is representative of larger debates within the scientific community today and reflected in efforts of decolonization.

Over the last decade, numerous efforts have been made towards decolonizing certain sciences such as archeology and anthropology (Silliman, 2010; Two Bears, 2022). Even more recently, work has been done to decolonize the fields of geology and paleontology as well (Cisneros et al., 2022; Raja et al., 2022). In fields centered around discovery and collection of specimens, there are often patterns of exploitation. Often referred to as “parachute science” or “parasitic science,” scientific colonialism has its foundations in the perception of middle- and low-income countries as suppliers of data and specimens for the high-income ones, devaluing and sometimes even ignoring altogether the contributions of local collaborators (Cisneros et al., 2022, p. 2). Although there was ample evidence from my interviews and from other program materials that the Biosphere RET worked in some capacity with a local museum and local field coordinators, it was also the case that references by participants to local or indigenous contributors to the scientific work being done was limited. This is not surprising as there is a "notable lack of publications being led by local scientists in many regions outside of North America and Europe" and when collaboration does take place "the privilege of first authorship usually goes to foreign researchers, rather than creating an equitable partnership" with the local communities (Raja et al., 2022, p. 150).

When examining Steven's and Louise's use of the term real-world science, I noticed they often used it to contrast the science that was happening in the classroom, or classroom science. Their use of real-world science was similar to the work of Miranda and D'Amico (2015) when they reference the "dichotomy of real-world and classroom science" (p. 1258). At the same time, Miranda and Damico (2015) emphasized the idea that classroom science should emulate real-world science.

In Steven's storied identity, although he felt that the RET presented him with a better idea of what real-world science looked like, he still felt there was a distinction between what real-world science was, and what science could be in the classroom. Steven found he was able to replicate certain features of real-world science in his classroom, such as increasing student questioning, relying less on text-books, and emphasizing science as interdisciplinary. He also felt that he could share his experiences in the RET with his students to give them a better idea of what real-science looked like, such as the tedious aspects of lab work. However, despite his shift in teaching science as a process rather than a list of facts, he still felt he could not fully immerse students in real-science. Additionally, for Steven, in order for science to be real, individuals must be working towards an "end goal" (Steven Interview, May 5, 2022). However, this leads me to ask the following questions about the phrase "end goal:" Can students in classrooms be doing science that is working towards an end goal? Does working toward an end goal only mean science that leads to a publication or contributes to an achievement in medicine? Are all classrooms equipped with the necessary tools and resources to be doing the types of things that contribute to an end goal? Although this may in fact be an unattainable goal, I would argue that it be a part of the discussion amongst RET facilitators and the NSF. This last question became even more evident in Louise's science storied identity.

Louise also held to the idea that there was a dichotomy between classroom science and real-world science. However, for Louise, this dichotomy was situated in the impracticalities of teaching and implementing scientific inquiry in a classroom with many students. There was one story that I did not include in Louise's storied science identity that I have chosen to include here. When I asked Louise how she would define scientific inquiry, she responded: "That's a really good question. It's a troubling question, too." Louise elaborated:

> Teaching based on inquiry is a really, really tricky proposition if you've got 150 kids. So, I think that that's my basic answer right there. It's an unknown quantity when you've got 150 kids. I mediate the best I can, by encouraging as much questioning as I can. . . But kids' questions drive my curriculum design, but sometimes not until the next year. So that's the best I can do with inquiry. I have yet to find or think of a way to run a classroom that is satisfying for all of us. (Louise Interview, March 25, 2022)

In this quote, Louise points out a common dilemma teachers run into in many classrooms across the United States, and likely in other countries as well. Teachers feel they are in classrooms with too many students and too few resources in order to practically implement "real" science or scientific inquiry, especially when there is little clarity as to what those words actually mean. In Louise's story, I can infer that real scientific inquiry meant having each student devise an investigation with little to no parameters, driven by student questions and requiring an unknown quantity of unknown materials. In terms of practicality, I would side with Louise in saying this is indeed impractical.

This section of my discussion highlights the urgent need of the NSF and RET facilitators to take the time to determine what it is they mean by real-world science. As highlighted here, by maintaining ambiguity in their calls for RETs, NSF as well as other organizations working to improve science education, may in fact be providing a disservice to classroom teachers who are caught in the middle of an expectation for their science classrooms and the inability to enact such an expectation. In addition to being a disservice, by keeping the phrase real-world science vague, the NSF and others may be contributing to continued acts of harm against those who hold views of science outside of the western conception. In the following section, I provide an overview of my findings in chapters four and five, implications for RET program developers, the limitations of my research, as well as recommendations for future research.

Conclusion

This study aimed to investigate a problem situated between Research Experience for Teachers and science teacher identities. More specifically, this study addressed how the figured world of the RET and other figured worlds of science that teacher's experience, impacted their conceptions around the nature of science and their identities in science and as science teachers. Research experiences for teachers (RETs) are highly valued for their role in the professional development of science teachers, presenting teachers with firsthand experiences with science.

The main premise behind RET programs is that by partnering science teachers with scientists as mentors, science teachers will glean insight about science from the scientists that they can bring back into their classrooms. Currently, although there is a significant body of literature around the impacts of RETs as sites of professional development for science teachers, review of the literature suggests several gaps within the literature that this study aimed to address. Specifically, when talking about the conceptions of the nature of science, RET literature typically uses conceptions put forth by Lederman et al. (2002) or the Next Generation Science Standards, whereas very little work has been taken to apply critical frameworks. This study, by implementing the framework of ecofeminism and figured worlds, highlighted aspects of RETs that need consideration.

First, although the NSF aims “to increase the participation of underrepresented groups” (NSF, 2021, p. para 3) the current literature rarely indicated diversity as a priority in teacher recruitment or the student populations those teachers serve. Specifically, even when teachers taught within districts designated as underrepresented by the NSF, it was unclear what specific population of students those teachers were teaching within their individual classrooms. Within this study, by examining not only teachers’ district demographics, but also their individual classroom populations, this study supports the notion that RETs may be admitting teachers that teach higher level courses over those who may teacher general education, remedial courses, or students with special needs, behavior disabilities, and/or learning disabilities.

Second, the current literature on RETs indicated scholars are not always intentional about the terms and metaphors they choose to use to describe the relationships between teachers and scientists in an RET. For example, in the literature such terms as apprentice or at the elbow are used in positive ways to describe the relationship of the teacher to the mentor scientists. However, by using such language, RET scholars were unintentionally propagating patriarchal epistemologies about who holds the knowledge within the relationship as well as the worth associated with science teacher expertise. Scholars of ecofeminist research argued that by continuing the use of language that supports deficit perspectives, researchers may inadvertently be contributing to harm.

Third, the term “real-world science” is used by scholars in varying ways throughout the RET literature. While this lack of clarity leads to issues with implementation in the classroom, it also has the potential to reproduce simplistic, positivist, and anthropocentric views of science. For example, RET literature is often silent, as is the NGSS, around issues of environmental justice and discrimination within the field of science. Additionally, by using the term real without clarity, it infers there is simply one view of science, most often mirroring that of western science.

Teachers in this study provided limited evidence of working with contributors of local communities and/or Indigenous populations. This lack of acknowledgement of local and/or indigenous contributions to science suggest the need for RETs to make initiatives to collaborate with indigenous populations in the development of future RET programs, working towards diversifying what is meant by the phrase real-world science. My findings also supported the notion that there is an inconsistency between the directive of real-word science and the implementation of real-world science in the classroom. Even more so, teachers within this study supported the belief that real-world science and classroom science are dichotomous.

Finally, although there are several studies that discuss teacher beliefs around science, very few studies explicitly center around science teacher identity. If RETs are meant to impact the way teachers perceive the nature of science, then researchers must take up the task of examining how experiences with research impact those perceptions. By focusing particularly on the figured worlds of science teachers, this study addressed the gap in the literature, highlighting ways in which teachers' figured worlds of science impacted participants' identities in science and as science teachers.

Throughout the collection and analysis of my findings, I used the framework of figured worlds, as it represents identity through a series of overlapping and intermingled experiences (or figured worlds) with others (human and non-human), places, and events. By using this framework in my analysis, several findings emerged related to identity construction of science teachers and their conceptions of science that contribute to the body of literature on RETs, while also addressing both my first and second research questions.

First when discussing the identity of science teachers, it is important to recognize that their identities as teachers and identities in science are inextricably linked, something I referred to within my study as science/teacher identities. Second, it is equally as difficult to separate science/teacher identities from their conceptions of science. Across the RET scholarship, these two constructs are often presented as distinct from one another, or even more often, identity is left out completely. This study supports the work of Helms (1998) who discussed a teacher's identity as inextricably linked to their subject matter, finding that science teachers in particular develop identities in science and in teaching relative to their conception of what science is.

Third, by examining science teachers' identities and conceptions of science using the framework of figured worlds, my work supported that of Barton et al. (2013) who discussed identity development in terms of stabilization and destabilization. This study supported the notion that as science teachers move through figured worlds of science, their science/teacher identities and conceptions of science are in constant flux. Therefore, it is important to recognize the impact different figured worlds of science can have on science teachers and their conceptions of the nature of science as well as how they see themselves within science. Recognizing that certain experiences, including RETs, can work to stabilize, or destabilize an identity as a science person or quite possibly as someone who is not welcomed within the science community.

In regards to my third research question, by looking across science teachers' storied science identities, I identified four shared storylines related to their science/teacher identities and/or their conceptions around the nature of sciences: 1) The impact of elementary and middle school science figured worlds on science/teacher identity; 2) The roles of recognition and sense of belonging in the development of science/teacher identity; 3) Science/teacher's identity informing pedagogical practice and commitments; and 4) Science teachers feeling valued for their role as expert communicators in RETs.

For the majority of my participants, a key feature of their stories about science was the inclusion of a story related to a particular science teacher who they found to be memorable. More importantly, participants attributed this teacher as someone who provided them with a sense of recognition for being a science person (Carlone & Johnson, 2007). However, by examining participants more closely, for some of my participants (two females) they valued, more than being recognized for what they could do, having a sense of belonging within the science community. This finding supports the work of Hazari et al. (2020), by suggesting that for young women, feelings of belonging are crucial for their persistence in science.

Throughout the figured worlds of science, the storyline of recognition and sense of belonging was persistent. Additionally, it became evident that there was a relationship between sense of belonging and issues of language, similar to those presented in my review of the literature around RETs. Specifically, for two of my participants, despite expressing feelings of feeling welcomed within the science community of RETs, they still used language that reflected mentor scientists as the holders of knowledge and authority. Such language included the term "big wig" in reference to scientists, "neophyte" in reference to themselves, and "extension of" in reference to the relationship of teacher to scientist.

I would be remiss if I did not point out that Oliver and Steven, two of the male participants in this study, did not come to their RET programs with deficit science identities. They already felt like they fit in within scientific spaces, and wanted to be recognized for the contributions they were making, in the form of publications. However, for Denise and Louise, both identifying as female, they came to the RET with stabilized identities that suggested they were not science people. Therefore, rather than longing to be recognized, I would argue they were looking for a sense of belonging within science spaces. Therefore, RETs have a unique opportunity to provide individuals, who may have held science/teacher identities like an outsider, opportunities to be welcomed into scientific communities, and should take special consideration to foster feelings of belonging as well as opportunities for recognition.

However, despite teachers' different experiences related to the constructs of recognition and sense of belonging, female and male teachers, in both the Neutron and Biosphere RETs walked away from their experiences feeling valued as educators for their expertise in communicating. Therefore, the findings of this study support the work of Shanahan and Bechtel (2019) where teachers felt valued as expert communicators because but not for their science knowledge. This finding seemed even more stark for the two female teachers and highlights a need for clarity around the purpose of RET programs, and what the roles of teachers and scientists are meant to look like. Although teachers in this study felt valued as expert communicators, they did not feel recognized for the expertise they held in the field of science.

Lastly, when looking across storied science identities, it was evidenced that participant's science/teacher identities and conceptions of the nature of science were clearly reflected in their pedagogical commitments. Although this work supports that of Helms (1998) who found that teachers make connections between their lives and their disciplines, it also emphasizes the importance of RET programs and other science teacher professional development opportunities potential impact on teacher's classroom practice.

Implications

Throughout my discussion, I addressed questions related to who participates in RET programs as well as what RET participants describe as real-world science. Therefore, in the section that follows, I discuss implications, specifically as it relates to RET program recruitment and program design.

Recruitment

From the outset, it may appear that the participants of this study would be exactly the type of person expected to participate in an RET. RETs are voluntary professional development programs, targeted predominantly at science teachers, during their summer vacation. It might seem logical that it would be the go-getter, science prototype, research enthusiast who would jump on an opportunity to spend their summer in the lab or in the field, and get paid to do it. However, by recruiting the science archetype, not once, but multiple times in different RETs, RET programs may be neglecting the reason they were established in the first place. This is not to say that no individual should participate in more than one RET, however, RET and RET like programs may want to be more stringent in their selection process by selecting science teachers who may not have had opportunities to engage in research before. In fact, from Oliver's description, it appeared that he became more likely to be accepted in future programs, the more programs he completed.

It is not uncommon for science teachers to come to the field of teaching as second career seekers (Boyd et al., 2011; Ruitenburg & Tigchelaar, 2021). However, because RETs aim to address a need to provide science teachers with limited experience in research settings, opportunities to work in science research, they should perhaps look first to those teachers who have not worked in science fields prior to teaching or who have had limited experience working in science research. However, I make this recommendation with caution. From my study, it was evident that not all teachers held conceptions of the nature of science that aligned with the conception presented in the NGSS prior to their participation in the RET. For example, both Steven and Helen, who worked as engineers in the field, left their experience in the Neutron RET with shifts to their limited conceptions of science. After participation in the Neutron RET, Helen and Steven developed an understanding of the NOS as interdisciplinary as well as seeing the nature of science as messy, rather than an accumulation of facts. In contrast, and perhaps more glaring, in the case of Oliver, who had worked previously in a science-adjacent field and who held an undergraduate degree in science, came to the RET with a conception that science is comprised of discrete disciplines, and left the RET with an unchanged conception. These findings support the work of Antink-Meyer and Brown (2016) who found that even though teachers who previously worked in the field of science or engineering may be able to provide examples to their students based on those experiences, they may still hold a limited epistemological understanding of science.

In addition to enhancing recruitment strategies of teachers with limited experience in research, RETs should also continue to work towards diversifying the pool of teachers who participate. Although efforts have been made to target teachers of diverse populations as well as those who teach in schools located within areas of low-socioeconomic status, based on the findings from this study as well as a comprehensive review of the literature on RETs, RET programs still tend to attract predominantly White teachers. Future studies should examine the characteristics of RETs that currently serve as gatekeeping mechanisms, resulting in limited participation of teachers of color.

In addition to increasing participation of teachers of color, RETs should also look more closely at the types of classes teachers teach. Although participating teachers may teach diverse populations and/or in low socioeconomic areas, based on my findings, they appear to be teaching students in higher-level courses. Although some studies on RETs include teacher grade levels and/or content areas, they fail to include the level of course the teacher teaches. By accepting teachers who only teach students in honors, advanced placement (AP), or international baccalaureate (IB) courses, RETs are themselves serving as gatekeepers of which students receive the knowledge, skillsets, and resources teachers acquire from their participation. Research shows that even in diverse districts, there is still a tendency for higher level courses to be less diverse, with a majority of White and Asian students taking higher level courses, while a majority of Black and Hispanic students are in remedial courses, what some refer to as within-school racial segregation (Francis & Darity Jr., 2021). In addition to the possibility of accepting teachers with predominantly White population of students, they also may be limiting participation to teachers of students who are not classified with special needs or as neurodivergent. Once again, this speaks to who RETs, intentionally or unintentionally, decide is worthy enough to have their teacher participate in an RET program and who is supposed to be returning to the classroom with a better understanding of what so-called real-world science is.

Program Design

Similar to considering how to recruit diverse participants, RETs must also consider who is hosting RET programs. If teachers are supposed to be walking away from RETs with an understanding of what real-world science is, RETs must consider which scientists, which institutions, and whose version of science is being represented as ‘real-world.’ In this section, I discuss recommendations for RET program design, particularly in relation to my findings around the phrase real-world science.

Along with teacher participants being mainly White, and the possibility of their personal classroom demographics consisting of mostly White students, the Principal Investigators, based on the literature as well as the interview data from this study, also tend to be White and male. Although this study, as well as the literature available may not provide a comprehensive look of the PIs who host RETs, from what is available, data suggest the NSF needs to be more intentional when deciding which PIs have the opportunity to host research experiences for teachers, providing opportunities as well as seeking out scientists who identify as other than White male. Along similar lines, if it is a majority of White and male PIs applying to host RETs, then the NSF must closely examine why scientists of color, particularly female scientists of color, are less likely to want/be able to host an RET program at their universities.

In addition to the lack of PIs of color, the RET literature was limited in its inclusion of collaborators from local and indigenous communities as well as the collaboration of non-humans. Similarly, in the case of the Biosphere RET, if local or indigenous communities did play a role, the participants in this study neglected to acknowledge such collaborators. In regards to non-human collaborators, participants in the Biosphere RET often used anthropocentric language when talking about their experiences with fossils. Rather than acknowledging the contributions fossils made to their scientific understanding, participants seemed to discuss them as objects to collect as well as avenues to fame within the science community. These findings led me to the following recommendations for future RET programs to consider related to their program design.

Recommendations Related to Local, Indigenous, and Non-Human Collaborators. First, RET programs can make a greater effort to work in collaboration with local communities and indigenous populations. Although this type collaboration may be happening already, this was not evident in this study nor in my review of the literature around RETs. By encouraging RETs to collaborate with local and indigenous groups, I want to emphasize that when I use the term collaboration, I mean all parties involved receiving equal acknowledgement for the scientific work being done. RETs may also consider working alongside local and indigenous populations in the development of RET programs moving forward, allowing for the science represented in RET programs to include indigenous approaches to science and science learning, including Traditional Ecological Knowledge (Kimmerer, 2013; McGinty & Bang, 2016)

Second, and in relation to valuing the contributions of non-human collaborators RET facilitators can look to models outside of western conceptions of science for guidance. In her book Braiding Sweetgrass, Kimmerer (2013), indigenous scholar and scientist, revisited her own science experiences at university learning about Botany. She recalled,

> the questions scientists raised were not, “Who are you?” but, “What is it?” No one asked plants, “What can you tell us?” The primary question was “How does it work?” The botany I was taught was reductionist, mechanistic, and strictly objective. Plants were reduced to objects; they were not subjects. (p. 55)

She contrasted the conception of science presented by her science professors to an indigenous perspective of plants as contributors in the field of Botany. By incorporating indigenous as well as ecofeminist perspectives on science in RETs, not only those situated in the field of paleontology, but in any field of science, RETs may consider the role of non-human organisms as valuable contributors, rather than as specimen existing for the sole purpose of human need. By making such changes to program design, RET developers may reduce their role in the perpetuation of positivist and patriarchic practices, as well as begin a conversation around whose world is considered when using the phrase real-world science.

Clarity Regarding the Implementation of Real-World Science. In addition to considering whose world is reflected within the real-world science we want teachers to bring back to their classrooms, RET program and policy developers must provide greater clarity around what that means for practical implementation. In the development of my findings, I was confronted with new questions as a result of my discussions with participants, particularly Steven and Louise, regarding the dichotomy between classroom science and real-world science. Such questions include: Should the goal of classroom science be real-world science? Does teaching about real-world science equate to doing real-world science? Do only certain teachers have the necessary resources to teach "real-world" science in their classrooms?

According to Braund and Reiss (2019) "increasing divergence between science as practiced in the real world and science as represented in schools . . . was unhelpful for science students (p. 232). More specifically, presenting classroom science as different from real-world science, may impact student science identity development (Vincent-Ruz & Schunn, 2018). Perhaps we can start by addressing why the phrases real-world science and classroom science are presented as dichotomous. It seems this dichotomy often arises when science is presented in the classroom as a collection of facts rather than as a dynamic process. Although recent educational research and policy, such as the NGSS, have encouraged a move away from this style of science teaching, it appears that this science teaching cliché remains pervasive throughout everyday dialogue, cultural representations, and even actual classrooms. Television and movies still tend to present science classrooms as boring, filled with textbooks, with an occasional dissection or explosion, and science people as nerdy, good at memorizing facts, and lacking in creativity. Therefore, before RET programs and policy documents continue to profess a need to have real-world science in science classrooms, there must first be substantial work done to determine what the difference is between real-world science and classroom science, if indeed there is one.

Considerations Related to Logistics. Alongside considerations around the phrase real-world science, RETs may also consider how the logistics of their program design encourage or detract teachers from being able to participate. For both of the RETs included in this study, teachers were required to stay on site, sometimes a several hour drive or even a flight away from their home. Oliver mentioned his wife being supportive of his participation in such programs, nevertheless I could imagine a scenario where a spouse or partner may be less supportive. I could also envisage potential RET participants, especially if they are caretakers for parents, children, or others, unable to leave their responsibilities for a period of six-weeks. However, once again, I make my critique with caution.

Some of the characteristics of the RETs included in this study that participants appreciated the most were centered around their experience away, whether it provided them uninterrupted opportunities to think and learn, as was the case for Helen, or because it offered them an adventure of a lifetime, as was described by both Denise and Louise. Additionally, it is widely accepted within the professional development literature that conceptual change takes time, and programs short in duration have limited impact on teacher learning (Darling-Hammond et al., 2017). Therefore, by having programs take place over a period of six-weeks, RETs are more likely to influence science teachers' conceptions around the nature of science. I also want to highlight that my study only represents two RETs, and that other RET programs may target local communities of teachers and do not require them to stay on site or even travel long distances to participate. Therefore, in order to make a broader claim about RETs making their programs accessible to wider audiences of science teachers, I suggest a comprehensive examination of the types of RET programs offered in terms of location and proximity to participants place of residence.

Limitations

Although I make recommendations for RETs in general, I want to be transparent with the limitations of this study. First, although I had originally intended on including five RETs with teacher participants from different regions of the country, my study only included two programs with teacher participants from three regions, reducing the number of teachers from fifteen to six. However, even if I had obtained fifteen participants, it would have still only represented a very limited perspective of the teachers who participate in RET programs, therefore possibly decreasing the generalizability of my findings. Nevertheless, and even with a small sample size, my findings seem to support the type of teacher represented in the literature who chooses/is accepted into RET programs.

Additionally, in selecting my participants I was reliant on the recommendations of the program coordinators and PIs, as well as the willingness of the teachers to participate in my research. Although my sample size was small, and therefore may not have been representative of RET participants more generally, by having a majority of white participants agree to be a part of my study, I must consider the possible ways in which the recruitment strategies I used may have led to limited responsiveness from teachers of color.

Additionally, and as discussed in other sections of this paper, my data collection took place via zoom. Although I was still able to gather rich data from my participants in the form of interviews and classroom materials, my study could have been even more robust if I would have spent time with each participant in person. However, due to restrictions from COVID-19 as well as the timeline for my dissertation research, using zoom was the only reasonable method for data collection. Similarly, by having a majority of self-reported data, I did not address the limited data on RETs from classroom observation.

Opportunities for Future Research

Based on the findings presented in this study, as well as my discussion around who participates in RETs and the phrase real-world science, I offer recommendations for future research. First, in an effort to address the gap in the literature, I suggest future researchers move away from solely collecting self-reported data, and work to collect data from teachers both during their participation in their RET program, as well as in the consecutive years following their program experience, by visiting teacher classrooms and observing teachers' classroom practice. Currently, the large majority of research on RET programs is based on what teachers report after participating, however, very few studies actually continue their studies past the conclusion of the summer experience. Although RETs are typically six weeks in length, and therefore longer than many other forms of professional development, studies suggest it takes even longer for teachers to experience conceptual change (Hewson et al., 1998). Along with conceptual change, this also brings up the problem of enactment (Kennedy, 1999). Kennedy (1999) defines this problem as the phenomenon where teachers may seem to have learned a new concept, while at the same time continue to enact their original conceptions, often without having any idea that they are doing so. In the case of RETs, even if teachers do have a change in their conceptual thinking around the nature of science, it is possible and even likely that when they return to their classrooms, they will return to enacting practices reminiscent of their previous conceptions. Therefore, studies should focus specifically on addressing ways in which the problem of enactment may arise once teachers return to their classrooms, which would require the act of going to classrooms, rather than depending solely on teacher responses.

Second, in an effort to expand upon the findings of this study specifically, I suggest future work look specifically at the ways RET programs impact teachers' sense of belonging, paying particular attention to teachers who have felt as though they were excluded within their previous figured worlds of science. As was evidenced from this study, RETs provided two of the women in this study with a sense of belonging in the science community, something they had not always felt in other science spaces. This finding highlights an important possibility for RET programs to foster in individuals who may have experience marginalization in science before, to feel welcomed by scientific others. Even further, RETs may actually consider looking specifically for science teachers who have felt marginalized as a criterion for participation. However, simply accepting marginalized applicants does not necessitate developing a sense of belonging. Therefore, RETs must be intentional in not merely recruitment but in program design in order to reduce the possibility of further excluding those who have already been excluded.

Third, and in relationship to individuals who have felt othered, I suggest a more comprehensive examination of who is participating in RET programs as well as the recruitment strategies currently being deployed by RETs. The data around participating RET demographics still remains quite limited, and in order to meet the call of the NSF to diversify the demographics of the participants, we must first identify how far off the mark RET programs currently are. This would include taking more detailed demographic data of participants as well as collecting data from a much larger sample of RET programs. Based on my review of the literature as well as simply word of mouth or a google search, it is evident there are many RET and RET-type programs that are not being studied and/or reported on in the same way as to be included in a review of literature on RETs.

Lastly, based on the use of language in the literature and in the present study, I suggest scholars examine more closely the presentation of the nature of science presented in RET programs and in what ways more critical views of science, such as that of ecofeminism, can be infused within their program structure and development. I also suggest studies work to identify programs that may already be using non-western views of science, in an effort to bring to the forefront how those programs work and ways to expand their approaches more broadly across RET and RET like professional development opportunities for science teachers.

Concluding Remarks

This study suggests that RETs, as figured worlds of science, shape science/teacher identities and their conceptions around the nature of science, in turn impacting science teachers' classroom practice. However, it also highlights the need for RETs to take an even more critical examination of the teachers who are participating, the scientists teachers are paired with, as well as the students who those teachers teach. Additionally, RETs and science policy documents need to do better when it comes to the language they use in relationship to the nature of science and science learning. By continuing to use phrases such as real-world science, they are aiding in the perpetuation of limited perspectives of science that perpetuate positivist, patriarchal, and anthropocentric views of science as well as excluding those who practice non-western views of science as valid contributors.

References

AAAS. (1990). *Project 2061: Science for all Americans*. Washington, DC.

Abd-El-Khalick, F. (2012). Examining the sources for our understandings about science: enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education, 34*(3), 353–374. https://doi.org/10.1080/09500693.2011.629013

Alshamrani, S. M. (2008). Context, accuracy and level of inclusion of nature of science concepts in current high school physics textbooks. *Dissertation*.

Antink-Meyer, A., & Brown, R. A. (2016). Second-career science teachers’ classroom conceptions of science and engineering practices examined through the lens of their professional histories. *International Journal of Science Education, 39*(11), 1511–1528. https://doi.org/https://doi.org/10.1080/09500693.2017.1338787

Autenrieth, R. L., Lewis, C. W., & Butler-Purry, K. L. (2017). Long-term impact of the enrichment experiences in engineering (E3) summer teacher program. *Journal of STEM Education*, *18*(1), 25–31.

Avraamidou, L. (2014). Developing a reform-minded science teaching identity: the role of informal science environments. *Journal of Science Teacher Education*, *25*(7), 823–843. https://doi.org/10.1007/s10972-014-9395-y

Avraamidou, L. (2019a). Science identity as a landscape of becoming: rethinking recognition and emotions through an intersectionality lens. *Cultural Studies of Science Education, 15*(2), 323–345. https://doi.org/10.1007/s11422-019-09954-7

Avraamidou, L. (2019b). Stories we live, identities we build: how are elementary teachers' science identities shaped by their lived experiences? *Cultural Studies of Science Education, 14*(1), 33–59. https://doi.org/10.1007/s11422-017-9855-8

Bach, H. (2007). Composing a visual narrative inquiry In D. J. Clandinin (Ed.), *Handbook of narrative inquiry: mapping a methodology* (pp. 280–307). Sage.

Bahbah, S., Golden, B. W., Roseler, K., Elderle, P., Saka, Y., & Shoutherland, S. A. (2013). The influence of RET's on elementary and secondary grade teachers' views of scientific inquiry. *International Education Studies, 6*(1), 117–131. https://doi.org/10.5539/ies.v6n1p117

Bailey, L. E. (2012). Feminist research. In S. D. Lapan, M. T. Quartaroli, & F. J. Riemer (Eds.), *Qualitative research: An introduction to methods and designs* (pp. 391–422). Jossey-Bass.

Baker, W., & Keller, J. (2010). Science Teacher and Researcher (STAR) Program: Strengthening STEM education through authentic research experiences for preservice and early career teachers. *The Association of American Colleges and Universities, 12*(2), 22–26.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Cambell, K. M., & Weis, A. M. (2013). *Report of the 2012 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research, Inc. Retrieved from https://files.eric.ed.gov/fulltext/ED541798.pdf

Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Duke University Press. https://doi.org/10.1017/CBO9781107415324.004

Barnes, M. B., Hodge, E. M., Parker, M., & Koroly, M. J. (2006). The teacher research update experience: Perceptions of practicing science, mathematics, and technology teachers. *Journal of Science Teacher Education, 17*(3), 243-264. https://doi.org/10.1007/s10972-006-9007-6

Barton, A. C. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching, 35*(4), 379–394. https://doi.org/10.1002/(SICI)1098-2736(199804)35:4<379::AID-TEA8>3.0.CO;2-N

Barton, A. C., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls identity work over time and space. *American Educational Research Journal, 20*(1). https://doi.org/https://doi.org/10.3102/0002831212458142

Barton, A. C., & Osborne, M. (2002). Reconstructing the harsh world: Science with for social action. *Science Education, 210*, 167–118.

Basile, C. G. (2015). Research experiences for teachers as capstone for content knowledge. *Teacher Education & Practice, 28*(2/3), 331–350.

Baumgartner, E., Duncan, K. M., Handler, A. T., & Yalap, Y. P. (2009). Scientist-teacher workshops as a mechanism for building partnerships and scientific inquiry teaching skills. Pacific-Asian Education Journal, 21(2), 27–43.

Bencze, L., & Elshof, L. (2004). Science teachers as metascientists: An inductive-deductive dialectic immersion in northern alpine field ecology. *International Journal of Science Education, 26*(12), 1507–1526. https://doi.org/10.1080/0950069042000205431

Birkland, J. (1993). Ecofeminism: Linking Theory and Practice. In *Ecofeminism: Women, Animals, Nature*. Temple University Press.

Blake, R. A., Liou-Mark, J., & D. Lansiquot, R. (2015). Promoting the geosciences among grades 8–12 minority students in the urban coastal environment of new york city. *Journal of Geoscience Education, 63*(1), 29–40. https://doi.org/10.5408/13-101.1

Blanchard, M. R., Southerland, S. A., & Granger, E. M. (2009). No silver bullet for inquiry: Making sense of teacher change following an inquiry-based Research Experience for Teachers. *Science Education, 93*(2), 322–360. https://doi.org/https://doi.org/10.1002/sce.20298

Boyd, D., Grossman, P., Ing, M., Lankford, H., Loeb, S., O'Brien, R., & Wyckoff, J. (2011). The effectiveness and retention of teachers with prior career experience. *Economics of Education Review, 30*(6), 1229–1241. https://doi.org/10.1016/j.econedurev.2011.08.004

Braund, M., & Reiss, M. J. (2019). The 'Great Divide': How the arts contribute to science and science education. *Canadian Journal of Science Mathematics and Technology Education, 19*, 219–236. https://doi.org/https://doi.org/10.1007/s42330-019-00057-7

Brey, J. A., Mills, E. W., Day-Miller, E. A., Geer, I. W., Weinbeck, R. S., Blair, B. A., Hopkin, E. J., O'Neill, K. L., Nugnes, K. A., & Asokan, A. (2015). The ams datastreme earth's climate system teacher professional development course: Results from a three-year study. *Journal of Geoscience Education, 63*(1), 47–56. https://doi.org/10.5408/13-038.1

Brown, H. (2017). Figured worlds' and the construction of positive learner identities through digital technologies outside of school. *Digital Culture & Education, 9*(2), 83–97. https://www.digitalcultureandeducation.com/cms/wp-content/uploads/2017/09/lesage.pdf

Brown, N. W. (1996). The destructive narcissistic pattern *Social Behavior and Personality 24*(3), 263–272. https://doi.org/10.2224/sbp.1996.24.3.263

Brown, S., & Melear, C. (2007). Preservice teachers' research experiences in scientists' laboratories. *Journal of Science Teacher Education*, *18*(4), 573–597. https://doi.org/10.1007/s10972-007-9044-9

Bryan, L., & Atwater, M. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Education, 86*, 821–839. https://doi.org/10.1002/sce.10043

Buck, P. E. (2003). Authentic Research Experiences for Nevada High School Teachers and Students. *Journal of Geoscience Education, 51*(1), 48–53. https://doi.org/10.5408/1089-9995-51.1.48

Burrows, A. C., Breiner, J. M., Keiner, J., & Behm, C. (2014). Biodiesel and integrated STEM: Vertical alignment of high school biology/biochemistry and chemistry. *Journal of Chemical Education*, *91*(9), 1379–1389. https://doi.org/10.1021/ed500029t

Buxner, S. R. (2015). Exploring how Research Experiences for Teachers changes their understandings of the nature of science and scientific inquiry. *Journal of Astronomy & Earth Sciences Education (JAESE)*, *1*(1), 53–53. https://doi.org/10.19030/jaese.v1i1.9107

Cajete, G. A. (2017). Children, myth and storytelling: An Indigenous perspective. *Global Studies of Childhood*, *7*(2), 113–130. https://doi.org/10.1177/2043610617703832

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218. https://doi.org/https://doi.org/10.1002/tea.20237

Carlone, H. B., Scott, C. M., & Lowder, C. (2014). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching*, *51*(7), 836–869. https://doi.org/10.1002/tea.21150

Caton, E., Brewer, C., & Brown, F. (2000). Building teacher-scientist partnerships: Teaching about energy through inquiry. *School Science and Mathematics*, *100*(1), 7–15. https://doi.org/10.1111/j.1949-8594.2000.tb17315.x

Cattadori, M., Florindo, F., & Rack, F. (2011). Short- and long-term effects in the school system of a research immersion experience for science educators: An example from ANDRILL (Antarctic Geological Drilling). *Geosphere, 7*(6), 1331–1339. https://doi.org/10.1130/GES00678.1

Pew Research Center (2021). *STEM jobs see uneven progress in increasing gender, racial and ethnic diversity.* Retrieved from https://www.pewresearch.org/science/wp-content/uploads/sites/16/2021/03/PS_2021.04.01_diversity-in-STEM_REPORT.pdf

Chowdhary, B., Liu, X., Yerrick, R., Smith, E., & Grant, B. (2014). Examining science teachers' development of interdisciplinary science inquiry pedagogical knowledge and practices. *Journal of Science Teacher Education, 25*(8), 865–884. https://doi.org/10.1007/s10972-014-9405-0

Chung-Parsons, R., & Bailey, J. M. (2019). The hierarchical (not fluid) nature of preservice secondary science teachers' perceptions of their science teacher identity. *Teaching and Teacher Education, 78*, 39–48. https://doi.org/10.1016/j.tate.2018.11.007

Cisneros, J. C., Raja, N. B., Dunne, E. M., Pinheiro, F. L., Fernandez, O. R. R., Sales, M. A. F., Rodriguez-de la Rosa, R. A., Miranda-Martinex, A. Y., Gonzalez-Mora, S., Bantim, R. A. M., de Lima, F. J., & Pardo, J. D. (2022). Digging deeper into colonial palaeontological practices in modern day Mexico and Brazil. *Royal Society Open Science, 9*, 1–26. https://doi.org/https://doi.org/10.1098/rsos.210898

Clandinin, D. J. (2013). *Engaging in Narrative Inquiry*. Routledge.

Cohen, D. K., & Hill, H. (2001). *Learning policy: When state education reform works.* Yale University Press.

Connelly, M. F., & Clandinin, D. J. (1990). Stories of experience and narrative inquiry. *Educational Researcher, 19*(5), 2–14. https://doi.org/10.3102/0013189X019005002

Crawford, B. A. (2012). Moving the essence of inquiry into the classroom: Engaging teachers and students in authentic science. In *Issues and challenges in science education research* (pp. 25–42). Springer. https://doi.org/https://doi.org/10.1007/978-94-007-3980-2_3

Crutzen, P. & Stoermer, E. (2013). "The 'Anthropocene'" (2000). In L. Robin, S. Sörlin & P. Warde (Ed.), The Future of Nature: Documents of Global Change (pp. 479–490). New Haven: Yale University Press. https://doi.org/10.12987/9780300188479-041

Cutucache, C. E., Leas, H. D., Grandgenett, N. F., Nelson, K. L., Rodie, S., Shuster, R., Schaben, C., & Tapprich, W. E. (2017). Genuine faculty-mentored research experiences for in-service science teachers: Increases in science knowledge, perception, and confidence levels. *Journal of Science Teacher Education, 28*(8), 724–744. https://doi.org/10.1080/1046560X.2017.1415615

D'Souza, L. (2018). Using storied-identity to explore a case study of teacher mediocrity. *Journal of Ethnographic and Qualitative Research, 12*, 157–172. http://www.jeqr.org/previous-volumes-1

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. https://learningpolicyinstitute.org/sites/default/files/product-files/Effective_Teacher_Professional_Development_REPORT.pdf

Darwiche, H. A., Barnes, M. B., Barnes, L. W., Cooper, L. A., Bokor, J. R., & Koroly, M. J. (2017, Summer). Bench to bedside: The effectiveness of a professional development program focused on biomedical sciences and action research. *Science educator : the National Science Education Leadership Association journal, 26*(1), 32–47.

Davidson, S. G., Jaber, L. Z., & Southerland, S. A. (2021). Cultivating science teachers' understandings of science as a discipline. *Science & Education*, 1–27. https://doi.org/10.1007/s11191-021-00276-1

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research, 76*(4), 607–651. https://doi.org/10.3102/00346543076004607

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582–601. http://dx.doi.org/10.1002/1098-2736(200008)37:6<582::AID-TEA5>3.0.CO;2-L

DeJong, B. P., Yelamarthi, K., & Kaya, T. (2016). An engineering research program for high school science teachers: Year two changes and results. *Journal of STEM Education: Innovations & Research, 17*(1), 15–21.

Dewey, J. (1910). Science as subject-matter and as method. *Science, 31*(787), 121–127.

Dewey, J. (1938). Experience & education. *Journal of Chemical Information and Modeling*. https://doi.org/10.1017/CBO9781107415324.004

Dictionary, T. A. H. I. (2002). At Someone's Elbow. In *The American Heritage Idioms Dictionary*.

Dira-Smolleck, L. (2004). *The Development and Validation of an Instrument to Measure Pre-Service Teachers' Self-Efficacy in Regard to the Teaching of Science as Inquiry* The Pennsylvania State University.

Dixon, P., & Wilke, R. A. (2007). The influence of a teacher research experience on elementary teachers' thinking and instruction. *Journal of Elementary Science Education, 19*(1), 25–43. https://doi.org/10.1007/bf03173652

Drake, C., Spinalle, J. P., & Hufferd-Ackles, K. (2001). Storied identities: teacher learning and subject-matter context. *Journal of Curriculum Studies, 3*(1), 1–23. DOI: 10.1080/00220270119765

Drayton, B., & Falk, J. (2006). Dimensions that shape Teacher-Scientist Collaborations for teacher enhancement *Science Teacher Education 90,* 734–761. DOI 10.1002/sce.20138

Dresner, M. (2002). Teachers in the woods: Monitoring forest biodiversity. *Journal of Environmental Education, 34*(1), 26–31. https://doi.org/10.1080/00958960209603479

Dresner, M., & Worley, E. (2006). Teacher research experiences, partnerships with scientists, and teacher networks sustaining factors from professional development. *Journal of Science Teacher Education, 17*(1), 1–14. https://doi.org/10.1007/s10972-005-9000-5

Enderle, P., Dentzau, M., Roseler, K., Southerland, S., Granger, E., Hughes, R., Golden, B., & Saka, Y. (2014). Examining the influence of rets on science teacher beliefs and practice. *Science Education, 98*(6), 1077–1108. https://doi.org/10.1002/sce.21127

Erduran, S. (2014). Beyond nature of science: The case for reconceptualising 'science' for science education. *Science Education International, 25*(1), 933–111.

Erduran, S., & Kaya, E. (2018). Drawing nature of science in pre-service science teacher education: Epistemic insight through visual representations. *Research in Science Education, 48*, 1133–1149. https://doi.org/10.1007/s11165-018-9773-0

Eren, E. (2021). Exploring science identity development of women in physics and physical sciences in higher education. *Science and Education*, *30*, 1131–1158. https://doi.org/https://doi.org/10.1007/s11191-021-00220-3

Faber, C., Hardin, E., Klein-Gardner, S., & Benson, L. (2014, 11/01/). Development of Teachers as Scientists in Research Experiences for Teachers Programs. *Journal of Science Teacher Education, 25*(7), 785–806. http://dx.doi.org/10.1007/s10972-014-9400-5

Feldman, A., Divoll, K. A., & Rogan-Klyve, A. (2013). Becoming researchers: The participation of undergraduate and graduate students in scientific research groups. *Science Education, 97*(2), 218–243. https://doi.org/10.1002/sce.21051

Foucault, M. (1980). *Power/knowledge: Selected interviews and other writings*. Pantheon.

Francis, D. V., & Darity Jr., W. A. (2021). Separate and unequal under one roof: How the legacy of racialized tracking perpetuates within school segregation. *The Russel Sage Foundation Journal of the Social Sciences, 7*(1), 187–202. https://doi.org/https://doi.org/10.7758/rsf.2021.7.1.11

Fraser-abder, P., & Leonhardt, N. (1996). Research Experiences for Teachers: Working with laboratory scientists provides fresh insights and knowledge that transfer to the classroom. *The Science Teacher, 63*(1), 30–33. https://doi.org/10.1126/science.139.3555.660-a

Gaard, G. (1993). *Ecofeminism: Women, animals, nature*. Temple University Press.

Galili, I. (2019). Towards a refined depiction of nature of science. *Science & Education, 28*(3-5), 503-537. https://doi.org/10.1007/s11191-019-00042-4

Gaventa, J., & Cornwall, A. (2001). Power and knowledge. In P. Reason & H. Bradbury (Eds.), *Handbook of action research: Participative inquiry and practice* (pp. 70–80). Sage.

Godwin, A., Cribbs, J., & Kayumova, S. (2020). Perspectives of identity as an analytic framework in STEM education. In *Handbook of Research on STEM Education* (pp. 11). Routledge.

Gough, A., & Whitehouse, H. (2018). New vintages and new bottles: The "Nature" of environmental education from new material feminist and ecofeminist viewpoints. *The Journal of Environmental Education*, *49*(4), 336–349. https://doi.org/10.1080/00958964.2017.1409186

Griffiths, M., & Woolf, F. (2009). The Nottingham Apprenticeship Model: schools in partnership with artists and creative practitioners. *British Educational Research Journal 35*(4), 557–574.

Grove, C. M., Dixon, P. J., & Pop, M. M. (2009). Research experiences for teachers: Influences related to expectancy and value of changes to practice in the American classroom. *Professional Development in Education*, *35*(2), 247–260. https://doi.org/10.1080/13674580802532712

Gunel, M. (2009). Critical elements for the science teacher to adopt a student-centered approach: the case of a teacher in transition. *Teachers and Teaching: Theory and Practice, 14*(23), 209-224.

Hagan, W. L., Whitcraft, C., & Henriques, L. (2020). Project G.R.O.W.: A scientist-science teacher partnership that supports meaningful learning. *Science Teacher*. 87(9), 64-70.

Haney, J., & McArthur, J. (2002). Four case studies of prospective science teachers' beliefs concerning constructivist teaching practices. *Science Education, 86,* 783–802. https://doi.org/10.1002/sce.10038

Haraway, D. J. (2016). *Staying with the trouble*. Duke University Press. https://doi.org/10.1215/9780822373780

Hardré P. L., Nanny M., Refai H., Ling C., Slater J. (2010). Re-engineering a dynamic science learning environment for K-12 teachers. Teacher Education Quarterly, 37(2), 157-178.

Hardrè, P. L., Nanny, M. A., Morales, S., Kenton, R., Lewis, L., Guo, S., Peng, Q., & Xu, H. (2020). Rural teachers learning bioanalytical engineering: Design and development of learning, transfer, and communication supports for rural secondary math and science teachers. *International Journal of Designs for Learning, 11*(1), 31–40. https://doi.org/10.14434/ijdl.v11i1.22862

Harpole, S. H., Kerley, L. H., Silvernail, D. L., Kinard, F., & Brooks, P. (2010). SCIENCE on the SHIPYARD: Bridging the gap between industry and the classroom. The Science Teacher, 77(4), 48–52.

Harrison, C., & Tanner, K. D. (2018). Language matters: Considering microaggressions in science. *Life Sciences Education 4*(Spring), 1–8.

Harvester, L., & Blenkinsop, S. (2010). Environmental education and ecofeminist pedagogy-bridding the environmental and the social. *Canadian Journal of Environmental Education*, 120–134. Retrieved from https://files.eric.ed.gov/fulltext/EJ942810.pdf

Hazari, Z., Chari, D., Potvin, G., & Brewe, E. (2020). The context dependence of physics identity: Examining the role of performance/ competence, recognition, interest, and sense of belonging for lower and upper female physics undergraduates. *Journal Research in Science Teaching, 5*, 1583–1607. https://doi.org/https://doi.org/10.1002/tea.21644

Helms, J. V. (1998). Science—and me: Subject matter and identity in secondary school science teachers. *Journal of Research in Science Teaching, 35*(7), 811–834.

https://doi.org/https://doi.org/10.1002/(SICI)1098-2736(199809)35:7<811::AID-TEA9>3.0.CO;2-O

Helms, J. V., & Carlone, H. B. (1999). Science Education and the Commonplaces of Science. *Issues and Trends*.

Herrington, D. G., Bancroft, S. F., Edwards, M. M., & Schairer, C. J. (2016). I Want to be the inquiry guy! How Research Experiences for Teachers change beliefs, attitudes, and values about teaching science as inquiry. *Journal of Science Teacher Education, 27*(2), 183–204. https://doi.org/10.1007/s10972-016-9450-y

Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for Conceptual Change. In (pp. 199–218).

Holland, D., Lachicotte, W. S., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural Worlds*. Harvard University Press.

Holland, D., & Leander, K. (2004). Ethnographic studies of positioning and subjectivity: An introduction. *Ethos, 32*(Ethnographic Studies of Positioning and Subjectivity: Narcotraffickers, Taiwanese Brides, Angry Loggers, School Troublemakers), 127–139. http://www.jstor.org/stable/3651830

Hufnagel, E., Kelly, G. J., & Henderson, J. A. (2018). How the environment is positioned in the Next Generation Science Standards: a critical discourse analysis. *Environmental Education Research, 24*(5), 731–753. https://doi.org/10.1080/13504622.2017.1334876

Hughes, R., Molyneaux, K., & Dixon, P. (2012). The Role of Scientist Mentors on Teachers' Perceptions of the Community of Science During a Summer Research Experience. Research in Science Education, 42(5), 915-941. https://doi.org/10.1007/s11165-011-9231-8

Ibourk, A. (2018). A storied-identity analysis approach to teacher candidates learning to teach in an urban setting *Cultural Studies of Science Education*. https://doi.org/10.1007/s11422-021-10053-9

Ingersoll, R. M. (2003). Is there really a teacher shortage? *Center for the Study of Teaching and Policy Center for the Study of Teaching and Policy*, 1–28.

Ingersoll, R. M. (2011). Do we produce enough mathematics and science teachers? *Phi Delta Kappan, 92*(6), 37–41. https://doi.org/10.1177/003172171109200608

Intemann, K. (2010). 25 years of feminist empiricism and standpoint theory: Where are we now? *Hypatia*, *25*(4), 778–796. https://doi.org/10.1111/j.1527-2001.2010.01138.x

Jewett, A. (2012). *Science, democracy, and the american university: From the civil war to the cold war*. Cambridge University Press.

Johnson, G. C. (2004). Reconceptualising the visual in narrative inquiry into teaching. *Teaching and Teacher Education, 20*, 423–434. https://doi.org/10.1016/j.tate.2004.04.009

Juuti, K., Lavonen, J., Salonen, V., Salmela-Aro, K., Schneider, B., & Krajcik, J. (2021). A teacher–researcher partnership for professional learning: Co-designing project-based learning units to increase student engagement in science classes. *Journal of Science Teacher Education, 32*(6), 625–641. https://doi.org/10.1080/1046560X.2021.1872207

Keller, M. M., Goetz, T., Becker, E. S., Morger, V., & Hensley, L. (2014). Feeling and showing: A new conceptualization of dispositional teacher enthusiasm and its relation to students' interest. *Learning and Instruction, 33*, 29–39. https://doi.org/https://doi.org/10.1016/j.learninstruc.2014.03.001

Kennedy, M. M. (1999). The role of preservice teacher education. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 54–85). Jossey Bass.

Kim, A. Y., & Sinatra, G. M. (2018). Science identity development: An interactionist approach. *International Journal of STEM Education, 5*, 1–6. https://doi.org/https://doi.org/10.1186/s40594-018-0149-9

Kim, A. Y., Sinatra, G. M., & Seyranian, V. (2018). Developeing a STEM identity among young women: A social identity perspective *Review of Educational Research*, *88*(4), 589–625. https://doi.org/10.3102/0034654318779957

Kimmerer, R. W. (2013). *Braiding Sweetgrass*. Milkwee Editions.

Kings, A. E. (2017). Intersectionality and the changing face of ecofeminism. *Ethics and the Environment*, *22*(1), 63–87. https://doi.org/10.2979/ethicsenviro.22.1.04

La Croix, D., Doepke, M., & Mokyr, J. (2018). Clans, Guilds, and Markets: Apprenticeship Instituions and Growth in the PreIndustrial Economy. *The Quarterly Journal of Economics, 133*(1), 1–77.

Ladson-Billings, G. (1998). Just what is critical race theory and what’s it doing in a nice field like education? *International Journal of Qualitative Studies in Education, 11*(1), 7–24. https://doi.org/10.1080/095183998236863

Larkin, D. (2019). Attending to the public understanding of science education: A response to Furtak and Penuel. *Science Education, 103*, 1294–1300.

Larkin, D. (2020). *Teaching science in diverse classrooms: Real science for real students*. Routledge.

Latour, B. (1998). *The Pasteurization of France*. Harvard University Press.

Latour, B., & Woolgar, S. (1979). *Laboratory life : The social construction of scientific facts*. Sage.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In *Handbook of Research on Science Education* (pp. 831–879). Lawrence Erlbaum.

Lederman, N. G. (2019). Contextualizing the relationship between nature of scientific knowledge and scientific inquiry: Implications for curriculum and classroom practice. *Science and Education, 28*(3-5), 249–267. https://doi.org/10.1007/s11191-019-00030-8

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. Journal of Research in Science Teaching, 39(6), 497-521. https://doi.org/10.1002/tea.10034

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. Sage.

Little, J. W. (1993). Teachers’ professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis, 15*(2), 129–151.

Lloro-Bidart, T. (2015). A political ecology of education in/for the anthropocene. *Environment and Society*, *6*(1). https://doi.org/10.3167/ares.2015.060108

Lloyd, G. M. (2006). Preservice teachers' stories of mathematics classrooms: Explorations of practice through fictional accounts. *Educational Studies in Mathematics, 63*(1), 57–87. https://doi.org/10.1007/s10649-005-9004-2

Longino, H. (1990). *Science as social knowledge*. Princeton University Press.

Loucks-Horsley, S., Stiles, K., Mundry, S., Love, N., & Hewson, P. (2010). *Designing professional development for teachers ofscience and mathematics*. Corwin.

Luft, J. A., & Roehng, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2), 38–63.

Malm, A. (2013). The Origins of Fossil Capital. *Historical Materialism, 21*(1), 15–68. DOI:10.1163/1569206X-12341279

Mansour, N. (2009). Science teachers' beliefs and practices: issues, implications and research agenda. *International Journal of Environmental & Science Education, 4*(1), 25–48.

Maulucci Rivera, M. S. (2013). Emotions and positional identity in becoming a social justice science teacher: Nicole's story. *Journal of Research in Science Teaching, 50*, 453–478. https://doi.org/ https://doi.org/10.1002/tea.21081.

McComas, W. F., & Nouri, N. (2017). The nature of science and the next generation science standards: Analysis and critique. *Journal of Science Teacher Education, 27*(5), 555–576. https://doi.org/10.1007/s10972-016-9474-3

McGinty, M., & Bang, M. (2016). Narratives of dynamic lands: science education, indigenous knowledge and possible futures. *Cultural Studies of Science Education, 11*, 471–475. https://doi.org/10.1007/s11422-015-9685-5

McLaughlin, C. A., & MacFadden, B. J. (2014). At the elbows of scientists: Shaping science teachers' conceptions and enactment of inquiry-based instruction. *Research in Science Education, 44*(6), 927–947. https://doi.org/10.1007/s11165-014-9408-z

Merchant, C. (2006). The scientific revolution and the death of nature. *Isis, 97*(3), 513–533. https://doi.org/10.1086/508090

Messias, D. K. H., & DeJoseph, J. F. (2004). Feminist narrative interpretations: Challenges, tensions, and opportunities for nurse researchers. *Aquichan* (pp. 1657–1697).

Miranda, R. J., & Damico, J. B. (2015). Changes in teachers ' beliefs and classroom practices concerning inquiry-based instruction following a year-long RET-PLC program. *Science Educator., Vol. 24*(Issue 1), 23–35. Retrieved from https://files.eric.ed.gov/fulltext/EJ1069987.pdf

Moore, J. (2014). The value of everything? Work, capital, and historical nature in the capitalist worldecology. *World-Ecological Imaginations, 37*(3-4), 245–292.

Morabito, N. P. (2018). Exploring variability in science teachers' summer research experiences: A cross-case comparison of participation in a professional development program. *Science Educator, 26*(2), 61–72.

Morrison, J. A. (2014). Scientists' participation in teacher professional development: The impact on fourth to eighth grade teachers' understanding and implementation of inquiry science. *Journal of Science & Mathematics Education, 12* (4), 793–816. https://doi.org/10.1007/s10763-013-9439-3

Morrison, J. A., & Estes, J. C. (2017). Using scientists and real-world scenarios in professional development for middle school science teachers. *Journal of Science Teacher Education, 18*(2), 165–184. https://doi.org/10.1007/s10972-006-9034-3

NGSS. (2013). *Next Generation Science Standards: For states, by states* The National Academies Press. Retrieved from https://www.nextgenscience.org/

Noble, H., & Smith, J. (2015). Issues of validity and reliability in qualitative research. *Evidence-Based Nursing, 18*(2), 34–35. http://dx.doi.org/10.1136/eb-2015-102054

NRC. (1996). *National Science Education Standards (NSES)*. T. N. A. Press.

NRC. (1998). *How people learn: Bridging research and practice*. National Academy Press. Retrievd from https://www.nap.edu/read/9457/chapter/2#4

NSF. (2021). Research Experiences for Teachers sites in biological sciences (biorets): Program solicitation. Retrieved from https://www.nsf.gov/pubs/2021/nsf21584/nsf21584.htm

Odrowaz-Coates, A. (2021). Definitions of sustainability in the context of gender. *Sustainability, 13*(13), 1–12. https://doi.org/10.3390/su13126862

Olesen, V. (2011). Feminist qualitative research in the millennium's first decade: Developments, challenges, prospects. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (4th ed., pp. 129–146). Sage.

Page, C. A., Lewis, C. W., Autenrieth, R. L., & Butler-Purry, K. L. (2013). Enrichment experiences in engineering (e3) for teachers summer research program: An examination of mixed-method evaluation findings on high school teacher implementation of engineering content in high school stem classrooms. *Journal of STEM Education, 14*(3), 27-33

Patel, L. (2015). *Decolonizing educational research: From ownership to answerability* (1st ed.). Routledge. https://doi.org/ https://doi.org/10.4324/9781315658551

Pierce, G. (2011). Poststructural feminist pedagogy in a post-katrina world. *Feminist Teacher, 21*(1), 36–53. https://doi.org/10.5406/femteacher.21.1.0036

Pinnegar, S., & Daynes, J. G. (2006). *Locating narrative inquiry historically*. Sage.

Pinnel, M. F., Suzanne; Petry, Leanne; Mian, Ahsen; Doudican, Brett; Srinivasan, Raghavan (2018). Leveraging regional strengths for stem teacher professional development: Results from an NSF RET program focused on advanced manufacturing and materials. *Research* *in the Schools, 25*(1), 20–34. Retrieved from https://corescholar.libraries.wright.edu/mme/484/

Plutzer, E., M. , McCaffrey, A. L., Hannah, J., Rosenau, M., Berbeco, M., & Reid, A. H. (2016). Climate Confusion among U.S. Teachers. *Science, 351*, 664-665. https://doi.org/doi:10.1126/science.aab3907

Pop, M., Dixon, P., & Grove, C. M. (2010). Research experiences for teachers (RET): Motivation, expectations, and changes to teaching practices due to professional program involvement. *Journal of Science Teacher Education, 21*(2), 127–147. https://doi.org/10.1007/s10972-009-9167-2

Price, J. F., & McNeil, K. L. (2013). Toward a lived science curriculum in intersecting figured worlds: An exploration of individual meanings in science education. *Journal of Research in Science Teaching, 50*, 501–529. https://doi.org/10.1002/tea.21084

Raja, N. B., Dunne, E. M., Matiwane, A., Kang, T. M., Natscher, P. S., Ghilardi, A. M., & Chattopadhyay, D. (2022). Colonial history and global economics distort our understanding of deep-time biodiversity. *Nature Ecology & Evolution, 6*(22), 145–154. https://doi.org/https://doi.org/10.1038/s41559-021-01608-8

Reichelt, M., Collischon, M., & Eberl, A. (2019). School tracking and its role in social reproduction: Reinforcing educational inheritance and the direct effects of social origin 70(4), 1323-1348. https://doi.org/ https://doi.org/10.1111/1468-4446.12655

Richardson, L. (2000). Evaluating ethnography *Qualitative Inquiry, 6*(2), 253–255.

Richardson, L., & St. Pierre, E. A. (2008). Writing: A method of inquiry. In N. K. Denzin (Ed.), *Collecting and interpreting qualitative materials* (pp. 473–498). Sage.

Rudolph, J. L. (2020). The lost moral purpose of science education. *Science Education*, *104*(5), 895–906. https://doi.org/10.1002/sce.21590

Ruitenburg, S. K., & Tigchelaar, A. E. (2021). Longing for recognition: A literature review of second-career teachers' induction experiences in secondary education. *Educational Research Review, 33,* 1–20. https://doi.org/https://doi.org/10.1016/j.edurev.2021.100389

Rushton, E., & Reiss, M. J. (2019). From science teacher to 'teacher scientist': Exploring the experiences of research-active science teachers in the UK. *International Journal of Science 41*(11), 1541–1561. https://doi.org/10.1080/09500693.2019.1615656

Saka, Y. (2013). Who are the science teachers that seek professional development in research experience for teachers (ret's)? Implications for teacher professional development. *Journal of Science Education and Technology*, *22*(6), 934–951. https://doi.org/10.1007/s10956-013-9440-1

Saunders, J. M., & Ash, G. E. (2013). Entering the arena: The figured worlds transition of preservice teachers. *Journal of Adolescent & Adult Literacy*, *56*(6), 490–499. https://doi.org/10.1002/jaal.170

Schwartz, R. S., Lederman, N. G., & Crawford, B. (2004). Developing views about nature of science in authentic contexts: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610– 645.

Shanahan, M. C., & Bechtel, R. (2019). "We're taking their brilliant minds": Science teacher expertize, meta-discourse, and the challenges of teacher–scientist collaboration. *Science Education, 104*(2), 354–387. https://doi.org/10.1002/sce.21550

Shell, D. F., Snow, G. R., & Claes, D. R. (2011). The cosmic ray observatory project: Results of a summer high-school student, teacher, university scientist partnership using a capstone research experience. *Journal of Science Education & Technology, 20*, 161–177.

Silliman, S. W. (Ed.). (2010). *Writing new archeological narratives: Indigenous North America* (Vol. 145). Left Coast Press.

Silverstein, S. C., Dubner, J., Miller, J., Glied, S., & Loike, J. D. (2009). Teachers' participation in research programs improves their students' achievement in science. *Science, 326*(5951), 440–442. https://doi.org/10.1126/science.1177344

Southerland, S. A., Granger, E. M., Hughes, R., Enderle, P., Ke, F., Roseler, K., Saka, Y., & Tekkumru-Kisa, M. (2016). Essential aspects of science teacher professional development. *AERA Open, 2*(4), 1–16. https://doi.org/10.1177/2332858416674200

Spannring, R. (2016). Animals in environmental education research. *Environmental Education Research*, *23*(1), 63–74. https://doi.org/10.1080/13504622.2016.1188058

Tan, E., & Barton, A. C. (2008). From peripheral to central, the story of Melanie's metamorphosis in an urban middle school science class. *Science Education, 92*(4), 567–590. https://doi.org/10.1002/sce.20253

Tan, E., & Barton, A. C. (2010). Transforming science learning and student participation in sixth grade science: A case study of a low-income, urban, racial minority classroom. *Equity & Excellence in Education, 43*(1), 38–55. https://doi.org/10.1080/10665680903472367

Thomson, M. M., & Turner, J. E. (2019). The role of emotions in teachers’ professional development: Attending a Research Experience for Teachers (RET) program. *Education Research International*, *2019*, 1–12. https://doi.org/10.1155/2019/5856793

Tolbert, S., Schindel, A., & Rodriguez, A. J. (2018). Relevance and relational responsibility in justice-oriented science education research [Article]. *Science Education, 102*(4), 796–819. https://doi.org/10.1002/sce.21446

Two Bears, D. R. (2022). Decolonizing Research for my Dine (Navajo) community: The old Leupp boarding school historic site. *Archeological Papers of the American Anthropological Association 33*(1551–823x), 55-72. https://doi.org/10.1111/apaa.12157

Urrieta, L. (2007). Figured worlds and education: An introduction to the special issue. *The Urban Review, 39*(2), 107–116. https://doi.org/10.1007/s11256-007-0051-0

Vaidya, S. R., & Thompson, J. (2020). A case study of STEM professionals who chose teaching as a second career. *International Education Studies, 13*(11), 108–113. https://doi.org/10.5539/ies.v13n11p108

van der Toorn, J., Pliskin, R., & Morgenroth, T. (2020). Not quite over the rainbow: The unrelenting and insidious nature of heteronormative ideology. *Current Opinion in Behavior Sciences*(34), 160–165. https://doi.org/10.1016/j.cobeha.2020.03.001

Varelas, M., House, R., & Wenzel, S. (2005). Beginning teachers immersed into science: Scientist and science teacher identities. *Science Education, 89*(3), 492–516.

Varelas, M., Kotler, R. T., Natividad, H. D., Philips, N. C., Tsachor, R. P., Woodard, R., Gutierrez, M., Melchor, M. A., & Rosario, M. (2021). “Science theatre makes you good at science”: Affordances of embodied performances in urban elementary science classrooms. *Journal of Research in Science Teaching, 59*, 493–528. https://doi.org/https://doi.org/10.1002/tea.21735

Vincent-Ruz, P., & Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *International Journal of STEM Education, 5*(48), 1–12. https://doi.org/https://doi.org/10.1186/s40594-018-0140-5

Waldrip, B., & Prain, V. (2012). *Learning from and through representations in science*. Springer.

Warren, K. (2000). *Ecofeminist philosophy: A western perspective on what it is and why it matters.* Rowman and Littlefield.

Webster, L., & Mertova, P. (2007). *Using narrative inquiry as a research method: An introduction to using critical event narrative analysis in research on learning and teaching*. Routledge.

Weinberg, A. E., Balgopal, M. M., & Sample McMeeking, L. B. (2021, Feb 9). Professional growth and identity development of stem teacher educators in a community of practice. *International Journal of Science and Mathematics Education, 19*, 1–22. https://doi.org/10.1007/s10763-020-10148-9

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press. https://doi.org/https://doi.org/10.1017/CBO9780511803932

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality*. Educational Testing Service.

Westerlund, J. F., Garcia, D. M., & Koke, J. R. (2002). Summer scientific Research for Teachers: The experience and its effect. *Journal of Science Teacher Education, 13*(1), 63–83.

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education, 87*, 112–143.

Wong, S. S., & Hodson, D. (2010). More from the horse's mouth: What scientists say about science as a social practice. *International Journal of Science Education, 32*(11), 1431–1463.

Yoon, K. S., Duncan, T., Lee, S. W.-Y., Scarloss, B., & Shapley, K. (2007). Reviewing the evidence on how teacher professional development affects student achievement (Issues & Answers Report, REL 2007–No. 033). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest. Retrieved from http://ies.ed.gov/ncee/edlabs

Zell, S. K. (1998). Ecofeminism and the science classroom: A practical approach *Science & Education, 7*, 143–158.

Appendix A: Visual NOS Prompt

Prompt: Using visuals (either drawn) how would you convey how you personally connect to science.

- You can include as many/little visuals as you would like.
    - There can be some words, but aim for less words more pictures
    - You can use the jam board link I have created or paper that you take a picture and send to me
    - There is no right or wrong here, I am not assessing your understanding of science, I just want to see how you would choose to depict science through visuals
- Do you have any questions for me about this part of the interview?

Appendix B: Science Teacher Interview 1 (1.5 hrs)

Thank you for agreeing to be a part of this study. The goal of my work is to gain a sense of how science teachers have experienced science throughout their lives and in different ways and places both within and outside of school, how they have come to understand and identify themselves in science from those experiences, and how they portray science in their classrooms. It is also my stance that individuals' science identities can be best expressed and understood through the telling of their different science stories. One example of an experience that a science teacher may have had with science is their RET or research experience for teachers. Which I will refer to as an RET throughout the remainder of our time together. You were chosen for this study because you are/were a science teacher in a secondary setting and you have participated in an RET within the last five years.

- All data will be kept confidential and I will be using pseudonyms in my dissertation and any future publications.
- I will also give you an opportunity to read your story and provide feedback, to make sure that I did not misinterpret anything you shared with me or if I have left out something you feel is important to your science story.
- Do you still agree to participate in two, 1-hour long interviews?
- Do you agree to be audio recorded?
- Let's get started.
- Can you start by telling me a little bit about yourself?

As I stated earlier, I am very interested in how you have come to understand science and I am also interested in how you would visually show me what your view of science is.

Over the next 20 minutes I am going to ask you to work on your visual. At the end of the 20 minutes, I will hop back on and ask you some final questions before we end our time together. If you decide to draw, if you could take a picture and send it to me when you've finished.

1. Would you describe your visual to me?
    a. Would you explain why you chose to include the images you did?
    b. Was there something you wanted to include but couldn't find/draw?
    c. Probe for additional explanation as needed.
2. How did you come across the images you selected? (What was your process in finding the images? What did you use as your google search terms, etc.?) OR What was the first thing you decided to draw? Why?
    a. How did you decide what to draw/search next?
3. Did you find this process helped you convey your view of science? Why or why not?
    a. Did it cause you to think about science in a new way?

The purpose of the second part of this interview is to highlight the specific experiences that have shaped who you are in relationship to science and how you have come to the understanding you currently have of science. Before we get started, I want to emphasize that I am very interested in the specific memories you have from different people or moments in time that have impacted how you personally relate to science. Perhaps you recall memories of a particular event or moment in time, even the feelings you experienced in the moment. I also want to do my best to have more of a conversation and less of a structured interview.

1. In what ways do you personally connect with science?
    a. How did you become interested in science?
    b. Would you say you are passionate/love about science? Why?

   c. How would you describe your identity in science?

2. Do you have an earliest memory of science? (Tv shows, class/family trips, etc)?
3. Were there any individuals in your life that impacted how you see science? (Family members, teachers, friends, etc)?
4. If they have not already talked about these periods of time, prompt to hear more about:
   a. early childhood (before schooling),
   b. early education (elementary school and middle school),
   c. high school,
   d. college/university,
   e. teaching
5. Do you feel comfortable expressing your identity, or how you identify?
   a. Do you think your gender, sexual orientation, or race has impacted your view of science or your identity in science?
6. Can you tell me a little about why you decided to participate in an RET? (Why you chose to apply? How did you hear about it?)
7. Can you tell me a little about your experience? What are some moments that stand out to you?
8. Can explain your role in the research? (What was the research about? What was your experience with the scientist you were partnered with like? Etc).
9. Can you talk specifically about how your view of science may have changed or was impacted by participating in your RET?
10. Do you think your visual would have looked differently if you were asked to create one prior to your participation in an RET? If so, how?

   a. Is there anything you would add to your visual now, after this second interview together?

The purpose of the third part of the interview is to gain a sense of who you are as a science teacher.

1. Could you tell me a little bit about why you chose to become a science teacher

   a. When was it that you decided to become a science teacher?

   b. Did anyone or anything play a major role in this decision?

   c. If so, can you tell me a little bit about this person/thing/event?

2. Did you ever consider other careers/have other careers?

   a. Can you tell me a little more about this?

3. If you had to describe yourself as a science teacher to someone who doesn't know you, how would you do it?

4. How would you describe how you teach science?

   a. Can you talk a little bit about how your own understandings of science in your teaching? (Lesson design, assignments, assessments, etc?)

5. How would you describe your students to people who don't know them?

6. Can you tell me a little about the lesson/class materials you chose to share with me?

   a. Prompt to explain how they exemplify who they are as a science teacher and the way they choose to convey science to their students?

Appendix C: RET Program Administrator Interview (1 hr)

1. Can you tell me a little bit about yourself?
2. How did you become involved in this RET?
    a. What is your role in the RET?
3. Can you tell me about ______________as a research experience for teachers?
    a. What are the goals of this RET?
    b. What do you hope teachers take away after participating in the RET?
4. From your experience thus far, what would a successful RET look like? Why?
    a. In what ways has this RET been successful?
5. In what ways do you present science to your teachers?
    a. How do you do this?
    b. Does the program emphasize inquiry?
    c. What vision of the nature of science?
    d. How does this program help portray that vision?
6. What are some things that you think teachers take away from their experiences in the program?