Stories of Women Science Majors:
A Diffractive Narrative Analysis of Three Women's Experiences with Science

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Dedication

I started the process of getting my doctorate while holding my approximately one-year old baby, William and thinking, “I want to be the best that I can be for you,” and “if I don’t start this process now, when?” I’m finishing my doctorate while holding my almost one-year old baby, Frederick and thinking, “I want to be the best that I can be for you,” and “if I don’t finish this process now, when?” This dissertation is dedicated to my sons William and Frederick, the inspiration for almost everything I do, and unquestioningly, the inspiration for the work presented in these pages.

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There are so many people to acknowledge that I could write an entire book just on the phenomenon of a dissertation and the intra-actions that shape the dissertation. Casual conversations with friends and moments of being in and out of the classroom with students have shaped this work more than I could ever capture. Thank you to all those who shaped me and my writing day in and day out. Here, I would like to acknowledge more specifically the people who have had their hands on my work more directly.

I started my doctoral program, as I discovered in my first class, as a positivist. I embraced constructivism in my pedagogy but saw the world as black and white, numbers and data. As luck would have it, the progress of my coursework aligned such that I was gifted with having Brian Casemore and Arshad Ali for several courses each. Their teaching opened my mind to a whole new way of viewing the world that not only shaped my scholarship and my teaching but shaped who I am. Thank you both.

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paper. Kim Sloan and Elizabeth Alvarado joined the writing group in the last few years. These women are some of the most loving, tenacious, brilliant people that I know. Without their feedback, support, and friendship I am sure I would not have finished this document.

Last but certainly not least, thank you to my family. My husband, David Bitler, kept me fed and kept our lives running forward during all of this. His patience and support have been unfaltering. My oldest son, William, often asks the equivalent of, "Are we there yet?" His life has been filled with, "sorry, I need to write." Despite that he is my cheerleader. My mom, Dorothy Campbell, read every word of this document, many words several times, as my on-call editor. Her academic journey has been an inspiration and her proverbial red ink made my writing coherent.

Abstract of Dissertation

Stories of Women Science Majors:
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The puzzle that this study addresses is the disproportionately low number of women in science careers. To add to the existing body of research on the underrepresentation of women in science, this study explored the human and more-than-human, entangled experiences of undergraduate women who were pursuing science degrees and potential teaching careers. The women were interested in science—as was evident in their studies in science—and were exploring an alternative to becoming a research scientist, as was evident in their studies in education. Narrative inquiry was used to explore their experiences in science. Karen Barad's onto-ethical-epistemology of agential realism provides the theoretical framework through which the experiences' diffraction patterns were explored. The narratives showed examples of resonance and examples of dissonance between the epistemologies of the women and the culture of science that they experienced. Readers will intra-act with the narratives, awakening wisdom regarding issues influencing women's persistence in science. Material ways of knowing science and relational ways of knowing science are seen throughout the narratives. These ways of knowing are typically ignored by studies on the epistemologies of science, but have been highlighted in feminist epistemologies. I therefore advocate for an embracing of multiple epistemologies of science, one of which being feminist epistemologies.

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Chapter 1: Introduction

Overview

We live in a society in which men are more likely to pursue careers in laboratories and women are more likely to go into a field like teaching. According to data released by the National Science Foundation, only 34 percent of those in science occupations are female (National Science Foundation, National Center for Science and Engineering Statistics, 2015). This number varies across science, technology, engineering, and mathematics (STEM) fields, with the highest proportion of women in health-related and other "people-oriented" occupations (Su & Rounds, 2015).

An analogy frequently used when discussing women's growing disinterest in science throughout their education is that of a leaky pipeline (Blickenstaff, 2005). The "leak" begins in early grades with more girls than boys losing interest in science class (Blickenstaff, 2005) and continues as women with degrees in science choose non-science careers. Factors such as unequal access to science classes, curriculum geared toward males, and societal expectations have been found to impact the growing disinterest over time (Blickenstaff, 2005; Brotman & Moore, 2008; Sinnes, 2006). According to the Economics and Statistics Administration's Executive Summary on women in STEM (2011), women with STEM degrees are less likely to work in STEM jobs (26 percent) than men with STEM degrees (40 percent). As in most quantitative data of this type, education and social science are not included as STEM jobs in this analysis. In comparison, women are twice as likely to enter the fields of education and healthcare (Economics and Statistics Administration, 2011). This moment of "leaking", between degree obtainment and career choice, is currently an under-researched moment.

The underrepresentation of women in science fields impacts women and their livelihood. Science and other STEM careers are unique in the volume of high-paid positions that are becoming available. As stated by Milgram (2011), "growth in STEM jobs was three times as fast as growth in non-STEM jobs, even in difficult economic times. STEM workers also command higher wages, earning 26% more than their non-STEM counterparts" (p. 5). Because of high wages and a growing job pool, science and other STEM fields are in high demand, yet women are not receiving the advantages these careers have to offer at nearly as high a rate as men.

Not only are women impacted by the disparities in sciences, but having fewer women in science also likely impacts the scientific community through lack of diversity in thought. Many scholars have made this point while arguing for the importance of research on this topic. For example, Milgram (2011) argues, "the absence of women from STEM education and careers affects more than the women; it is a missed opportunity for those fields. Women bring a different perspective that shapes and influences STEM disciplines" (p. 5). The most cited study when making this claim is an example from business. Dezso and Ross's (2012) study found that management firms with females on the board outperform firms with all male boards. This is believed to be due to a greater diversity of ideas considered by the board. Several other studies support the idea that more diverse teams have greater innovativeness and productivity (Cady & Valentine, 1999; Dwyer, et al., 2003; Francoeur, et al., 2008; Ostergaard, et al., 2011).

Freedman and Huang (2015) looked more specifically at how diversity in teams of coauthors of science papers impacts the potential influence of the article. They used the names and addresses of authors of 2.57 million articles to identify the homogeneity of

the authors. They then compared the distribution of authorship to the influence of the article as measured by the impact factor of the journal of publication and by the number of citations. As stated by Freedman and Huang (2015), they found "greater homophile is associated with publications in lower-impact journals and with fewer citations" (p. S289). This finding supports the idea that greater diversity in people involved in a project leads to more innovative and more influential findings. Like other forms of homogeneity, the unbalanced representation of gender in the field of science has a negative impact on the diversity of thought that is present.

The underrepresentation of women in STEM fields has been a very public issue over the past decade. In a speech on February of 2013, President Obama proclaimed the necessity of increased female interest in STEM.

> One of the things that I really strongly believe in is that we need to have more girls interested in math, science, and engineering. We've got half the population that is way underrepresented in those fields and that means that we've got a whole bunch of talent . . . not being encouraged the way they need to. (Office of Science and Technology Policy, n.d.)

Many possible explanations for the gender imbalance have been proposed, but despite a multitude of initiatives aimed at creating a gender balance in the field, the discrepancy remains (Sinnes & Loken, 2014; Scantlebury & Baker, 2010).

Statement of the Problem

For this research I was faced with the difficult choice of either addressing gender disparities in science or gender disparities in all STEM fields. When the theories applied within the research are closely examined, the varied ways in which science, technology, engineering and math are conceptualized becomes abundant. The reasons for and

solutions to the male domination of STEM vary greatly across and within the four fields of science, technology, engineering and mathematics. For this reason, although literature on STEM is referenced, as it has been above, my research explores the narrower puzzle of the underrepresentation of women in science.

Additionally, although gender is a factor many researchers have explored, it is only one of many factors impacting the homogeneity common in science, with race, ethnicity, social status and economic status impacting the characterization "scientist." Despite the importance of understanding how science ignores the voices of many, there is only one perspective with which I have firsthand knowledge. As a white, middle-class woman, born and raised in the United States of America, the gendered nature of science is an area in which my voice as a woman is counter to that of the norms in the field. Thus, although I believe that perspectives from all of those currently "othered" in the field are of vital importance, this argument is framed in the realm in which I have firsthand knowledge. This argument is about the exclusion of female voices in science. The one characteristic that the three women with whom I spoke as part of this study have in common is identifying as female. Their voices come from a variety of intersectional identities. The women's identities are made up of factors including but not limited to their gender, race, native language, native country, and socioeconomic status.

I would like to clarify the use of the term "gender." Although discussions around sex and gender can seem to essentialize male and female, the idea of gender goes beyond that of biological determinism. My use of male/female descriptors follows a long tradition of feminist scholars who explore the roles as socially constructed variables that impact society in both subtle and explicit ways. As stated by Sinnes and Loken (2012),

"We live in a gendered society where sex is a main organizing principle and hence a major determining factor of how males and females are raised" (p. 347). Though sex is used in this work to discuss the inequalities in the field of science, this work is entered into with full belief in individual characteristics that are separate from and unrelated to a person's sex.

Although there is an underrepresentation of women in many STEM fields and there is an underrepresentation of many marginalized groups in science, this research explores a narrower puzzle. Also, due to the limited research examining the experiences of women who obtain degrees in science but do not continue to careers as research scientists, this research focuses on that moment in the leaky pipeline. This research explores the underrepresentation of women in science by attending to the narratives of three women who were obtaining degrees in science but did not plan to become research scientists, sharing their unique stories of experience.

Purpose and Research Questions

There is an abundance of research on women in science oriented toward the aims of equality in science education and providing instruction that would interest girls and for challenging gender stereotypes in science. Girls have been and are still treated differently than boys in science contexts and that impacts their perceptions of science as a gendered discipline and their interest in the discipline (Brotman & Moore, 2008; Clancy, et al., 2017; Ecklund, et al., 2012; Miller, et al., 2018; Pringle, et al., 2012; Seymour & Hewitt, 1997; Sinnes & Loken, 2014; Steinke & Tavarez, 2018; The National Academies of Sciences, 2018). Research also shows that the altruistic aspects of science and socially-geared pedagogical practices can impact females' interest in science (Diekman, et al., 2010; Ecklund, et al., 2012; Hilts, et al., 2018; Sax, 1994; Seymour & Hewitt, 1997; Su &

Rounds, 2015; Wegemer & Eccles, 2019). Additionally, several studies show that positive science identities correlate with science degree obtainment and career choice (Carlone & Johnson, 2007; Hazari, et al., 2010; Lee, 1998). Over time, the focus of research on the underrepresentation of women in science shifted from documenting inequalities to exploring the complex nature of science education and the multifaceted identities of women. This study adds to this more nuanced, recent and growing body of literature and explores the intra-actions between science and women.

Many feminist scholars call for a feminist epistemology of science (Haraway, 2004; Harding, 1986; Keller, 1985; Longino, 1990). In contrast, empirical studies of students' epistemologies of science abound, but with arguably homogenous theoretical leanings. For example, most of the current conceptions of the epistemologies of science are based on Perry's 1950's study, which studied mostly male participants at elite institutions and ranked the students' epistemologies from naïve to sophisticated. This study failed to consider how ways of knowing may differ among cultures, genders, or socioeconomic groups. Some researchers are arguing for a shift away from viewing epistemologies as advanced or naïve and toward an appreciation for multiple ways of understanding science (Bang & Medin, 2010; Russ, 2014). In order to respect multiple epistemological lenses, Elby, Macrander, and Hammer (2016) suggest openness and starting from the ground up when studying epistemologies of science:

> The best way forward is for a significant portion of research to take a step back and treat this field as being in its early childhood. This means embracing theoretical and methodological diversity, not for its own sake but because we

> honestly do not know which mix of theoretical perspectives and methodological orientations will be most productive. (p. 122)

Research, like mine, that starts with women and is open to epistemological diversity can move the call for feminist epistemologies of science forward.

My research addresses the recognized need for further exploration of the experiences of women who do pursue science (Brickhouse, 2001; Brotman & Moore, 2008) by presenting the experiences of women who are obtaining degrees in science while pursuing careers other than being research scientists, specifically teaching. My research also falls within the more recent body of work attempting to capture the manifold entanglements between science and women. My work starts with the experiences of woman and was approached with openness toward multiple epistemologies. The purpose of the research is to share the human and more-than-human experiences of women in science through co-constructed narrative accounts. The research questions guiding the study are as follows:

- What are the stories of female undergraduate science students' experiences in science?
- What are the diffraction patterns between the students' epistemologies and the culture of science that they have experienced?

I use David Bell's definition of culture from his work on the culture of science and technology (2006). He explains that culture refers to the products, practices, institutions, and theories in a field. I approach this work from a feminist perspective that questions the current culture of science. More specifically, I utilize a Baradian material feminist perspective that focuses on human and nonhuman entanglements, agential realism.

Statement of Significance

The narratives presented in this document provide new stories to the readers to add to and intra-act with their prior experiences and prior engagements with literature allowing new perspectives and new wisdom to emerge. As stated by Hendry, Mitchell, and Eaton, "Science / method / narrative is not about reducing complexity (positivism), representing the world (signification), or achieving consensus (rationality) but about creating concepts and analytics which offer new and different perspectives on orientations toward the cosmos" (p. 3). These narratives allow for new orientations toward the puzzle of the underrepresentation of women in science to emerge for readers, facilitating the materialization of new ways of thinking about prior knowledge and materialization of new lines of thought.

This research has implications for multiple stakeholders including but not limited to policy makers, curriculum and science content writers, science educators, pre-service and in-service teacher educators, individuals involved in extra-curricular science programs, parents, female scientists, and female science students. Ethically being in the world as an engaged person who is invested in the puzzle of the underrepresentation of women in science, one cannot rely upon a check list of things to and not to do. It requires continual reflection, decisions, and renegotiations with the world. Getting a glimpse into the experiences that held significance for some women and how they made meaning of those experiences allows for new insights.

Speaking to women at the moment when they are approaching completion of a degree in science but deciding not to become a research scientist, addresses a currently under-researched moment. The narratives show that this moment is not a sudden occurrence but is reflective of the ever-emerging phenomenon that is their relationships

with science. A life time of intra-actions with the world around them continually shifted their interests in and knowledge of science.

The narratives focus on the women's epistemologies of science and when those epistemologies did and did not resonate with the culture of science that they experienced. Therefore, this research adds to the existing body of literature on epistemologies of science. Approaching the work with an openness for epistemological diversity allows it to also speak to literature on feminist epistemologies of science and multiple epistemologies of science.

Theoretical Foundation and Conceptual Framework

The current dominant culture of science came primarily out of the enlightenment, one of many time periods when masculinity was greatly revered over femininity. As science evolved, it was defined with characteristics such as objectivity and reason that aligned with the ideals of masculinity (Brickhouse, 2001; Harding, 1986). The "scientific" ways of experiencing the world could be silencing the voices of women who are enculturated to value other means of coming to know (Harding, 1986). By broadening the views of the nature of science, more individuals might align their own epistemologies with that of a scientist.

Karen Barad (2007) offers a material feminist epistemology of science that provides a fruitful framework for thinking about the women's experiences and feelings about those experiences. Barad's theory of *agential realism* is an onto-ethical-epistemological framework in which reality is made up of discrete phenomena. Agential realism has its roots in the work of Neils Bohr, who argues that all that can be known through experimentation is a *phenomenon*. Bohr (1935) states that "conditions constitute an inherent element of the description of any phenomenon to which the term 'physical

reality' can be properly attached" (p. 700). Phenomena are what can be measured and observed when things (such as objects and apparatuses) intra-act. If the intra-actions change, the phenomenon changes.

Barad interprets Bohr's scientific statements and applies them to the social sciences. Agential realism provides a fruitful theory for exploring intra-actions, such as how women intra-act with science. Barad argues that how we explore and learn about a phenomenon (epistemology) impacts the nature of that phenomenon (ontology) and that we, therefore, need to try to make good decisions about how we explore a phenomenon (ethics). For example, Barad discusses something she calls *agential cuts*. When we study something we inevitably focus on some things and ignore, or cut out, others. The agential cut determines the phenomenon of study and how that phenomenon is understood. Consideration of these cuts is an ethical obligation of the researcher.

The method of agential realism is studying diffraction patterns created by phenomena. In physics, a diffraction pattern shows the areas of resonance and dissonance between waves. Barad provides an example of how to use diffraction in social science by reading theorists' works diffractively against each other to look at the patterns of where authors' thoughts align in fruitful ways and where thoughts do not align. In this study read diffractively the "texts" of the experiences that women had in science.

Language: A Clarification

I would like to take a moment to discuss the language used in this text. Feminist literature puts forward debates regarding complexity and simplicity of language (Breger & Robinson, 2015; Grace, 2013; hooks, 1994; Lather, 1996; St. Pierre, 2000). Some feminist scholars argue females should write with complexity in order to be respected

within the male-dominated academy and to better represent the complexity of the ideas being presented. Others argue that feminist scholarship should be written in a manner that can reach a wide range of members of society and should push against the binary of simple versus complex. Hooks (1994) argues that when theory is written in a complex manner it reinforces the "false dichotomy between theory and practice" (p. 65). One overarching goal of feminist endeavors is to break down false binaries and language is one way to do that.

One of the most common critiques of Karen Barad's work is that it uses overly and unnecessarily complex language and language structures. For example, Pincher (2011) asserted, "sections of this book contains [*sic*] some of the densest prose I have recently read in the field" (p. 432). Pincher is not using the word dense as a compliment. I aspire to use Barad's complex theory in a manner that is accessible to those outside of the academy. My writing group members have described my writing as "walking the reader through concepts and pointing out what previous literature said." In that way my writing voice is similar to my teaching voice. In both situations, I aspire not to complexity or to simplicity, but clarity. In teaching, this promotes my students embracing their agency and making meaning *with* me. Likewise, I present my research in a manner that allows the reader to make meaning with the text. Both the reader and the text will have agency and will intra-act with each other to make meaning.

Summary of Methodology

This study adds to the existing body of literature on the underrepresentation of women in science by presenting diffractive and storied narratives of experiences in science of three undergraduate women. These experiences include times when the women's epistemologies aligned, or constructively interfered, with the culture (products,

practices, institutions, and theories) of science they have experienced and times when there was not alignment, or there was destructive interference. For example, one woman enjoyed some classes that required a great deal of memorization and another woman stopped caring about a class when the professor made it clear that he expected her to memorize the content rather than understanding what was happening. The research builds upon existing literature that unsettles some of the predominant ideas in epistemologies of science research. It highlights the need to value multiple epistemologies of science.

My research was developed around the puzzle of the underrepresentation of women in science and was guided primarily by this puzzle. The specific research question under investigation were:

- What are the stories of female undergraduate science students' experiences in science?
- What are the diffraction patterns between the students' epistemologies and the culture of science that they have experienced?

Narrative inquiry was used for several reasons. First, it is one method that is well-suited to revealing the complex and multi-faceted nature of phenomena thus avoiding the pitfalls of absolutism. This is in contrast to quantitative research which "tests objective theories" (Creswell & Creswell, 2018, p. 4) and in contrast to phenomenological studies which typically attempt to distill the lived experiences of several individuals in order to describe the essence of the experience (Creswell, Qualitative Inquiry & Research Design: Choosing Among Five Approaches, 2013). Also, the purpose of narrative inquiry is to present the experiences that people share

through stories. This is in contrast to ethnographic studies, which study patterns in a group through observation (Creswell, 2013). Additionally, narrative is one method that focuses on being respectful of participants since the narratives unfold with the participants and can give voice to under-represented populations such as women in science.

Narrative inquiry was also selected because narrative studies about women in science are not nearly as common as other types of studies, particularly quantitative studies. I believe there are many ways of knowing science and therefore an embracing of multiple epistemologies generatively adds to science. Likewise, I believe that there are many ways of knowing any phenomenon and therefore using a variety of methods of study adds to the understanding of a phenomenon. Ann Harman (1990) states this idea beautifully:

> This editor takes the position that there are many truths and there are many ways of knowing. Each discovery contributes to our knowledge, and each way of knowing deepens our understanding and adds another dimension to our view of the world. We need large-scale studies in which variables can be reduced to measurable units and the results translated into the language of statistical significance. We need in-depth "thick descriptions," grounded in context, of a single case, a single instance, or even a brief exchange. For example, large-scale studies of trends in marriage today furnish helpful information about a rapidly changing social institution. But getting inside one marriage as in "Who's Afraid of Virginia Wolfe?" richly displays the complexities of one marriage, leading us to new insights about the pain, the joys, the expectations, the disappointments, the

> intimacy, and the ultimate aloneness in relationships. Both the scientific and artistic methods provide us with ways of knowing (p. 3).

In depth, detailed, artistic descriptions of phenomena can awaken in readers understandings that cannot be known and felt through other approaches.

Through use of narrative inquiry, I metaphorically painted a picture of the diffraction patterns produced when the women with whom I spoke experienced science. The three-dimensional approach to narrative inquiry proposed by Clandinin and Connelly (2000) was used. The three dimensions are temporal (past, present, and future), interactional (personal and social), and contextual (place). Additionally, I integrated feminist research methods into the narrative inquiry approach by making methodological decisions that challenged the assumption of necessary separation between the researcher and the research participant and that moved forward a goal of empowerment of the oppressed or transformation of oppressive systems (Cook & Fonow, 1986; Hughes C. , 2015). More specifically, I integrated a Baradian material feminist perspective, focusing on the entanglements between human and nonhuman agents.

Three students who identify as female, who were pursuing degrees in science, and who were also interested in becoming teachers were interviewed. The women were recruited from GWTeach, a program for undergraduate STEM majors to also get a minor in STEM teaching. I am one of instructors in the program and worked closely with them over their time as students in the program. I facilitated several courses that each of the students took. The classes were mostly small and structured around discourse and group work. The criteria for participation in the study were that the students (a) were at least 18

years of age, (b) identify as female, (c) were science majors, (d) completed at least two education classes, and (e) were considering becoming teachers.

Women who met the criteria and were interested in participating joined me for at least three face-to-face open-ended conversations. The overarching purpose of the meetings was to provide the women an opportunity to share about experiences that they had in science. Specific purposes for each meeting was communicated to the women. As outlined by Sidman (2013), the focus of the conversation were for the women to: (a) share about their past in science and general demographic and background information, (b) share about specific experiences related to science, and (c) to reflect on the intellectual and emotional meaning they attribute to the experiences shared. Once the purpose for each meeting was set, the conversations were open-ended. The conversations were audio recorded.

Following each interview, I recorded field texts in order to document specifics about the conversations. Recordings were listened to multiple times and were transcribed. While writing the narratives, particular attention was given to the three-dimensions of narrative inquiry: interaction (personal and social), temporality (past, present, and future), and situation (place). Attention was also given to moments of resonance and dissonance between the women's epistemologies and the culture of science that they have experienced. A diffractive reading of the narratives through each other and through existing literature highlights moments of fleeting wisdom.

Limitations and Delimitations

The research presented in this dissertation takes place with a specific group of students in one program at one university. The goal of this research is to give an in-depth look at the experiences of three women in science. These experiences are highly

contextualized. The purpose of this research is not to capture the experience of all women in science but to portray the experiences of some women more fully. By presenting the research as storied narratives, readers will be able to identify how the stories presented have resonance with their own stories. Readers will be able to make meaning from the stories that awaken in them new wisdom regarding the underrepresentation of women in science and transfer that wisdom to the contexts in which they work and think. Readers will not be able to distill a list of universally useful strategies to increase women's interest in science.

Chapter 2: Intra-Acting with the Existing Literature

In this section I outline some of the literature relevant to the underrepresentation of women in science. I begin by outlining research specifically designed to address this concern. Then I review the literature on epistemologies of science in order to show how science and science learning have been defined and understood in the literature. Next, I critique popular conceptions of science through a feminist lens. Following the critique, I outline some of the more prominent feminist epistemologies of science. Finally, I describe one feminist epistemology—agential realism. This chapter builds to an argument that agential realism is a productive framework through which to explore women's experiences in science.

Intra-acting with the Literature on Underrepresentation of Women in Science

The analogy of a leaky pipeline is often used when discussing females in science (Blickenstaff, 2005). This analogy provides an explanation for the lower percent of women in science careers as compared to men, which is not due to one factor but through a cumulative effect of multiple factors. Research shows that experiences from early childhood through experiences on-the-job impact females' interest in science (Blickenstaff, 2005). It is a cumulative effect of separate but often-related factors that influences each woman's career and leads to the field's gender disparities.

The proposed explanations for and suggested solutions to the imbalance between males and females are abundant, spanning many areas of research and grounded in many belief systems. As evidence of the breadth of research done on the topic, when I first searched ERIC database for abstracts that include the words "gender" and "science," it resulted in over 3,500 publications, more than 2,000 of which are peer reviewed. As a

basis for comparison, when I then searched for "growth mindset"—a current buzz phrase in education—it resulted in merely 77 publications, 47 of which are peer-reviewed. Limiting the search for peer reviewed articles with abstracts containing the words "gender" and "science" to the last five years, yielded approximately 750 articles, over ten times more than the search for "growth mindset" with no date limitation. In other words, studies seeking to understand gender differences in sciences are abundant. To narrow and focus the body of literature used, I focused on literature from the past 20 years with a larger emphasis on the past five years. Also, priority was given to articles with the greatest number of citations by other authors.

Many researchers have suggested categories for discussing and analyzing the existing literature. For this literature review, I utilize three categories that Astrid Sinnes (2006) suggests for addressing gender perspectives in science education. The categories are aligned to the three waves of feminism. Since my work is framed within feminist literature, it makes sense to outline the existing literature within feminist movements. Also, the feminist lenses through which most gender-related studies are conducted are evident; therefore, it is a relevant and simple organizational structure to follow. Sinnes argues that even when the feminist lens is not made explicit, there is an underlying belief that guides the work and that belief places the work within a specific category. The three categories suggested by Sinnes are gender-neutral science education from first wave feminist thought, female-friendly science education from second wave feminist thought, and gender-sensitive science education from third wave feminist thought. Although the three waves of feminism are typically associated with particular historical time periods and political movements, they are also associated with ongoing sets of beliefs. Sinnes

and Loken (2014) wrote in greater detail about what type of research and what findings would fall within each category without reviewing much existing literature. Consequently, their work is used to set up the framing of each section with findings from specific studies described within the section.

Gender-Neutral Science Education

As described by Sinnes (2006), "gender-neutral" science education is based in the first wave feminist or equality feminist belief that males and females are essentially the same and that they should, therefore, be engaged equally. First wave feminism began with the suffrage movement during the nineteenth and early-twentieth century. Although best known for gaining women the right to vote, suffragists fought for equal rights—mostly legal rights—for women more broadly, a fight that continues in less visible ways even until today. According to Sinnes, the overarching premise of research on women in science supporting gender-neutral science education is that there are fewer females in science because girls are not treated the same as boys.

According to Sinnes and Loken (2014) research that falls within the category of gender-neutral science education verifies that girls are, in fact, treated differently and that more girls become interested in science when these disparities are decreased. Seymore and Hewitt (1997) provide a good overview of the work done in the area during the 1980s and 1990s (pp. 231–234). Since then, research documenting the different ways girls are treated in science classrooms became much less common (Brotman & Moore, 2008). However, the decrease of studies does not indicate an elimination of bias. A 2012 article geared toward understanding the underrepresentation of African American girls documents a male teacher saying that science is a "guy thing" and builds on the abundant

body of prior research to show that teachers' beliefs impact how they interact with students (Pringle, et al., 2012).

The experiences of women scientists corroborate the argument that women still experience discrimination in the sciences and that this discrimination is a factor in women's attrition in the field. A 2012 study surveyed 2,503 and interviewed 150 physicists and biologists about the reasons for the unbalanced gender distribution in their respective fields (Ecklund, et al., 2012). The female participants were much more likely to say that discrimination was a major contributing factor than their male counter parts. The interviews showed that in addition to discrimination, many women were actively discouraged from entering the field, particularly in physics. However, overall there was little difference between the perceived discrimination of women in biology versus physics, particularly with women earlier in their careers. Therefore, discrimination, as perceived by women in the field, does influence other women's decisions to leave the field; however, discrimination does not explain the vast difference in numbers of women who pursue biology versus physics.

The perceived abundance of sexual harassment is supported by other recent findings. A scathing 2018 consensus study report by The National Academies of Science claims that one of the main reasons there is not more progress on closing the "gender gap" in science is due to sexual harassment (p. 1). Based on a report completed for this consensus study, 20 percent of female science students in the University of Texas System experienced sexual harassment by a faculty or staff member. The consensus study also highlights the findings of a 2017 study by Clancy et al. The researchers surveyed 474

astronomers and planetary scientists. The surveys revealed that thirty percent of women felt unsafe because of their gender, compared to one percent of men.

Although the report by The National Academies of Science (2018) focused on overt forms of sexual harassment in science, engineering, and mathematics, it also pointed out what is referred to as the "iceberg" of harassment (p. 38). The imagery of an iceberg depicts the most discussed and researched forms of blatant harassment as being visible, above the water line. More subtle and common forms of harassment, what might be thought of as micro-aggressions, often remain invisible below the water line. The report also highlighted some of the complexities of how intersecting identities impact harassment toward women, indicating that often racial bias is more overt than gender bias (p. 45).

A 1999 report explicitly explored the "micro-aggressions" that occurred toward females in science at the Massachusetts Institute of Technology (MIT). The researchers, who were female science faculty at MIT, found "differences in salary, space, awards, resources, and response to outside offers between men and women faculty with women receiving less despite professional accomplishments equal to those of their male colleagues" (p. 4). The report showed that previously ignored, and in many cases unseen, inequities created very different experiences and opportunities for the female faculty.

Although current research typically does not often set out to prove that girls are being treated differently than boys (Clancy, et al., 2017), most research operates under this assumption and therefore is framed within equality feminism (Howes, 2002). Sinnes and Loken (2014) indicate that the implications from gender-neutral science education research include the need for gender-neutral curriculum and curricular materials, which

means curriculum that is relevant to both males and females and in which males and females are referenced and portrayed equally. Beyond curricular changes, they recommend equal numbers of male and female science teachers, equal classroom responsibilities for and expectations for male and female students, and equal teacher attention to all students. These implications are likewise asserted in other literature reviews on the topic with a current emphasis being the need for female science role models and representations in media (Blickenstaff, 2005; Brotman & Moore, 2008; United Nations Educational, Scientific and Cultural Organization, 2017; Wang & Degol, 2016).

When females exclusively see and hear about male scientists, they equate the discipline with the gender. This makes them less likely to see themselves as potential future research scientists. A recent large-scale study (Miller, Eagly, & Linn, 2014) showed that in the 66 studied nations across the world, both males and females retain strong implicit gender/science bias, according to the Project Implicit's web analysis. The study did show hope. In nations with more female scientists, there was found to be less gender/science bias.

Children's implicit gender/science biases have been measured over the past 50 years by having children draw a "scientist" and then analyzing those drawings for indicators of gender. Miller, Nolla, Eagly, and Uttal (2018), conducted a meta-analysis of the 78 studies that have been done using this method. The representation of scientist as females increased over the more recent decades. Data collected between 1966 and 1977 reported that 99.4 percent of representations were of males and data collected between 1985 and 2016 reported that 72 percent of representations were of males.

Although the downward trend is promising, the numbers are still stark. In contrast to the encouraging findings that the implicit bias is decreasing over time, the meta-analysis also highlighted the finding that as children get older, they tend to develop a greater male to scientist association. This trend begins at eight years of age. The two findings of increasing female representation through the years and decreasing female representation as age increases were true for boys and girls.

The decrease in male-scientist bias over the last 50 years is likely due in large part to an increase in the representation of scientists as women in popular media. However, there is still a great deal of progress that can be made in this area. A 2018 study by Steinke and Tavarez analyzed the portrayals of STEM characters in 42 popular films released between 2002 and 2014. They found that STEM characters with speaking roles were twice as likely to be male and that the female STEM characters were typically cast in co-lead or secondary roles, not lead roles. I argue that the data in this study is skewed in favor of representing female scientists as keywords such as "movie and woman scientist" and "woman researcher" were used to identify the movie along with gender-neutral keywords such as "movie and scientist" and "movie and physicist." The keywords did not include any reference to male scientists specifically.

In addition to having a greater representation of women as scientists in popular media, one way to combat implicit biases is through female role models. Several studies demonstrate that exposure to same-sex STEM experts, "enhances women's self-concept in STEM, attitudes toward STEM, and motivation to pursue STEM careers" (Stout, et al., 2010, p. 255). Although one recent study shows a demotivating effect of female role models on middle school girls (Betz & Sekaquaptewa, 2012), the vast abundance of

literature shows a positive impact (Blickenstaff, 2005; Brotman & Moore, 2008; United Nations Educational, Scientific and Cultural Organization, 2017; Stout, et al., 2010; Wang & Degol, 2016). The Betz and Sekaquaptewa (2012) article was a study of middle school girls. The age of the girls is a common factor determining the effectiveness of female role models. Because of this trend Drury, Siy, and Cheryan (2011) recommend that female role models be used more as a method to retain women who are already pursuing science than to recruit girls into science.

Female-Friendly Science Education

Sinnes (2006) defined "female-friendly" science education as acknowledging and valuing the differences between males and females, which exist either because of biological or sociological differences. This idea stems from second wave or difference feminism. Second wave feminism came into being during the 1960s in retaliation to the post-World War II emphasis on the domesticity of women. During this movement, feminists fought for greater equality in areas beyond the law such as in the workplace and in the home. Women debated about equality versus difference, leading to difference feminism. Difference feminists critiqued the patriarchal society, arguing that feminine characteristics—whether innate or taught—are equal to or better than men's characteristics. According to Sinnes, research on female-friendly science education evolved from second wave feminism and looks at contexts in which girls succeed. Scholars doing female-friendly science education research advocate for creating environments that are more girl-friendly.

Sinnes and Loken (2014) describe how research in the category of female-friendly science education indicates that science teachers should acknowledge and value

differences among male and female students, paying extra attention to nurturing girls in combined gender classes or separating boys and girls into separate classes. Female students should be encouraged to explore their own interests and build off of their experiences. Specifically, content should be related to health, societal, and environmental issues—as, whether enculturated or innate, these have been found to be of interest to many females.

A 2010 study showed that STEM careers are perceived by both male and female students as less geared toward "communal goals," and that the more a student identified him or herself as being motivated by communal goals the less likely he or she was to be interested in a STEM career (Diekman, et al., 2010). Gender was shown to predict communal goals and communal goals were shown to predict STEM career interest. Similarly, a 2015 meta-analysis of normed data found that women are more interested in people-related STEM activities and men are more interested in thing-related STEM activities (Su & Rounds, 2015). Therefore, women are more likely to go into fields like biology and medicine because they are seen as more altruistic endeavors (Wegemer & Eccles, 2019). Several studies found that an interest in social good was a determining factor for women choosing to stay with or change from a science undergraduate degree (Ecklund, et al., 2012; Sax, 1994; Seymour & Hewitt, 1997). A focus on making clear the altruistic aspects of science in school may lead more women to be interested in pursuing science.

According to Sinnes and Loken (2014), teachers should also use pedagogical techniques that are shown to benefit female students, such as using group work and fostering a non-competitive environment. A meta-analysis of research on the impact of

innovative science and math instructional approaches (inquiry-based, context-based, computer-based, collaborative learning strategies, and extra-curricular activities) showed significant effects on students' attitude and achievement with little variance based on the specific approach (Savelsbergh, et al., 2016). The authors of the meta-analysis express regret that data could not be further disaggregated by categories such as gender as that information was not provided in most of the 533 publications used.

Many of the instructional methods that are considered female-friendly include socialization and cooperation. A 2018 study supported the idea that women's interest in science is positively impacted by relationships with peers in science classes (Hilts, Part, & Bernacki, 2018). The study surveyed 206 STEM majors and asked about how their relationships impact their perceived relatedness to their STEM peers, their perceived competence, their intent to leave the major, and their course performance. The study found that, unlike men, women's intent to leave the major was decreased with increased classmate contact. Also, women were the only subgroup studied whose intent to leave the major was decreased with an increased sense of relatedness. This research supports the idea that women would have an increased interest in science with greater opportunities to interact with their peers.

Also relevant under the umbrella of female-friendly science education is research that shows that some criteria used to identify students who "should" continue in science under-identifies women. Miller, Zwickl, Posselt, Silverstrini, and Hodapp (2019) point out that the future of who become scientists is largely determined by who gets into PhD programs. Admissions into PhD programs are largely determined by graduate record exam (GRE) scores that are "not evenly distributed by race and gender" (p. 1) and are not

correlated with PhD completion. The authors used data from the education testing services (ETS) database to show that, "the median U.S. female score is 580 (28th percentile), while the median U.S. male score is 650 (46th percentile)" (p. 2). Therefore, many women are not accepted into PhD programs based on their GRE scores despite there being no correlation between scores and graduate success. Based on data collected from 3,962 students from 27 PhD programs Miller et al. found that the most reliable predictor of PhD completion is a student's undergraduate grade point average. This study highlights the need for institutional practices that do not rely on inaccurate and biased information.

The need for female-friendly science education, outlined by Sinnes and Loken (2014), is supported by other literature reviews (Blickenstaff, 2005; Brotman & Moore, 2008; United Nations Educational, Scientific and Cultural Organization, 2017; Wang & Degol, 2016). However, when looked at more closely, references to female-friendly pedagogy tend to cite authors who are making recommendations rather than research-supported findings. Most of the research on innovative science instruction that is cited in literature reviews is not gender specific, such as Savelsbergh et al. (2016).

Gender-Sensitive Science Education

"Gender-sensitive" science education, according to Sinnes (2006), is a category of research forwarding the belief that ideas of gender are socially created and should be challenged. This idea stems from third wave or postmodern feminism. Third wave feminists critiqued second wave feminists for over-generalizing the "women." Most feminists prior to this movement, which began in the 1990s, were White middle-class women thus the feminine characteristics discussed by second wave feminists were

narrowly defined. Third wave feminists focus on differences between women based on race, class, ethnicity, and more. According to Sinnes, rather than a focus on girls' interests, researchers that fall within gender-sensitive science education focus on individual students' interests and experiences. Teaching materials that are gender-sensitive are designed to meet the needs and interests of a large variety of students. Research in this vein highlights the need for diverse interests and beliefs and encourages a critical perspective on the nature of science. A more detailed review of critical approaches to the nature of science can be found in the theoretical framework and the review of literature on feminist epistemologies of science. Although research on women in science seems to be moving the direction of gender-sensitive science education, the main body of current literature is based in second wave feminist ideals.

One study that focused intensely on the experiences of one girl in science was done by Bricker and Bell in 2014. The study was an ethnography of a young student named Brenda over several years. The student was observed at home, at school, and at extracurricular events. The thick description produced showed the interplay between the various environments and contexts in which Brenda was engaged with the act of science and scientific concepts. As described by the authors, the research shows "how everyday moments, experiences across settings, pursuits, social groups, and time, may result in scientific learning, expertise development, and identification" (p. 281). The study demonstrated the inseparability of the doing of science from the relationships and environments involved.

One example of how Bricker and Bell (2014) showed inseparability between science and the social and environmental contexts was Brenda's experimentation with a

perfumery kit. Inspired by Brenda and her cousin's mixing of their grandmother's perfumes, Brenda's parents purchased her the kit. Brenda and her mom used it frequently together. Brenda found the kit to be "fun" and she appreciated the choice involved in the explorations. She loved to organize the contents of the kit and to use them in new ways each time. Throughout her use of the kit she engaged in many "practices that are highly valued in scientific research" (p. 271). However, these practices did not seem to transfer into more formal science learning experiences at school. In this context Brenda was much less likely to talk and collaborate with others and took a more passive role with the experimentation.

One topic common in the current literature, which I place under gender-sensitive science education but is not addressed by Sinnes and Loken (2014), is identity research. Identity research in education stems from Lave and Wenger's (1991) framework of situated learning in which the social context of learning is the focus. Identity research on women in science looks at how an individual's identity as a woman might challenge an emerging identity as a scientist (Archer, et al., 2012; Barton, et al., 2012; Calabrese et al., 2010; Hughes G. , 2001; Settles, et al., 2016). This idea is made clear in a quote from a woman with a PhD in molecular biology in a recent article in Popular Science: "When you're in science, you're forced to sacrifice and squash down all your other identities if you want to be a pure, objective scientist" (Ahmed, 2018). Rather than coming from a psychological perspective where identity is set based on personal characteristics and traits, the research on science identity was developed from the feminist theory of intersectionality. Within this framework, identity is constantly evolving and involves internal negotiations.

Several studies show that positive science identities correlate with science degree obtainment and career choices (Carlone & Johnson, 2007; Hazari, et al., 2010; Lee, 1998). For example, Dou, Hazari, Dabney, Sonnert, and Sadler (2019) used data collected from 15,847 students across 27 colleges to conclude that the individuals who had stronger STEM identities were much more likely to go into STEM careers. As they stated, "for every one-point increase in students' STEM identity score on the 6-point Likert scale their odds of choosing a STEM career in college increased by 85%" (p. 629). Although these findings were for both male and female students, in combination with the previously discussed research which shows women are less likely to have STEM identities, it is clear that STEM or science identity development impacts career choices. Therefore, exploring the development of science identities is a potentially productive line of inquiry to understand the underrepresentation of women in science.

One recent study by Rhodes, Leslie, Yee, and Saunders (2019) had findings that support the idea that identifying as a female is negatively correlated to identifying as a scientist. The premise of the study was to determine students' persistence in a task when being addressed as a scientist, which reinforces science as an identity, versus being described as doing the act of science. Four studies were conducted with between 84 and 168 students participating in each study. In each study students were introduced to the scientific method and then were asked to repeat a specific science task as many times as they liked. During the introduction half the students were exposed to category labels such as, "today we're going to be scientists." The other half were exposed to action terms such as "today we're going to do science." Each study showed that, "action-focused language consistently led to increased persistence among girls" (p. 10). This

finding supports the conclusion that female students are less likely to identify as scientists and that resistance towards this identification may negatively impact their persistence in science.

Since identity of women in science research is a relatively new line of inquiry, the research being done is often geared toward developing an understanding of how female and science identities interact. Some of the suggested implications from this research are: (a) students are more open to a science identity if they experience success in science (Stets, et al., 2017), talk about science with family and friends at an early age (Dou, et al., 2019), and read or watch science related media at an early age (Dou, et al., 2019); (b) identity negotiation is best accomplished through explicit identity work (Archer, et al., 2012; Calabrese Barton & Tan, 2010); (c) students more readily identify as scientists when experiences outside of school are related to course work (Calabrese Barton & Tan, 2010); (d) teachers need to pay attention to institutional narratives in their classrooms (Archer, et al., 2012; Tan, et al., 2013); and (e) female students' psychological well-being needs to be taken into consideration (Settles, et al., 2016).

Gaps in Literature on Underrepresentation of Women in Science

Over time, studies around women and science have moved away from a first wave feminist approach toward a third wave feminist approach. In other words, researchers have moved away from looking purely at the inequalities present in the field of science and in science education (though it is still important to reaffirm that these inequities exist) and toward understanding both the complexities of the field and the multifaceted identities of women. Exploring the intersectionalities of women in science is a fairly new and emerging research agenda that still has a great deal of work to be done (Scantlebury,

2014). Doing this fully involves research that does not over-generalize participants (Scantlebury, 2014) and that recognizes and explores the multiple and continually shifting identities of women. Additionally, Scantlebury (2014) and Sinnes (2006) argue that transformative research about women in science needs to make a feminist theoretical framework explicit and integral. My research operates within a specific new material feminist lens, agential realism, and attempts to look holistically at the women and their experiences. For examples of research exploring the teaching and learning of science conducted within a material feminist framework see the compiled writings in *Material Practice and Materiality: To Long Ignore in Science Education*, edited by Catherine Milne and Kathryn Scantlebury (2019).

Even with a gradual shift toward a third wave feminist approach, the vast majority of research highlighted above focuses on factors that make science unattractive to women—a deficit model—with few studies focusing on why some women do choose to pursue science. Citing four other articles pleading this point, Brotman and Moore (2008) highlight "exploring more deeply the experiences of girls who do enjoy and engage in the physical science at various ages" as one new direction for research on gender and science (p. 993). My research involves women who were obtaining undergraduate degrees in science. Due to their field of academic studies, presumably they were interested in science, thus they had valuable insights worth exploring. Regardless of the career the women chose, they were in the minority by obtaining science degrees.

Furthermore, existing research on women in science explores women's experience from preschool through science careers, showing a decrease of interest over time. One of the least understood time periods in this spectrum is the transition from

college to career. As previously mentioned, women with STEM degrees are less likely to work in STEM jobs (26 percent) than men with STEM degrees (40 percent) (Economics and Statistics Administration, 2011). Despite this specific leaky point in the pipeline, very little research has been done on gender disparities in science that emerge after undergraduate degree obtainment (Sax, 2001). Raymond and Brett (1995) argue that "it would be useful to know more about the early career interests of those who major in science but leave at graduation" (p. 407). The few years prior to graduation, when female science students are deciding to become research scientists or do something else is a little understood and vitally important moment. Therefore, the women who participated in this study were college juniors and seniors.

Intra-acting with the Literature on Epistemologies of Science

In order to explore the experiences of women who are interested in science, we need to first know what is meant by science: what is "science" and how one comes to know science. In other words, what are the epistemologies of science? Epistemological questions are generally "What is knowledge?" and "How do we get that knowledge?" (Wickman, 2004). However, those working in different disciplines as well as individuals in the same discipline use the term "epistemology" in different ways and with slightly different connotations. Scientific epistemology generally describes the sources, value, and validity of scientific knowledge (Sandoval, 2005). According to Elby, Macrander, and Hammer (2016), "current work on epistemic cognition in science stems from two threads of research: personal epistemology and nature of science (NOS)" (p. 113). In the following section, I explore how the epistemology of science was described and studied within various schools of thought.

Nature of Science

The nature of science (NOS), sometimes called formal epistemologies of science (Burgin & Sadler, 2013), "refers to the values and assumptions inherent to the development of scientific knowledge" (Lederman N. G., Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research, 1992, p. 331). The first explicit argument for the importance of teaching NOS was made in a 1907 report of the Central Association of Science and Mathematics Teachers. However, some scholars claim that the importance of NOS instruction has been a concern for even longer. The emphasis for instruction focusing on NOS endured over time, to the point of being a central concern in the Next Generation Science Standards (NGSS Lead States, 2013).

A 2000 National Science Teacher Association position paper on NOS provides a summary of the generally accepted values and assumptions: "(i) observation and inference are distinct, as are (ii) laws and theories; (iii) science is culturally embedded; (iv) scientific knowledge is both empirical and creative; (v) is subjective; and (vi) is tentative" (Elby, Macrander, & Hammer, 2016, p. 115). The Next Generation Science Standards document also outlines a definition for NOS that greatly overlaps with the detailed explanation in the NSTA position paper.

Some NOS research focuses on how students' experiences in science impact their understandings of NOS (Ryder, et al., 1999; Samarapungavan, et al., 2006; Samarapungavan, et al., 2006). Other research focuses on how explicit instruction around NOS impacts students' understandings (Khishfe, 2014). Current debates also focus on how NOS is best taught and what measures best evaluate understandings of NOS (Elby, et al., 2016). For a full list of NOS instruments that were developed before 2007, see Lederman (2007, p. 862).

One measure commonly used to assess NOS is Carey et. al.'s (1989) Nature of Science Interview (NSI) which involves 21 interview questions. Sandoval and Redman (2015) tested the validity of the NSI in their 2015 study where they interviewed 15 research chemists, thereby also testing the assumption that there are NOS norms in the field. The primary finding was that there was a lack of consistency within a participant's responses. This finding has implications for my study which are addressed later. Sandoval and Redman state that scientists' perceptions are much too complex to capture with ratings within particular themes. They call into question the use of instruments that evaluate participants' beliefs about science on a scale and advocate for more detailed representations of the individual's complex beliefs. They end the paper expressing the belief that people's thinking changes over time and in different contexts and that researchers should be attentive to those fluctuations and to "productive epistemic ideas" (p. 1100). The idea of valuing the productivity or epistemologies are discussed more fully in the section on multiple epistemologies.

The research conducted by Sandoval and Redman (2015) strongly supports the use of more open-ended research methods for exploring students' beliefs about the nature of science. It also suggests employing the usefulness of an epistemology as a benchmark for that belief's value, an idea more fully expressed by scholars advocating for multiple epistemologies. Both of these suggestions impacted my research methods. By interviewing women with unstructured interviews rather than using surveys or structured interviews and by representing what the women shared through narratives rather than analyzing what they say through codes, I approached the research in an open-ended manner. These methods valued epistemologies based on their usefulness since

participants chose what they wanted to share about. Sandoval and Redman's findings also support a theoretical framework that values multiple epistemologies, like the one that I adopted.

One additional finding stated in the work of Sandoval and Redman (2015) is particularly relevant in relationship to my research. Sandoval and Redman indicated that participants rarely expressed the idea that research is beneficial to humanity. Since they were interviewing scientists at a university, it is likely that these researchers either teach or work with students in their labs. As previously indicated, women have been shown to be motivated by altruism. If these researchers are not talking about the benefits of science to humanity in interviews, it is unlikely that they are talking about them with students in classes. This may impact students'—particularly women's—interest in continuing in science, a factor that did come up in my conversations with women.

As is further detailed in the next sections, NOS research differs from research on epistemologies due to epistemology researchers' focus on people's views about their own knowledge. NOS research and epistemology of science research have many overlapping themes but researchers in the two different areas rarely reference or directly build off of the other area (Elby, Macrander, & Hammer, 2016).

Personal Epistemology

Personal epistemologies are used to describe beliefs about the nature of knowledge and knowing. They influence the way we make sense of the world around us (Dini & Hammer, 2017; Elby, 2009; Elby, Macrander, & Hammer, 2016; Hofer, Personal epistemology and culture, 2008). A shift in personal epistemology occurs due to cognitive dissonance, or dissatisfaction with current beliefs and thoughts (Hofer, Personal

epistemology and culture, 2008). In this way a more sophisticated and complex personal epistemology is believed to develop over time. Although personal epistemologies are not specifically epistemologies of science, many researchers of science have used personal epistemologies in their research (Bell & Linn, 2002; Elder, 2009).

The ideas related to personal epistemology originate from Perry's 1950s studies of Harvard students, which were inspired by Piaget. Perry and his colleagues interviewed Harvard students at the completion of each year during their four years of undergraduate studies (Perry, 1968). From this interview data, students' epistemologies were classified within nine distinct stages with dualism characterizing the lowest stages and relativism characterizing the highest stages (Moore, 2009). Table 1 in Appendix A describes each of the nine stages. Though no children were used as research subjects, children were assumed to begin at the lowest stages and progress, with appropriate schooling, to the higher stages (Elby, Macrander, & Hammer, 2016). Sandoval later used the term personal epistemologies to refer to the stages identified by Perry.

Perry's classifications are still being used in research, including science research. A 2010 article by Grove and Bertz showed that students who are more dualistic thinkers struggled in organic chemistry. Also, since Perry's study, much of the research on personal epistemologies, including current research, categorized, quantified, and ranked students' beliefs. Primarily this has been done using surveys such as the epistemic belief inventory (Schraw, et al., 2009) and questionnaires (Elder, 2009).

Schommer's (1990) model of personal epistemologies built on previous work and introduced the idea of there being multiple dimensions to epistemologies and each span from naïve to sophisticated. Schommer's dimensions—stated from the naïve end of the

spectrum—are: (a) knowledge is simple rather than complex; (b) knowledge is handed down by authority rather than derived from reason; (c) knowledge is certain rather than tentative; (d) the ability to learn is innate rather than acquired; and (e) learning is quick or not at all. Table 2 in Appendix A provides more details about Schommer's model. Following Schommer's example, subsequent researchers adopted the idea of multiple dimensions, but did not necessarily adopt the same dimensions.

In the 1990s, studies on personal epistemologies became more discipline specific. Research uncovered that students' beliefs about knowledge and knowing differed between subjects such as history versus science (Elby, Macrander, & Hammer, 2016). Therefore, research began to specify epistemological domains, such as personal epistemologies of science. Problematically, many of the codes that are used to analyze data in science research on personal epistemologies, and other areas, are based on Perry's original findings, not on codes that are based on research that was completed in that field (Elby, Macrander, & Hammer, 2016). Also, although evolutions in personal epistemologies have occurred over time, the underlying premise that epistemologies progress in stages, remains.

Practical Epistemology of Science

In addition to the emergence of a realization that epistemologies vary across domains, research also revealed that epistemologies vary between activities and contexts within particular domains (Elby, Macrander, & Hammer, 2016). This realization led to research on the epistemologies that students display in different contexts. Wickman (2004) first used the term "practical epistemologies" to refer to the ways that epistemologies are used during laboratory work in science. His goal for researching

practical epistemologies was to better understand how individuals internalize learning, thus changing how they approach situations. This research agenda was approached through analysis of conversations between groups of students and between students and their teachers.

In the research described in their 2004 article, Wickman observed a group of four students during a chemistry practical. The research questions were specific to the chemistry content rather than more broadly about how the students make sense of science. Wickman did identify that the students approached the lab problems first based on the stated objective of the practical, second based on suggestions from the instructor, and third based on previous experiences. He also identified that students were highly dependent on the instructor to determine what were and were not valid and meaningful observations. Wickman stated, "practical epistemologies could be used by teachers to find alternative routes of introducing new habits." This statement, along with the highlighted findings, indicate that what is found through studies of practical epistemology are specific to the content and pedagogy of instruction.

Sandoval (2005) proposed researching practical epistemologies through observation of students participating in science experiences followed by interviews asking students to explain what they were thinking during those experiences. He also advocated having students compare their beliefs to those held by the scientific community at large—formal or sophisticated epistemologies. In this manner the contextualized nature of beliefs can be uncovered and explored. Sandoval points out that a study of practical epistemologies can bring together two camps of researchers: those

who study students' beliefs about science and those who study students' scientific practices.

Sandoval (2005) suggests four epistemological themes that students should understand in order to have sophisticated epistemologies: scientific knowledge is constructed, scientific methods are diverse, there are different forms of scientific knowledge, and scientific knowledge varies in certainty (see Table 3 in Appendix A). Despite acknowledgement that epistemologies called upon from one moment to the next may differ greatly depending on the context, following the tradition set by Perry in the field of personal epistemology, practical epistemologies of students are typically evaluated on a spectrum from naïve to sophisticated (Burgin & Sadler, 2013).

Women's Epistemology

One critique of personal and practical epistemologies is that the theories were developed from research done with white male students at elite institutions in the United States (Hofer, Personal epistemology and culture, 2008, p. 3). For example, even though Perry's studies involved a handful of women, all of the specific references in his writings were to male participants (Belenky, et al., 1997). In order to include women in conceptualizations of epistemology, Mary Belenky, Nancy Goldberger, Jill Tarule, and Blythe McVicker Clinchy interviewed women about their relationship with and experiences with knowledge. In addition to the newness of the focus on women, they also expanded the population of participants beyond university walls, including women involved in learning from human service agencies. Their findings—which show that women's thinking did not fit neatly into Perry's categories—were culminated in the book *Women's Ways of Knowing* (1997), which was first published in 1986.

Belenky et al. (1997) found that a focus on women not only changed the categories through which personal epistemologies can be understood, but also extended the understanding of how knowledge is approached. As described by Clinchy (2009), "Perry's positions are defined mainly in terms of the nature of knowledge and truth . . . whereas we stress women's relation to knowledge and truth, their conceptions of their selves as knowers" (p. 64). According to their findings, categorizing individuals' relationships to knowledge as naïve or informed is not as relevant for understanding women's epistemologies as understanding how the women relate to the knowledge.

Despite a claim to not approach epistemologies in a hierarchical manner, the researchers identified five ways in which women *progress* in their relationship to knowledge. These epistemological categories are silence, received knowing, subjectivism, procedural knowing, and constructed knowing (see Table 4 in Appendix A). Silence is a theme that emerged from the women who were "among the youngest and most socially, economically, and educationally deprived" (Belenky, et al., 1997, pp. 23-24). These women talked about feeling unheard and their inability to express their ideas. Women who were identified as relying on received knowing talked about learning by listening and looking to outside authorities for truth. According to Belenky et al., when women's "social arrangements collapse and demands for change are imposed, many women must look inward for self-truth" (p. 51), moving into the category of subjective knowledge. Participants who were placed within the category of subjective knowledge relied on their intuition for truth. As women encountered situations that challenged subjective knowledge, they moved into procedural knowledge, or reasoned reflection and analysis. The final perspective described by Belenky et al. is constructed knowledge

where other forms of knowledge are integrated together and women find their own, unique voices.

Belenky et al. (1997) outlined the five epistemological categories as a sequence that women go through, progressing from one stance to another. Although they avoid identifying women's ideas as naïve or uninformed, they do use language that makes a hierarchy clear. For example, they describe procedural knowledge as more "humble" and more "powerful" than subjective knowledge (p. 87). The authors are quick to point out that their participants supported the order they ascribe. For example, they explain, "women themselves attached the notion of growth or developmental progression to the shift from silence of conformity to external definitions of truth into subjectivism" (p. 54).

In line with other common critiques of the book (Brookes, 1988), Blythe McVicker Clinchy (2009) seems to have rethought the linearity of the epistemological development outlined in *Women's Ways of Knowing*, stating "I now believe that we should be wary of moving too quickly to embrace theories that postulate a single, acontextual linear direction in epistemological development" (p. 85). Despite this change in how she approaches thinking about epistemologies she continues to describe the categories as "next steps" (p. 72) or "building on" other stances (p. 77).

Women's Ways of Knowing (1997) is a highly cited text but it is also criticized. The main criticism is that there is an underlying assumption that women are a monolithic entity; that all women come to know the world in the same ways (Yoonkyeong, 2003). In particular, critics question how diverse the body of participants was and if the findings would remain true for women from other cultural and environmental backgrounds (Gassler, 1988; Ostrander, 1988). A second common criticism is that, despite pushing

against Perry's work, the methods used by Belenky et al. mirrored Perry's methods (Brookes, 1988; Ostrander, 1988). Despite the critiques, in many ways this book was a starting point from which other works have built toward understanding women's epistemologies.

The categories outlined by Belenky et al. (1997) are specific to women, not to science. They were groundbreaking in their use of women as participants but limited in the lack of domain specificity. In addition to second guessing the linearity of the original text, Clinchy (2009) also advocates for more domain-specific research on women's epistemologies, providing the example of different approaches women take to humanities and science subjects (p. 85). Works that extend the discussion on women's epistemologies, specifically women's epistemologies of science, is discussed later.

Multiple Epistemologies in Science

Some researchers are arguing for a shift away from viewing epistemologies as right or wrong, advanced or naïve (Bang & Medin, 2010; Russ, 2014). In 2002, Hammer and Elby suggested that individuals have multiple epistemological stances that are negotiated when they are trying to make sense of the world. They point to a growing body of research that provides examples of students switching their epistemologies in different situations or when given different prompts. They continue by pointing out that researchers of epistemologies of science still discuss epistemologies as if they are set and fairly unchangeable and argue for a move away from that incorrect portrayal.

Rosenberg, Hammer, and Phelan (2006) explored Hammer and Elby's (2002) argument by analyzing a 15-minute excerpt of eighth-grade students discussing the rock cycle. Tasked by their teacher to explain the rock cycle, at first the students struggled.

They unproductively tried to make sense of information that was provided to them on worksheets and tried to define terms. Then the teacher stepped in with a suggestion that is epistemological in nature: "I want you to start with what you know, not with what the paper says" (p. 272). Following this suggestion, the students immediately switched their epistemological stance to one that was based on their own understanding, not relying on the expertise of outside information. The students developed a scenario starting with volcanoes erupting. They were able to recognize inconsistencies in their explanation and worked toward resolving those inconsistencies. Rosenberg, Hammer, and Phelan concluded that the students' epistemologies were not set. The students were able to quickly switch epistemological stances with some guidance regarding what stance might be more productive in the situation at hand. It is notable that the students started with focusing on outside expertise rather than valuing their own experience.

Rosenberg's, Hammer's, and Phelan's (2006) study highlighted that observing students in one situation will not allow a researcher to identify students set and unchanging epistemologies. It only allows the researchers to identify the students' epistemological approaches in that situation at that moment. Since my research involved discussing women's various experiences, the multiple epistemologies that the students negotiate are evident.

Citing research like that of Rosenberg, Hammer and Phelan (2006), some scholars argue for an approach that values epistemological approaches to science based on their usefulness to participants instead of their relationship to formal or "sophisticated" epistemologies. Russ (2014) provided the example of chemistry students doing calculations using Avogadro's number. In that moment, it is unproductive for students to

think of the scientific knowledge of Avogadro's number as tentative. Thus, it is not evidence of a naïve epistemology for the students to approach the number as a given truth.

One researcher pushing for a less hierarchical interpretation of epistemologies is Meghan Bang. She advocates supporting a learner's navigation of, what she calls, multiple epistemologies. In a 2010 article, Bang and Medin discussed the impact of a three-week summer camp on Native American students. The curriculum of the summer camp was designed around culturally-based practices and designed to support the navigation of multiple epistemologies of science. Interviews were conducted with the students before and after the camp. By the end of the three weeks students were more willing to agree with statements that recognized their ancestors as longtime contributors to the scientific community. Students also showed a shift in recognizing their community and community people as sources for learning about science. There was a change from thinking about science as a body of facts created by non-Native scientists to thinking about science as activities in which Natives partake. Additionally, when describing science following the camp, students used a great deal more detail when discussing the relationships between scientific ideas. One of the things that Bang and Medin asked students about, "associated motivation for and identification with science," did not seem to be explicitly addressed in the analysis. I think that it would have added to the study to hear about how the students felt about science and how they felt about themselves as scientists.

Bang and Medin (2010) showed that respecting multiple epistemologies can have a positive impact on student learning. Scientific communities and Native American

communities have different ways that they develop and interpret information about the natural world. Elby, Macrander, and Hammer (2016) provided the example that native practices "focus more on ecological contexts, grouping organisms by the network of their relationships, while Western practices focus more on evolutionary contexts, grouping organisms by genus, class, and phyla" (p. 119). The divergent foci of each community lead to distinctive observations, distinctive questions, and distinctive interpretations of findings. By accepting multiple epistemologies, learners can value differing practices and be open to learning from a variety of contexts and perspectives.

Bang et al. (2013) described the work of Michael Blackstock, an indigenous scientist whose research on water managements and climate built from an indigenous perspective of water as the center of life. Blackstock's elders taught him that water is alive. Western science defines living things as entities that are made of cells, obtain and use energy, grow, reproduce, and move from or adapt to their environment. The indigenous belief in water as living is contrary to Western science but was fruitful for Blackstock's work as a scientist. He argued that "science fails to take account of the way in which it [water] functions as the fluid component that fundamentally connects organisms in an ecosystem" (p. 307). Utilizing the teaching of his elders, Blackstock approached water management and climate change in new, innovative, and productive ways that would not have been possible if he were limited to the formal epistemologies of his scientific field.

Russ's (2014) and Bang's (2013) examples show the value of different scientific epistemologies in different situations and for different individuals. According to Bang and Medin (2010), "The current state of knowledge about human learning and motivation

has yet to adequately understand the ways in which culture is integral to learning" (p. 1014). Bang and Medin studied the multiple epistemologies of Native American students in spaces open to *both* formal and indigenous interpretations of scientific observations. Their work begins to highlight one context in which culture impacts the ways knowledge is developed and what knowledge is gained. Their research opens the space for studies to look at a variety of epistemologies in order to better understand the intersection between culture and epistemologies.

Gaps in Literature on Epistemologies of Science

In nature of science and epistemologies research, some views are considered better and more advanced than other views about science. As summarized by Elby, Macrander, and Hammer (2016), "most research continues to view as 'sophisticated' the beliefs that scientific knowledge is tentative and evolving rather than certain and fixed, complex and interconnected rather than piecemeal, justified by appeals to evidence and coherence rather than authority, and constructed by people rather than perceived in nature" (p. 113). Although these ideas are generally accepted, examples of when this way of thinking is not productive have been discussed, recall Avogadro's number and Michael Blackstock's research on water. Also, the hierarchy from naïve to sophisticated is based on a study of educated, middle- to upper-class males who were presumably white; providing a narrow basis for the definition of sophisticated, an idea called into question by Belenky et al. (1997).

A study by Gray, Adams, Wieman, and Perkins (2008) further complicates the idea of personal epistemologies by showing that students are aware of what physicists believe about physics but do not hold the same beliefs themselves. They state,

> We find that most students with novice beliefs about physics and learning physics are, in fact, quite aware of what physicists believe about physics and learning physics; they just do not believe that these ideas are valid, relevant, or useful for themselves. (pp. 020106-8)

This study also provides evidence that gender is an important factor when studying personal epistemologies because the gaps between personal beliefs and the beliefs attributed to physicists was larger in women than in men.

The above literature review on epistemologies of science demonstrates that exploring epistemologies through a gender lens (women's ways of knowing) and through a cultural lens (Native science) can yield productive expansions to the understanding of epistemologies of science. In order to create an opening for multiple epistemologies, Elby, Macrander, and Hammer (2016) suggest openness and starting from the ground up when studying epistemologies of science:

> The best way forward is for a significant portion of research to take a step back and treat this field as being in its early childhood. This means embracing theoretical and methodological diversity, not for its own sake but because we honestly do not know which mix of theoretical perspectives and methodological orientations will be most productive. (p. 122)

Therefore, researchers should be open to multiple epistemologies of science and should explore how productive different epistemologies and different mixtures of epistemologies are for scientific endeavors. I now turn to discussing feminist critiques of the science in order to highlight how female perspectives might be contradictory to institutional

understandings of science. This critique makes clear how a feminist perspective adds a productive lens to epistemologies of science.

A Feminist Critique of Science: A Theoretical Framework

To this point, I have laid out the argument that far fewer women are entering into lucrative and expanding science fields than are men. I have also described many schools of thought regarding how one comes to know science. In this section, I explore a feminist critique of science, using a critical feminist perspective to shed light on why an inclusive epistemological framework is needed to add to the complexity of thinking about women's interest in science. My argument is grounded in the work of third wave, standpoint and postmodern feminist thinkers; however, I feel it is also important to recognize the contributions of other scholars. Although some of the ideas drawn upon can be seen as contradictory and are often set against each other, I believe there is value in the diffractive pattern that emerges as they are read through each other.

Androcentrism of Science

The current vision of science came primarily out of the Enlightenment, one of many time periods when masculinity was greatly revered over femininity. As science evolved, it was defined with characteristics that aligned with the ideals of masculinity. As described by Brickhouse (2001):

> The Enlightenment gave rise to dualisms (e.g., masculine/feminine, culture/nature, objectivity/subjectivity, reason/emotion, mind/body), which are related to the male/female dualism . . . . Culturally defined values associated with masculinity (i.e., objectivity, reason, mind) are also those values most closely aligned with science. (p. 283)

As portrayed in this line of thought, stereotypical characteristics of what is female are opposite the characteristics that are scientific, excluding historically feminine ways of thinking from the field.

As early as the thirteenth century—when a mathematical and experimental approach was first used to study nature—until today, white, middle- to upper-class men from Westernized cultures have dominated the field (Harding, 1986). This is particularly evident in the power of the Royal Society in the eighteenth century, which was known for its exclusivity and for controlling what was to be studied, how it was to be studied and what findings were accepted. Today's "boys' clubs" are not as obvious, but the underrepresentation of women in the field means that men are still the primary decision makers.

Society's understanding of a field, any field, is shaped by those who created and contributed to that field, in the case of science, white, middle- to upper-class men from Westernized cultures. Sandra Harding (1986) clearly expresses this notion when she writes: "Products of thought bear the mark of their collective and individual creators, and the creators in turn have been distinctively marked as to gender, race, and culture" (p. 15). Since women have been primarily absent from the historical development of science, the field developed to the exclusion of female ways of thought.

What does the exclusion of feminine thought mean for the field of science? Since men have been the ones actively engaged in science, they have been the ones asking the questions. One piece of evidence that men and women ask different question is found in a 2017 article that analyzed 1.5 million medical papers. The study found that female researchers are much more likely to analyze findings for sex difference than male

researchers (Nielsen, Andersen, & Schneider, 2017). The nature of questions asked determines the conclusions found (Bodner, 2016). Whether consciously or unconsciously, individuals ask questions that are impacted by their beliefs and often ask questions that give themselves a leg up in the world. Harding provides a powerful example of questions about the same topic that can differ based on one's values. She describes how research questions regarding cancer could ask how to cure cancer or could ask about the causes of cancer (p. 76). Traditionally, more likely to strive for power and wealth, men are prone to ask the first type of question, as it is more likely to yield results with potential financial benefit. In this manner science is historically tied to capitalism (Rose, 2004). Therefore, through a gendering of the questions asked in science, those in power remain in power, exerting more and more control over the direction of the field.

One way that women may strengthen the field through asking different scientific questions is in the ethics of science. Harding (1986) explores how asking a question without thinking about underlying societal assumptions can impact the nature of the field by using a dramatic and poignant example. She follows the logic of what would happen if the question was posed: Why is there over-population? One answer being: Because of the high birth rate of third-world women. Therefore, sterilization and abortion should be encouraged in these communities (p. 77). Were this example not so distasteful, the recommendation might seem logical given the question. Although this is an extreme example of how the questions asked can shape an inquiry, more subtle differences between questions that are traditionally masculine and those that are traditionally feminine can also compile to have a profound influence on a field of study.

From Aristotle and Copernicus until today, science is seen and described as a way to master the earth and of things unknown—including peoples unknown—to the will of those holding the knowledge (Harding, 1986, pp. 114-115). By the eighteenth century, science was associated with progress and by the nineteenth century, science was a way to gain power over the Earth and—due to industries in synthetics, plastics, explosives, pharmaceuticals, and new technologies—to gain power through economic advancement. According to Harding and supported by research that was previously described (Diekman, et al., 2010; Sax, 1994; Seymour & Hewitt, 1997; Su & Rounds, 2015), females have typically been more motivated by caring than by control. Therefore, societal implications are more likely to be taken into consideration when women ask the questions.

The male domination of scientific fields also limits the methods that are used, thus narrowing and biasing the methods. Over time, pieces of equipment are designed for the purpose of validating the predictions made by scientists. They are created with intent, not with the value neutrality which those in the field claim. Thomas Hobbs was one of the first individuals to write about this incongruity. He took particular objection to Boyle's use of the air pump to validate expectations, claiming that the instrument embodied the assumptions and thus was part of a cyclical rationale. Further evidence that use of specialized scientific equipment is not purely objective is the level of specialization required to maintain, use, and interpret the findings from equipment.

In some cases, experimentation balances on or crosses an ethical line that makes the values of the methods more obvious. Hilary Rose (2004) asks:

> How can science claim to be ideologically pure, value-free, and above all neutral, when even a well-regarded text entitled *The Scientific Method* offers as an example of scientific development the making and testing of napalm on a university playing field, without any reference to the ethical or political problems. (p. 71)

Clearly, the importance attributed to finding a valuable weapon is prioritized above the safety of students in the vicinity. The act of experimentation is laden with assumptions and values of those designing the experiments.

You may be thinking that who is asking the questions and designing the experiments is irrelevant as long as the research gets us closer to the *truth*. However, the nature of the questions and procedures impacts the nature of the findings. Harding (1986) articulates this argument with a compelling question: "If problems are necessarily value-laden, if theories are constructed to explain problems, if methodologies are always theory-laden, and if observations are methodology-laden, can there be value neutral design and interpretations of research?" (pp. 22–23). Kuhn (1970) discusses how all scientific findings are accepted or rejected based on what is commonly believed within the general consensus of the field. Those whose scholarly works fall outside of the norm are "read out of the profession" (p. 19). In many cases there are multiple possible explanations that are ignored purely based on popular belief. Thus, scientific findings are based on the beliefs of the majority of those with power in the field.

The history of science being primarily a male enterprise impacts the sorts of findings that have been accepted. Science typically seeks a correct, objective and rational answer to every question asked, with no gray areas in thinking. In many ways, women

live on boundaries and in the in-between areas that are not as concrete as the perception of science. Harding (1986) provides an example for how male ways of thought break life into dichotomies that often do not fit female ways of life. The binary purposed is that of "work" versus "leisure." Traditionally men get paid for time that is work and have choice over time that is leisure. On the other hand, the traditionally female roles of child-care and cooking are both work and leisure. They are things that must be done but still can provide a great deal of joy (p. 88). Although not a scientific example, this shows how a need within the scientific community for answers to fall in definitive categories could be contradictory to females' perspectives on the world.

An example of a scientific theory that embraces in-between areas is Sandra Mitchell's 2002 conception of integrative pluralism. Exploring models used to explain the division of labor in bees and ants, Mitchell shows that competing models are neither in competition nor compatible. She makes the point that each individual colony has it's one unique "causal history" (p. 66). No one model can perfectly replicate a concrete situation and neither can one integration of all existing models.

The feminist argument presented thus far rests on the idea that science is thought to be an objective enterprise searching for absolutes. This is contrary to what is presented previously as the epistemologies of science. The current literature on the nature and epistemologies of science recognize that science is tentative. Unfortunately, this perception typically does not extend to the general public. Most everyone—from Bill Nye the Science Guy to Nobel Prize winners—discuss science as if the entire body of knowledge is beyond question. For example, Neil deGrasse Tyson is quoted as saying "the good thing about science is that it's true whether or not you believe in it." Sandra

Harding (1986) refers to this idea as "science as sacred" (p. 38). Some additional examples of the sanctity with which society holds science were shown on the posters used during the March for Science on April 22, 2017 that contained statements like "facts should be peer reviewed, not alternative." The purpose of these posters was to push back against politicians questioning whether or not society should use science to help make informed decisions. However, the language of "truth" and "fact" rather than "theories" and "data" convey an unwarranted belief that science is unfailing.

Harding argues that because of the sanctity with which society holds science, we are unwilling to question it. We are unwilling to see that there can be different interpretations ascribed to the same phenomenon and that findings can be and are influenced by perception. Also due to the perception of science as sacred, unlike social scientists, natural scientists are not typically taught to think critically about their work. Harding (1986) explores this idea:

> There is thought to be no need to train physicists, chemists, or biologists as critical theorists; consequently, little in their training or in the ethos of scientific endeavor encourages the development or appreciation of the critical interpretive theory and skills that have proved so fruitful in the social sciences. (p. 34)

Without the nurturing of a critical disposition in scientists, the work continues in the same vein: Similar questions are pursued; answers that are seen in binaries are found; truths that are expounded are held in reverence; and alternative ways of experiencing the field—feminine ways of experiencing the field—are ignored.

Women in Science

But there are women scientists. Are they not making an impact on the way science is approached? Harding (1986) discusses the idea that the field of science is, since the nineteenth century, run like a factory. Harding's argument is based on the premise that there are few, mostly white men, who run research teams. This premise still holds true (Directorate-General for Research and Innovation - European Commission, 2012; McCullough, 2019) . The men who run research teams make the decisions regarding the questions asked, determine the procedures used to find answers, and interpret the findings for publication. The people who work on the team are more like individuals in an assembly line than people pursuing the intellectual work of scientists (Harding, 1986, pp. 70–72).

Although labs may in fact be more collaborative than Harding's portrayal, a 2014 study showed that the overall idea holds true. Joshi (2014) studied the productiveness of science and engineering teams' recognition and utilization of the expertise of all members of the team. She showed that women's expertise was less likely than men's to be utilized; however, this improved with more women on the team and improved even more when a woman or women managed the team. Individuals may be recruited to science by the idea of doing exciting, meaningful, and collaborative work; however, what many actually do is what they are told to do.

In order to work in the field, scientists are told to do things from testing plants for pharmaceutical possibilities to building bombs, from injecting mice with diseases to testing water for impurities. The impact of the factory-like nature of scientific inquiry could be as simple as silencing the ideas and ways of thought of people other than those at the top or as severe as requiring people to act ambivalent to social issues that they

might otherwise be passionate about. Within this structure, many women on the assembly line of science are not provided space to impact the nature of the field (Harding, 1986, p. 73).

Many feminist scholars have taken up the call of Jerome Ravetz (1996) to reject the factory of science and return to science as a craft, where science is a personal and creative enterprise. Within the craft of science there is a union of the manual and intellectual labor, which acknowledges the social and societal context of science. In *Hand, Brain and Heart,* Hillary Rose (2004) attests that work that is traditionally women's work, such as raising children, involves a caring labor that is more akin to that of science as a craft and that having a caring labor in science would be beneficial to the field. As explained by Rose, "Transcendence of this division of labor set up among hand, brain, and heart makes possible a new scientific knowledge and technology that will enable humanity to live in harmony rather than in antagonism with nature" (p. 67). Some scientific areas embrace this conception more than others.

Harding (1986) points out that biology is one field in science where "craft forms of scientific inquiry are still possible" (p. 145). The questions asked in biology often relate to environmental and health issues. The questions asked in physics and engineering, on the other hand, are typically related to improving the economy or advancing warfare (Blickenstaff, 2005). Economy and warfare have long fallen under the domain of men where women have traditionally been responsible for the tasks that involve caring for the home and for others. This is one possible factor impacting why biology has a much higher percent of women. Returning to a craft of science in other fields may allow for more women to enter and find a voice within science.

The current culture of science (products, practices, institutions, and theories), came out of and is still dramatically shaped by it is predominately White and male forefathers. Therefore, the current culture is more aligned with masculine ways of thinking. Much of the writing on how women experience the heavily male influenced culture of science is theoretical rather than research based (Brickhouse, 2001; Brotman & Moore, 2008; Haraway, 2004; Harding, 1986; Keller, 1985). However, there is research showing that the culture of science makes it difficult for many minority students to assimilate into scientific communities (Brown, et al., 2016), particularly women of color (Carlone & Johnson, 2007). I believe that research on women and science would find similar findings to that on minorities and science.

Although there is limited research on how approaching science differently impacts women and minorities as well as the science itself, there are individuals trying to shift the way science is done. One biologist who approaches science from a different perspective is Max Liboiron, a feminist and anti-colonialist scientist studying plastics found in ecosystems. In a 2019 film by Hess and Hutton, Liboiron describes one example of a practice her lab adopted based on their philosophical underpinnings:

> There is a very simple protocol in our lab where you don't wear ear buds when you're dissecting a fish because that separates you from the fish. You can listen to music and the radio and you can sing all you want, in fact that would be preferable. But you don't get to be separate from the relation that you're dissecting. It assumes you're not better than the fish. It means that you're respecting the fish for what it's doing for your research, the value it's adding. It's your relation (9:25-9:46).

Liboiron and her colleague make decisions that are based on values that are different from those that guide most contemporary research.

For Liboiron and her colleagues, the purpose behind approaching research differently is to have a more ethical and informed scientific practice. As described by Liboiron:

> Every time you decide what questions to ask and not to ask others, which counting style you use, which statistics you use, how you frame things, where you publish them, who you work with, who you get funding from, all of that is political. It means that some things will be reproduced and some things won't be (Hess & Hutton, 2019, 4:53-5:08).

Although the purpose of approaching research with a feminist and anti-colonial lens is to produce a different science, I believe that the potential for a different lab environment is equally important. In the video, one of Liboriron's colleagues says that she worked in different labs before and that Liboriron's lab has "a very different atmosphere." Although this statement was not elaborated upon, I wonder if the environment is one in which women would feel more welcome and invested in the craft approach to science.

I perceive the opening of scientific fields to have cyclical possibilities: if science became more open to other ways of knowing, women would feel more accepted within the fields and thus, potentially, enter the fields in greater numbers. And as more women become scientists, the fields would broaden and become conceptualized in new and different ways. As pointed out by Sinnes and Loken (2014), no one person or group of people has a clearer picture of the world than any others. Feminist science could add a dimension that is currently missing. Through the acceptance of multiple ways of seeing

the world, new horizons could be explored. By broadening the views of science, more individuals could align their own identities with that of a scientist. Additionally, feminist science may balance the industrialization of science to make progress in areas otherwise seen as unfruitful. Therefore, in the following section, I outline several feminist epistemologies of science.

Intra-acting with the Literature on Feminist Epistemologies of Science

As previously discussed, *Women's Ways of Knowing* (1997) pushed back on the use of predominantly male participants to study epistemologies and broadened the definition of epistemology to include women's roles as knowers. Feminist scholars are also interested in expanding who is included in research and how epistemology is defined. Contemporary feminist epistemological research highlights that all knowers are situated by contexts such as gender, class, and race (Anderson E. , 2015). Despite the multitude of feminist theories including feminist standpoint theory, feminist postmodernism, and feminist empiricism, the unifying principle is that knowers are situated. Also, since all knowers are situated, all knowledge is situated based on who is defining that knowledge (Harding, 1986). The following are several of the most commonly cited feminist epistemologies of science. Though the authors frequently reference the same thinkers, including each other, they are not necessarily a progression. Rather they are different approaches to the same concern.

Dynamic Objectivity

In 1985, Evelyn Fox Keller proposed a feminist epistemology of science that she referred to as dynamic objectivity. Keller begins by pointing out that knowledge and power have become tightly linked. In the same vein, objectivity and dominance have become linked. The purpose of objective study is something outside of one's self. On

the other hand, Keller explains, “dynamic objectivity aims at a form of knowledge that grants to the world around us its independent integrity but does so in a way that remains cognizant of, indeed relies on, our connectivity with that world” (p. 117). Keller equates the connection that a scientist should have with his or her object of study with the connection called “love” that allows one to understand another person.

Keller (1985) begins her exploration of the ideal of the relationship between “love” and knowledge with a critique of Plato’s use of the word love. Giving Plato leeway in constraints due to the existing models of thought during his time, Keller wondered how the relationship between love and knowledge could be used productively. Keller asked, “How might a different conception of sexuality, and of masculinity, modify the conception of knowledge, of the relation of mind to nature, that Plato bequeathed to us” (p. 32). In other words, how might love be defined differently and how might this definition add to the possible ways of learning about the material world.

In redefining “love” Keller (1985) relies heavily on the psychoanalytical work of Ernest Schachtel (pp. 118–121). Schachtel (1959) wrote about allocentric perception, which Keller equated to dynamic objectivity. To be allocentric is to be focused on things outside of one’s self and not in relation to one’s self. Schachtel’s allocentric perception had two requirements: “first, the survival of a child’s native interest in the world, and second, the development of the capacity for focusing on objects as separate and distinct from one’s own needs desires, and individual perspective” (Keller, 1985, p. 119). Schachtel and Keller equate these two criteria with love. In order to approach scientific investigation with love, one needs to first understand how the something is separate from one’s self and in a manner that does not focus on one’s own interests. In other words,

allocentric perception requires that one consider objects in and of themselves, rather than as "objects-in-use"—something to be mastered and used. Schachtel claims that poets and artists are more likely to have an allocentric perception than scientists because science is more likely to consider the world as objects-in-use.

According to Keller, the dominant rhetoric in science is that of the pursuit to master nature. The language used is aggressive rather than loving. Scientific problems are "attacked" or "conquered" using "brute force" (p. 123). This aggressive approach seeks to manipulate the world to meet the scientist's goals, thus limiting the scientist's ability to truly understand nature. But a feminist epistemology of dynamic objectivity seeks to understand the kinship between the observer and the observed, the researcher and the researched. Keller argues that this approach allows for a greater potential of true understanding.

Situated Knowledges

In 1988 Donna Haraway first proposed a feminist epistemology of "situated knowledges" or "feminist objectivity." Her argument is placed between the positivistic view that scientific knowledge is about an external truth and the absolute relativistic view that there is nothing outside the personal understandings of a knower and thus all truths are valid. She argues, building on the ideas of Marx, Keller, Harding and others, that all knowledge is situated, or based on the perceptions of the knower. She extends this argument by discussing the situated nature of scientific knowledge. Haraway explains situated knowledges using the analogy of a camera. "There is no unmediated photograph or passive camera obscura in scientific accounts of bodies and machines; there are only highly specific visual possibilities, each with a wonderfully detailed, active, partial way

of organizing worlds" (Haraway, 2004). In other words, there is no one correct way to describe the world. Instead, each person has a unique perception that is detailed from that perspective, but unavoidably incomplete.

Due to the inevitability of partial knowledge, Haraway (1988) argues for a feminist science that embraces science as a partial understanding that is undergoing constant interpretation. As stated by Haraway, "science becomes the paradigmatic model not of closure, but of that which is contestable and contested" (p. 93). She argues that unlike the common *scientific* goal of objectivity, a feminist science does not seek an end goal of finding the *truth*, because there is no one true understanding. Rather, a feminist science should seek partial understandings.

More than just seeking partial understanding because it is all that can be known, Haraway (1988) makes the case that explorations of partial understandings are fruitful. She writes, "we do not seek partiality for its own sake, but for the connections and unexpected openings situated knowledges make possible" (p. 93). New meaningful scientific knowledge can be developed through the overlaps and interplay between the multiple understandings of science that situated knowledges allow.

Contextual Empiricism

In 1990 Helen Longino published *Science as Social Knowledge* in which she argued for a feminist science of contextual empiricism. Longino acknowledged that most people did not accept the positivistic goal of striving to find absolute truth, as possible. She agrees with this common assertion. However, she argued that an acceptable alternative philosophy had not yet been proposed (p. 21). Longino critiqued the holists who were the most common critics of positivism. Holists argued that scientific

explanations are selected based on theory and any description of science is immersed in theory-laden language. Accordingly, arguments derived from differing theories are incommensurable. Longino contends that the holists' reasoning is as flawed as is a positivist argument. She provides the rich debates that occur in science as evidence that data can be used to sway individuals with different theoretical principles. Thus, there is commensurability (p. 28).

Longino (1990) provides an alternative theory to that of the positivists and the holists, contextual empiricism. Contextual empiricism has two features. First, rather than data and theory being related through "rational" argument, they are related by assumptions and beliefs that scientists bring to their work. Scientists should make these assumptions explicit (p. 44). Second, the scientific method is a practice that occurs by social groups. Two or more scientists are required in order to focus on data and become aware of the impacts of beliefs (pp. 66–67). Criticism should be an integral aspect of the scientific method and critique should stem from a wide variety of perspectives (p. 144). In this manner it can be made clear what is believed and what is generally accepted.

The more critical scrutiny a theory undergoes and the more perspectives that were utilized within the critiques, the more validity a theory holds. Longino, unlike the positivist, does not see *truth* as the goal of inquiry. She sees knowledge as the goal of inquiry. Knowledge is the outcome of a social process. The interactions between people can transform subjective ideas into objective knowledge. Knowledge is valuable if it can withstand criticism from various angles and is useful. It does not need to have a claim upon truth.

Strong Objectivity

Building off the previous feminist epistemologies of science and situating her work under the umbrella of standpoint feminism, in 1992 Sandra Harding proposed the idea of strong objectivity. Harding argued that the common practices in science did not allow for the level of critique that is required to explore the impact of social beliefs on scientific findings. Therefore, the scientific idea of objectivity is weak—weak objectivity.

Harding (1992) argues that critique alone is not enough to strengthen claims of objectivity. Those doing the science see their research and the research of those before them through the lens of the elite, thus perpetuating biases (p. 459). Harding and other standpoint theorists believe that treating a variety of perceptions as equally valuable is misguided. According to standpoint theory marginalized individuals view the world from a perspective that is better—more authentic and accurate—than individuals in power. Therefore, starting research from the lives of women and other marginalized people creates less distorted findings (p. 438). Harding is careful to point out that there is no one, unified perspective of women, but an intersectionality of factors that influence a person's point-of-view. The more marginalized the individuals are who think about and work on scientific findings, the stronger the findings will be.

For there to be strong objectivity, Harding (1992) states that there must be critique not only of the science but also of the scientists. She refers to this idea as strong reflexivity. Since beliefs can impact every aspect of science, it is critical for there to be equal attention to the beliefs and biases in research *and* of the researchers (p. 460). However, the views of the privileged are distorted and thus unable to do this critique. Critique must be done by those whose lives have been marginalized.

Summary of Feminist Epistemologies of Science

Unlike work on personal and practical epistemologies, feminist epistemologies avoid categorization of knowledge and embrace expansive exploration that is contextualized to individuals. As stated by Rose (2004), "Feminist analysis . . . calls for interpretation constantly tested not simply against the demands of theory, but always and incessantly against the experiences of the specific oppression of women" (p. 68). Although each of the feminist epistemologies described earlier in this section have distinguishing features, there is a great deal of overlap and consensus between them, primarily that knowledge is situated. Anderson (2015) outlines multiple ways in which knowers and thus knowledge is situated. These categories are embodiment; first-person vs. third-person knowledge; emotions, attitudes, interests, and values; personal knowledge of others; know-how; cognitive style; background beliefs and worldviews; and relations to other inquirers. These categories are present in feminist epistemological research and theory in general and in feminist epistemologies of science more specifically. However, a few of these categories are more prevalent in the discourse around feminist epistemologies of science—particularly embodiment, affect, and community or rationality.

An experience that Robin Wall Kimmerer (2013), an indigenous science scholar, serves as an example of how a "feminine" interest in relationships can butt up against beliefs held in scientific communities. She shared that when she went to a college interview as was asked why she wanted to be a botanist, she described her longing to understand why asters and goldenrod grow beside each other and look so beautiful together (pp. 39–47). The advisor's response was "I must tell your that *that* is not

science" (p. 40). He enrolled her in an introductory botany class so that she could learn the truth of botany.

Kimmerer (2013) shared, "the professor made me doubt where I came from, what I knew, and claimed that his was the right way to think" (p. 41). Fortunately, where many young people may change majors after this type of experience, Kimmerer found that she liked the science of botany and continued her studies. It was not until during her graduate studies that she revisited the idea that a relational way of view plants may have scientific validity. It was not until much later that she brought together her indigenous ways of seeing the word with she scientific ways of seeing the world. In regards to a valuing of rationality, indigenous ways of knowing is similar to female ways of knowing.

If Kimmerer's advisor acknowledged her questions regarding asters and goldenrod as valid, she may have learned earlier that pollinators such as bees are just as attracted to the contrast between purple and yellow as humans are. She may have learned earlier that her question was scientifically valid. As stated by Kimmerer, "It's a question of science, a question of art, and a question of beauty . . . . It was an architecture of relationships, of connections that I yearned to understand" (p. 46). Questions that stem from different ways of knowing are no less scientific.

Critiques of Feminist Epistemologies of Science

The most common critique of feminist epistemologies of science is that they stymie scientific advancement through political constraints and censorship (Anderson, 2015). Rather than proposing productive means for scientific advancement, critics such as Gross and Levitt (1994); Haack (1993); and Pinnick, Koertge, and Almeder (2003) argue that feminists pass judgment on scientific findings and scientists to the point of

putting the whole institution of science into question. Also, since the feminist writers and thinkers are outside the institution of science, not practicing scientists, Gross and Levitt (1994) argue that they cannot present an accurate depiction of science.

The critiques don't lead me to believe that we should give up on the idea of a feminist epistemology of science but that an epistemology that stems from science and gives direction for productive scientific investigations is needed. A new, contemporary epistemology is needed. New materialism is an emerging trend within feminist thought—building mostly from Haraway's conception of situated knowledges—that could be used to update the discussion. Asberg and Braidotti (2018) are among many authors who propose new materialist ideas as a potential direction for thinking about science and science education. They state:

> People are entangled in co-constructive relationships with nature and the environment, with other animals and organisms, with medicine and technology, with science and epistemic politics . . . . Now is the time for greater scholarly attentiveness to such human and more-than-human worlds in sociocultural research, saturated as they are with ethical and political implications. (p. 1)

Recognizing that humans and nature are entangled has implications for social science research by emphasizing the need for nonhuman entities to not be ignored. It also has implications for science by emphasizing the need for human impact to not be ignored.

Karen Barad's (2007) agential realism is a new material feminist epistemology of science that could move the field forward in productive ways. Therefore, agential realism is used as the conceptual framework guiding my research. The next section outlines this epistemology.

Agential Realism: A Conceptual Framework

As a physicist and feminist theorist, Karen Barad (2007) was inspired by thinkers in both physics and feminist studies when articulating her theory of agential realism. Agential realism is an onto-ethico-epistemological framework in which reality is made up of discrete phenomena. The term onto-ethico-epistemology stems from Barad's belief that ontology, epistemology, and ethical responsibilities cannot be separated. To understand the meaning of agential realism, let's look at the conception's genealogy in which the theoretical writings of Neils Bohr were particularly important.

Neils Bohr's Phenomena

In order to articulate how Barad utilized Bohr's work in developing the conception of agential realism, I begin by describing the physics that Bohr was thinking and writing about. In classical physics everything is either a wave or a particle. The apparatus that is used to determine if something is a particle or a wave is called a two-slit apparatus. If particles were to go through the slits, they would hit the other side with most particles hitting directly across from the slits with slight dispersal as shown in Figure 1. When waves pass through the two slits, they interact with each other causing a diffraction pattern with repeating patterns of light and dark as shown in Figure 2. Something interesting happens when an electron is passed through a two-slit apparatus. Despite electrons being discrete particles, they cause a diffraction pattern.

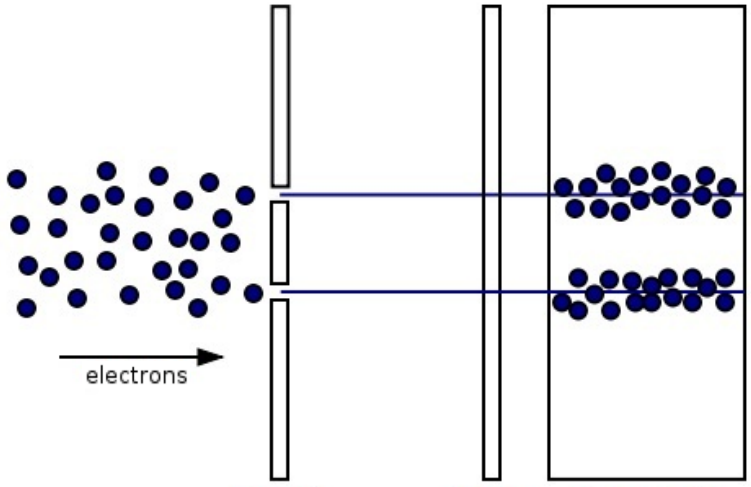

Figure 1. Electrons as particles. This image shows a two slit apparatus yielding the distribution pattern that would result if electrons act like particles. Retrieved from https://commons.wikimedia.org/wiki/File:Two-Slit_Experiment_Particles.svg.

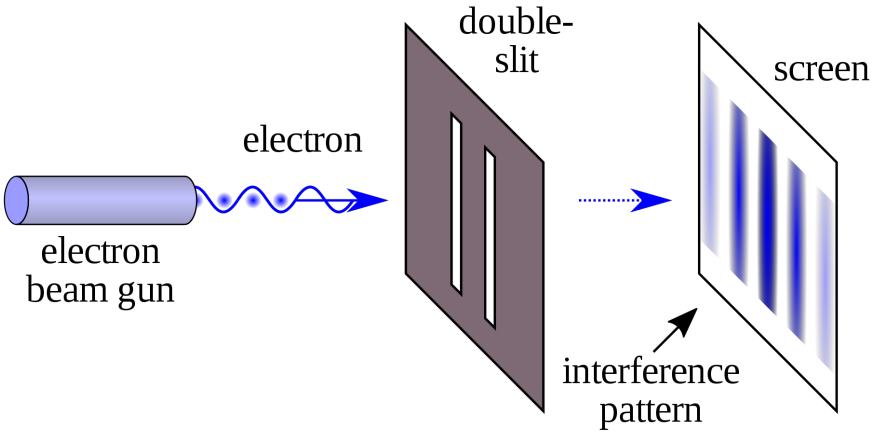

Figure 2. Electrons as wave. This image shows a two slit apparatus yielding the diffraction pattern that would result if electrons act like waves. Retrieved from https://commons.wikimedia.org/wiki/File:Double-slit.PNG.

Einstein (Einstein, et al., 1935), Heisenberg (1927), and Bohr (1928, 1935)—early quantum physicists—studied this surprising discovery. The three scientists disagreed with each other when trying to make sense of an electron behaving like a wave. During the 1927 Solvay conference Einstein and Bohr discussed a thought experiment proposed by Einstein. The thought experiment involved adapting the two slit apparatus so that it

could be determined which slit a particle went through. Einstein claimed that through this experiment a scientist would be able to catch an electron acting as both a particle and a wave. Bohr argued that the moment the apparatus detected the electron as a particle it would act as a particle, thus not creating a diffraction pattern. Heisenberg (1927) agreed with Bohr that it would change the pattern but disagreed with why it would cause a change. Heisenberg, in his famous Heisenberg uncertainty principle, claimed that by measuring one aspect of a particle—for example, the slit it traveled through—you disturb another measurement, thus setting a limit on what can be known. Bohr (1928, 1935), on the other hand, argues that we are not disturbing one measurement by taking a second. Rather properties are indeterminate until the measurement is taken. Bohr (1935) stated, "conditions constitute a [*sic*] inherent element of the description of any phenomenon to which the term 'physical reality' can be properly attached" (p. 700). In other words, Bohr is not just calling into question what researchers can know, but the actual reality of objects prior to measurement. He is making an ontological assumption about particles being studied.

Let us look more carefully at what Bohr was saying. Through a series of articles, letters, and face-to-face discussions Bohr (1928, 1935) argued that the particle itself has no inherent properties. Rather properties are created through the quantum entanglement between the particles and the two-slit apparatus. In a 1935 article Bohr stated, "to measure the position of one of the particles can mean nothing else than to establish a correlation between its behavior and some instrument rigidly fixed to the support which defines the space frame reference" (pp. 699–700). Bohr argues that everything that happens through experimentation is a *phenomenon* that is occurring due to the

entanglement between the observed object and the apparatus used to observe it, as well as everything else in that time and space. He is not saying that we are causing a shift in the behavior of the particle through measurement but that the actual ontology of the particle is being determined in that moment. The notion of an object is abstract and unknowable. As stated by Barad (2007):

> What he [Bohr] is doing is calling into question an entire tradition in the history of Western metaphysics: the belief that the world is populated with individual things with their own independent sets of determinate properties. The lesson that Bohr takes from quantum physics is very deep and profound: there aren't little things wandering aimlessly in the void that possess the complete set of properties that Newtonian physics assumes (e.g., position and momentum); rather, there is something fundamental about the nature of measurement interactions such that, given a particular measuring apparatus, certain properties become determinate, while others are specifically excluded. (p. 19)

It is the notion of a phenomenon—an interaction between an object and an apparatus—that can be known and studied and by using different apparatus the phenomenon changes because the apparatus is part of the phenomenon. The idea of exclusion caused by the use of a particular apparatus is an important idea that I address in greater detail later.

At the time of these disagreements among Einstein, Bohr, and Heisenberg, the technology was not available to be able to test their predictions. Now it is. Studies have shown that an experiment can measure both which slit a particle goes through and the resulting pattern produced (Mittelstaedt, et al., 1987) appearing to contradict Heisenberg's uncertainty principle. So, whose beliefs are supported by current

experimentation: Einstein or Bohr? Experimentation has found, as Bohr predicted, that detecting which slit the particle travels through *does* change the pattern (Menzel, et al., 2012). Therefore, current research in quantum physics supports Bohr's belief that objects are unknowable and phenomena—the quantum entanglements between objects—are the subjects of studies.

Agential Realism

Now that I have outlined the relevant arguments of Bohr, let us return to Barad. Claiming that what is true at the quantum level must also be true at the macroscopic level, Barad (2007) articulates the onto-ethico-epistemological framework of agential realism. Although scientists might not agree that findings within quantum physics should be applied to social sciences, I believe that agential realism can be a fruitful theory through which to explore the experiences of women in sciences. In this framework the world is made of phenomena that are created through intra-actions between entities, both human and nonhuman. Barad coins the term *intra-action* to avoid the individualism that is implicit in the common term "interaction." Rather than an individual entity interacting with an "other" outside entity, things are entangled and form one perceivable phenomenon.

Agential realism involves a redefinition of the common uses of the words "agency" and "realism." Barad (2007) describes agency as a relationship or the intra-action between things. Everything, human and nonhuman, has agency. Barad (2007) describes her conception of agency as posthumanist: "By 'posthumanist' I mean to signal the crucial recognition that nonhumans play an important role in natural cultural practices, including everyday social practices, scientific practices, and practices that do

not include humans" (p. 32). In other words, Barad argues that at the quantum level everything has agency because both human and nonhuman entities are impacting each other. An example of nonhuman agency is the impact—described by Bohr—that each unique apparatus has on forming the phenomena that are observed.

In addition to redefining agency, Barad makes a clear distinction between what she means by realism and how it has been used elsewhere. Realism typically is in contrast with constructivism where scientific realism is the belief that the universe, as described by scientists, is real. Constructivism, on the other hand, is the belief that people construct their own meaning of the world and therefore that all understandings of the world are formed by cultural factors. Barad (2007) argues that Bohr's conception of phenomena moves us past a dualist argument. "I would argue . . . that quantum theory leads us out the morass that takes absolutism and relativism to be the only two possibilities" (p. 18). Barad critiques constructivists' claim that words define science with the common argument that science makes predictions that are reproducible. Since science can make predictions, there is something that is knowable outside of what is created with language. She also critiques the typical realist belief that the truth of science is culture free and not impacted by context. Barad's realism is a realism of phenomena. Phenomena are intra-actions between things, which include culture. Barad readily accepts the realist tendencies of her writing but makes clear that the reality is the phenomenon not "things" or matter. This is why science is reproducible. By using the same piece of equipment in the same environment with the same observer, the resulting phenomena are predictable with minimal differences based on small uncontrollable factors.

Onto-Ethical-Epistemology

As was previously mentioned, Barad describes agential realism as an onto-ethical-epistemology, arguing for the inseparability of ontology, ethics and epistemology. Let's begin by looking at Barad's argument for why ontology and epistemology are inseparable. Like much of her work, the argument for inseparability stems from Bohr's theoretical writings. To Bohr, theory and practice were inextricable linked. As stated by Barad (2007), "Bohr situates practice within theory. As a result, method, measurement, description, interpretation, epistemology, and ontology are not separable considerations" (p. 121). As demonstrated with the two-slit apparatus, the method of gaining knowledge (epistemology) determines the nature of reality (ontology).

Near the end of his life, Bohr began to discuss the ontological implications for his theorizing (Lindley, 2007). Many other scholars, including but not limited to Barad, have also discussed the implications. Barad (2007) furthers a commitment to the inseparability of ontology and epistemology as a necessity when studying intra-actions and as a method for eliminating a binary manner of perceiving the world. She writes:

> The separation of epistemology from ontology is a reverberation of metaphysics that assumes an inherent difference between human and nonhuman, subject and object, mind and body, matter and discourse. *Onto-epistem-ology*—the study of practices of knowing in being—is probably a better way to think about the kind of understandings that we need to come to terms with how specific intra-actions matter. (p. 185)

In order to fully understand intra-actions, an ontological approach or trying to understand what is knowable is not possible without also trying to understand how we can develop knowledge. An onto-epistemological approach is needed.

Barad continues her argument, saying that an onto-epistemology is also insufficient. Barad (2007) argues that ethics in a vital and inseparable aspect of agential realism. "Particular possibilities for (intra-)acting exist at every moment, and these changing possibilities entail an ethical obligation to intra-act responsibly in the world's becoming to contest and rework what matters and what is excluded from mattering" (p. 178). Through intra-actions, phenomena—all knowable reality—are created. As components contributing to intra-actions, we have an obligation to consider and take seriously potential outcomes.

The ethics implicit in intra-actions brings us back to the idea of exclusion. I previously mentioned that Bohr wrote that through the selection of a particular apparatus some properties are measured, allowing those properties to be determinate, while others are excluded. Barad uses the term "agential cut" to indicate what is included and what is excluded in an intra-action. Particular agential cuts make some things visible and others easy to ignore. For example, as previously argued, having only male bodies partaking in science for hundreds of years limits how science is pursued (epistemology) and changes what science is (ontology) based on the androcentric intra-actions. If a lab were to commit to an ethical obligation of employing equal numbers of males and females, the epistemological practices and ontological findings of that lab would most likely change (Joshi, 2014). Agential cuts or exclusions that are being made through particular

methods, such as cutting out feminine methods in science, must be carefully considered. The ethical implications of epistemologies must be considered.

Diffraction

By relating the work of Bohr to the feminist writings of Donna Haraway, Barad suggests the utilization of diffraction patterns as an analytical tool. In physics, diffraction patterns are patterns that form because of interactions between waves. When waves are in phase, they constructively interfere with one another, increasing the intensity of the detection. When waves are out of phase with each other they destructively interfere with one another. Diffraction patterns therefore show the resonance and dissonance between waves.

Haraway (1997) uses the physics concepts of diffraction and reflection to critique the colloquial use of the term "reflect." Where reflection in physics and as a metacognitive act is just a mirroring with a focus on sameness, diffraction also focuses on difference. Where reflection is something that happens from a distance, diffraction requires engagement. Scholars who study feminism and science, including Haraway, had two main critiques of reflection. The first critique is that most of the time reflection can and does ignore social factors that influence a situation (Barad, 2007). For example, much research ignores the role of the researcher in the processes of "interpretation and representation" (Bozalek & Zembylad, 2018, p. 49). Playing out the analogy of a mirror doing the reflecting, no mirrors are able to create a perfect representation of an object. Slight variances in the mirror affect the clarity, color, and proportions of the reflected image. Likewise, differences in researchers affect the findings of research. The second critique is the common misconception that reflections capture reality and the act of

reflecting does not impact the objects being represented (Barad, 2007). No matter how distant a researcher tries to remain from their research, the act of research always makes change. Research on chemicals involves manipulation of those chemicals, research on people involves some sort of involvement with those people and research on texts involves reinterpretation of those texts. The term "reflecting" implies that objects of study can remain passive and unchanged. Haraway (1997) proposed diffraction as an alternative method that is attentive to social factors and is non-representationalist.

Haraway's (1997) method of diffraction resonates with Bohr's previously explained arguments that all that can be known are phenomena. If reflection is an attempt to mirror reality, this is unachievable because reality is unknowable according to Bohr. Rather, all we know is a phenomenon or intra-actions between things. The way that we develop understanding of how things intra-act is through their diffraction patterns. As stated by Bozalek and Zembylas (2018), "diffraction is . . . predicated on a relational ontology, an ongoing process in which matter and meaning are co-constituted" (p. 48). Through intra-actions the world around us is created simultaneously to the understanding that is developed through those intra-actions. Thus, a method of diffraction, that takes interactions into account, is a way to better understand phenomena.

Barad (2007), building off of the works of Bohr and Haraway, proposes using diffraction as a method and a practice by reading the world diffractively as a way to gain insight. She uses the method of diffraction in her writing and thinking by reading multiple scholars diffractively, particularly focusing on reading science and theory through each other. As described by Barad, "diffractively reading the insights of poststructuralist theory, science studies, and physics through one another entails thinking

the cultural and the natural together in illuminating ways" (p. 135). Rather than reflecting on what has been said in texts she highlighted the similarities and differences in texts, looking for patterns that allowed new meaning to emerge. Barad emphasizes that others have used science in thinking about theory or have used theory when thinking about science. She reads the ideas through each other to gain new insight.

One example of when Barad (2007) read science and theory diffractively through each other is when she was exploring the meaning of an apparatus. She put the notions of Kant, Aristotle, Heidegger, Althusser, Foucault, Butler, Latour, Haraway and Bohr regarding apparatus in conversation with each other to find new meaning. Barad described the usefulness of this conversation: "Reverberating at different frequencies, these differing lines of thought can productively be read through one another for the patterns of resonance and dissonance that illuminate new possibilities for understanding and being" (p. 142). By putting various theorists and scientists in conversation with each other, new patterns emerge, yielding new insights.

One of the reasons that Barad (2007) advocates for and uses the method of diffractive reading is to move scholars' works forward. Rather than "destroying" their work through critique, she utilizes their work in conjunction with others' works to build off strengths that emerge (resonance) and to explore areas of dissonance. In an interview, Barad stated:

> Critique is all too often not a deconstructive practice, that is, a practice of reading for the constitutive exclusion of those ideas we cannot do without, but a destructive practice meant to dismiss, to turn aside, to put someone or something

> down – another scholar, another feminist, a discipline, an approach, et cetera. (Dolphijn & van der Tuin, 2012, p. 49)

Barad continues by proposing reading the world diffractively as a more nuanced and ethical method of engagement. She suggests that reading the world diffractively allows productive ideas to build off of each other rather than tearing down old ideas in order to put forward new.

Bozalek and Zembylad (2018) highlight three specific benefits of diffractive readings. First, as previously described, a focus on diffraction patterns takes the emphasis off of difference and places it on the patterns that emerge between ideas. Second, diffraction allows for studying "non-human together with human" (p. 51). It allows a variety of agents to be explored in conjunction with each other rather than research presupposing human superiority. Third, diffractive analysis breaks down concepts of binaries and troubles dualisms. As stated by Bozalek and Zembylad, "diffractive patterns reveal that there is light in darkness and darkness in light" (p. 51). Diffractive patterns highlight that there are not discreet lines between ideas or entities. Concepts and bodies are found to be blurred and to overlap in sometime unexpected ways.

Summary

A great deal of research has been done on the underrepresentation of women in science. The general belief is that there are multiple factors that impact women's decisions, not one overarching problem that can be "fixed" simply. One concern, based on the works of feminist scholars, is that the "scientific" ways of experiencing the world could be silencing the voices of women who are enculturated to value other means of coming to know (Harding, 1986). By broadening the views of the nature of science to be

accepting of multiple epistemologies, more individuals might align their own epistemologies with the epistemic aims and criteria commonly attributed to science. Karen Barad (2007) offers one new material feminist epistemology of science that provides a fruitful framework for thinking about the women's experiences, agential realism. The guiding research questions were as follows: What are the stories of female undergraduate science student's experiences in science? What are the diffraction patterns between the students' epistemologies and the culture of science that they have experienced?

Chapter 3: Existing in the Borderlands to Rethink Method

The puzzle of the underrepresentation of women in science is a question about humans. Trying to understand this puzzle by better understanding the experiences of women situates it within the territory of narrative inquiry. However, the experiences of women are impacted by intra-actions between human and nonhuman agents. In this way, it is also situated within the territory of agential realism. This research is situated in the borderlands between narrative inquiry and agential realism.

Reading Agential Realism and Narrative Inquiry Diffractively

Just as Barad (2007) read the writings of different scholars diffractively through one another, I will now read her writing on agential realism and Jean Clandinin's writings on narrative inquiry through each other. As described by Clandinin and Rosiek (2012), narrative inquiry is not just a research method; it is a philosophical way of thinking about the world. Therefore, a researcher's conceptual framework needs to be reconciled with the theoretical underpinnings of narrative inquiry. I reconcile agential realism and narrative inquiry through a diffractive reading of the two that focuses on resonances, or the areas where the two topics productively intra-act with each other. As advocated by Barad, I put the two ideas in conversation with each other while trying to avoid privileging one over the other (pp. 92–93).

Despite an emphasis on resonances, I must begin by discussing one major area of dissonance, primarily that narrative inquiry is a method built on humanist ideologies and agential realism is a new material feminist theory—a posthumanist theory. Stemming from two, not only different but opposing areas of philosophy (humanism and posthumanism), it could be argued that agential realism and narrative inquiry cannot

operate together. However, both areas of scholarship have blurry boundary lines or, as Clandinin and Rosiek (2012) would state it, have wide borderlands. Those wide borderlands allow seemingly incommensurable areas to have productive and meaningful areas of agreement.

The very nature of thinking narratively not only allows but encourages an exploration of the borderlands between ideas. As stated by Clandinin and Connelly (2000), "learning to think narratively at the boundaries between narrative and other forms of inquiry is, perhaps, the single most important feature of successful narrative thinking" (p. 25). While encouraging researchers to investigate how theories can work within narrative inquiry, Clandinin and Connelly also warn against utilizing a theory in narrative inquiry without understanding their relationship to each other (pp. 24–25).

When discussing the borderlands of narrative inquiry Clandinin and Rosiek (2012) state that there is only one defining and unarguable feature of narrative inquiry, the studying of experience (p. 37). A study that is not focused on understanding the experiences of people cannot be narrative. This leaves the question: can research grounded in posthumanism be about the experiences of people?

Some scholars define the work of posthumanists as rethinking the human in light of how nonhuman entities have agency upon the human, particularly with contemporary technology (Callus & Herbrechter, 2012). However, unlike the fairly consistent use of the term "humanism," posthumanism is used in very different ways by different scholars (Asberg & Braidotti, 2018; Wolfe, 2010). Rather than focusing on a rethinking of the human, St. Pierre and Pillow (2000) stated that the "'posts'. . . do not offer a corrective to

humanism. Rather, they offer opportunities for limit-work, work that operates at the boundaries of the possibilities of humanism" (p. 6).

Likewise, within Barad's (2007) agential realism, the idea of the human is not eliminated or minimized for the advancement of nonhuman agents. Instead, the human is put on an even playing field as one of many agential entities. Barad explains where she situates her use of the term posthumanism in a postscript:

> I want to make clear that my interest is in thinking about the limits of humanism, and hence I use the term "posthumanism" to indicate this critical engagement; this should not be taken to mean that I advocate positions that use the notion of the posthuman as the next stage of the human, as if it no longer makes sense to talk about the human. (p. 428)

In other words, Barad talks about posthumanism as a move away from anthropocentrism and towards an understanding of the world that explores the intra-actions between all agents: human and nonhuman, living and nonliving.

Other scholars are looking at the question of the human within the posthumanist landscape. In a 2018 introduction to a volume of PhiloSOPHIA, this question is taken up. Kaiser and Thiele (2018) begin the article with a quote from Barad and throughout the text they utilize Baradian language of "intra-actions" and "entanglements" to build a case for the relevancy of exploring human experience within posthumanist philosophy. They argue that, "what is needed is to turn over—and thereby hopefully contribute to the overturning of—the underlying patterns and securing mechanisms that have kept the question of the human tied to human exceptionalism, racism, and sexism for so long" (p. 5). In other words, they argue for an area of inquiry where the human experience can be

explored without privileging the human over the nonhuman and the living over the nonliving. Asberg and Braidotti (2018) use the term "the more-than-human humanities scholar" (p. 5) to emphasize that new material feminist research is additive to rather than separate from human centered research.

The conception of narrative inquiry first outlined by Clandinin and Connelly (2000) is based on John Dewey's (1938) pragmatic philosophy of experience. They describe Dewey's conception of experiences as, "a changing stream that is characterized by continuous interaction of human thought with our personal, social, and material environment" (p. 39). Experience is something that is different from moment to moment based on the multiple interactions that make up that experience. In the following sections I outline the three ways Clandinin and Rosiek (2012) say that Dewey's descriptions of experiences are embraced in narrative inquiry: continuity, representationalism and the social. Then I address how each resonates with agential realism.

Continuity

A feature of narrative inquiry that is based in the work of Dewey is the idea of continuity. According to Dewey experiences grow on one another. One experience leads into the next in a never-ending flow of past, present, and future. Clandinin and Rosiek (2012) point out that the continuity is ontological. The present experience has an impact on future experiences. This is relevant to narrative inquiry in that the act of narrative inquiry impacts the experiences of the researchers and participants. It impacts their present, their future, and their past.

According to agential realism, intra-actions impact the flow of the past, present, and future phenomena. As intra-actions change over time, the phenomena change.

Current phenomena impact the materialization of future phenomena (p. 180). This is not unidirectional. As stated by Barad (2007), "as a result of the iterative nature of intra-active practices that constitute phenomena, the 'past' and the 'future' are iteratively reconfigured and enfolded through one another" (p. 383). Current intra-actions impact the continual unfolding and refolding of phenomena throughout time.

The way in which Dewey talks about experience resonates strongly with how Barad talks about phenomena. They both claim that what they are discussing are ontological in nature, and that both move through time with non-linear fluidity. Additional ways in which experience and phenomena are related is made evident in the remainder of this section.

Representationalism

Another of the features of Dewey's conception of experience that is used in the framing of narrative inquiry is the idea that no experience can ever fully be captured. As stated by Clandinin and Rosiek (2012), "experience . . . is always more than we can know and represent in a single statement, paragraph, or book. Every representation, therefore, no matter how faithful to that which it tries to depict, involves selective emphasis of our experience" (p. 39). All that we can know is our own experience of what is happening. Any description is filtered through our understanding of what we are describing. Every representation is limited.

Barad (2007) uses the term "agential cuts" to discuss the idea that we are always limited in what we can know about a phenomenon. Barad explains, "every measurement involves a particular choice of apparatus, providing the conditions necessary to give meaning to a particular set of variables, at the exclusion of other essential variables" (p.

115). Just as every representation is partial, every observation is partial. The selected method of observation, the environmental factors at the time of observation, and the person doing the observing all impact the phenomenon observed. Every decision cuts one phenomenon from being while determining the phenomenon that exists in the moment.

Dewey warns that since every representation is limited, inquirers should be forthcoming about the processes used in creating a representation. This commitment to being open about decisions is a commitment taken up within narrative inquiry. Clandinin and Rosiek (2012) state, "if the reality we seek to describe is presumed to be independent of our representation of it, then there is no need to tell the story of how our representation emerged within a stream of experience" (p. 40). A belief that all representations are incomplete yields a moral obligation to tell the story of how the representation was created.

Like Dewey, Barad (2007) warns that there is an ethical obligation that goes hand in hand with agential cuts. The way that one intra-acts with the world creates certain cuts. Those cuts materialize different phenomena. Therefore, as agential beings we have an ethical obligation to be aware of and open about the cuts that we are making.

The social

The third feature of Dewey's pragmatic philosophy that has been taken up within narrative inquiry is the social aspect of experiences. Clandinin and Rosiek (2012) describe that even though narrative inquiry respects the lived experiences of individuals as a vital source of knowledge; it does not do so with a belief of the individual as a stand-alone entity. Instead, narrative inquiry recognizes that experiences develop as a result of

multiple factors. As explained by Clandinin and Rosiek: "Narrative inquiries explore the stories people live and tell. These stories are the result of a confluence of social influences on a person's inner life, social influences on their environment, and their unique personal history" (p. 41). The social and environmental impact the inner. Outside factors influence the inner experience.

Clandinin and Rosiek (2012) make a distinction between the research that is narrative inquiry and some forms of post-structuralist research. When exploring the borderlands between the two forms of inquiry, they specify how a narrative inquirer does and does not approach cultural influences on experiences. A narrative inquirer treats information about cultural influences as part of the experience instead of "occasions for critical exposure" (p. 55). The researcher approaches the information with humility instead of with a goal of explaining the stories through a generalizing social lens. The goal of narrative inquiry is not to critique large systemic issues of oppression but to tell about the experiences of individuals. These experiences may or may not showcase how systemic issues impact a person.

As described in detail previously, agential realism includes all aspects that determine a phenomenon: the social and the material, the internal and the external. Although narrative inquiry focuses on the experience of individuals it does not limit analyzing the intra-actions that constitute the phenomenon that was that experience. In this research I used narrative inquiry to share about the phenomenon that was the experiences of three women in science. Since the research is focused on experience and is treating the experiences as a phenomenon, it exists in the borderlands between narrative inquiry and agential realism.

Research Puzzle

Although many studies have explored the underrepresentation of women in science, no "magic bullet" has been found to "fix" the problem. No one magic bullet exists; it is a complex and multifaceted issue. This study adds to the existing body of literature designed to increase the understanding of the puzzle of why women choose not to pursue careers as research scientists. I co-created narratives to share about the human and more-than-human experiences in science of women receiving bachelor's degrees in science and planning to become teachers. These experiences included times when the women's epistemologies aligned with the culture of science they have experienced and times when there was not alignment. By the use of the term "culture of science," I mean the products, practices, institutions, and theories in science (Bell D. , 2006).

Feminist approaches to the underrepresentation of women in science have evolved over time. The current direction of much feminist literature—new materialism—is a direction that could productively contribute to understanding the male domination of science (Hughes C. , 2015; Scantlebury, 2014). Studying the world diffractively is a new materialist method (Barad, 2007; Hughes & Lury, 2013). Barad describes the potential influence of a diffractive methodology:

> This approach provides important theoretical tools needed to move conversations in science studies, feminist studies, and other (inter)disciplinary studies beyond the mere acknowledgement that both material and discursive, and natural and cultural, factors play a role in knowledge production by examining how these factors work together, and how conceptions of materiality, social practice, nature, and discourse must change to accommodate their mutual involvement. (Barad, 2007, p. 25)

I created narratives, in part, by studying the diffraction pattern produced between the women and the cultures of science that they have experienced. Readers of the narratives will be awakened to greater wisdom regarding the underrepresentation of women in science. The emerging wisdom from this research unsettles some of the predominant ideas in the culture of science and opens the space for a valuing of multiple epistemologies of science.

This research, which was developed around the puzzle of the underrepresentation of women in science, was guided primarily by this puzzle. Clandinin and Connelly (2000) state that a puzzle, more than a specific research question, should be the driving force of narrative inquiry: "Narrative inquiries are always composed around a particular wonder, a research puzzle . . . . Narrative inquiry carries more of a sense of continual reformulation of an inquiry than it does a sense of problem definition and solution" (p. 124). The purpose of the research is to share the experiences of women in science through narrative accounts, metaphorically painting a picture of how the women experience science. The specific research questions that were under investigation are as follows:

- What are the stories of female undergraduate science students' experiences in science?
- What are the diffraction patterns between the students' epistemologies and the culture of science that they have experienced?

The research was completed according to the timeline represented in Table 1 found in Appendix B.

More About Narrative Inquiry

Given the need to avoid over-simplifying the complexities impacting women's experiences in science, it is important to use a method that aligns with this goal.

Narrative is one way. Hendry (2010) echoes my claim when she states: "narrative has the potential to remind us of the complex and multiple ways in which humans make meaning" (p. 78). It is also important to use a method that attempts to avoid the pitfalls of science described in my critique. Concerns about absolutism in science are also present in social science research, thus my work attempts to acknowledge and use the intricacies that are hidden in many studies. Narrative is more likely to avoid the pitfalls of absolutism than some other methods; however, utilizing a narrative approach does not eliminate the concern. As stated by Hendry, Mitchel, and Eaton (2018), "'stories' and narratives from [a] conventional, humanist perspective are still full of positivist concepts like validity, bias, subjectivity, data, triangulation, and coding (p. 5)." Therefore, individual decisions throughout the research process were approached with the goal of avoiding positivist conventions.

As described in Chapter 1, I believe that an embracing of multiple epistemologies of science would benefit science; likewise, I believe that multiple approaches to social science research benefit the social sciences. The wonderful way that Ann Hartman (1990) captures this idea warrants a repetition of a quotation from her writing:

> This editor takes the position that there are many truths and there are many ways of knowing. Each discovery contributes to our knowledge, and each way of knowing deepens our understanding and adds another dimension to our view of the world. We need large-scale studies in which variables can be reduced to measurable units and the results translated into the language of statistical significance. We need in-depth "thick descriptions," grounded in context, of a single case, a single instance, or even a brief exchange. For example, large-scale

> studies of trends in marriage today furnish helpful information about a rapidly changing social institution. But getting inside one marriage as in "Who's Afraid of Virginia Wolfe?" richly displays the complexities of one marriage, leading us to new insights about the pain, the joys, the expectations, the disappointments, the intimacy, and the ultimate aloneness in relationships. Both the scientific and artistic methods provide us with ways of knowing (p. 3).

In depth, detailed, artistic descriptions of phenomena can awaken in readers wisdom that cannot be known and felt through other approaches. A narrative approach to exploring the underrepresentation of women in science is not very common and thus warrants attention.

The research questions focus on better understanding the storied experiences of women. The way that people share about experiences is through stories. Therefore, narrative is well suited to the goals of this research. In *Narrative Inquiry* Clandinin and Connelly (2000) repeatedly indicate that "narrative is the best way of representing and understanding experience" (p. 18). Although researchers who use other methods may argue that narrative is not "the best" method, it is a method that explicitly targets the storied accounts of experiences of participants. Since memories of experiences are in the minds of an experiencer, the sharing of stories reveals the re-membered experience to others.

Additionally, any research about underserved populations, in this case women in science, should take care to be particularly respectful of the participants. It should focus on allowing the participants to have a voice. In a 2012 interview, Jean Clandinin makes the argument that typically researchers "do research on rather than research with" and

that narrative inquiry does the opposite. She continues by saying that in more prevalent approaches to research, researchers are deciding what is being told and thus are not really hearing the stories of the experiences that the participants find important. Narrative inquiry gives participants a voice to tell what they find important. Caine et al. (2017) make the argument that research such as narrative inquiry, that prioritizes the experiences of participants, is particularly important in social justice research. They state "when we begin research with policies and practices rather than with a focus on the lives of people. . . [it] can result in silencing the experiences of participants" (p. 7). Narrative inquiry, focuses on the lives and experiences of participants, giving them voice. In this case narrative inquiry gives voice to women in science.

The Personal Narratives Group (1989) also expresses the idea that narratives are important for giving voice to women. They point out that narrative is particularly appropriate when looking at research that explores issues related to gender. They state, "Since feminist theory is grounded in women's lives and aims to analyze the role and meaning of gender in those lives and in society, women's personal narratives are essential primary documents for feminist research" (p. 4). Feminist scholarship is based on women's lives and this should include stories from those lives.

Narrative is becoming a more and more popular term used in research, but does not have one unifying definition. As stated by Squire (2008), "unlike many qualitative frameworks, narrative research offers no automatic starting or finishing points" (p. 4). She continues by outlining all the different points of debate within the narrative research community. A definition that encompasses most of the forms of narrative can be taken from Barone (2007): "Narrative construction is an approach to social research in which

data are configured into any of a variety of diachronic, or storied, formats" (p. 454). Different scholars have developed slightly different conceptions of narrative research including but not limited to narrative analysis (Polkinghorne, 1995), life stories (Barone, Science, Art, and the Predispositions of Educational Researchers, 2001), portraiture (Lawrence-Lightfoot & Davis, 1997), life histories (Hendry, 2018), and personal narratives (The Personal Narratives Group, 1989). Although much of this scholarship has informed my research, particularly that of Hendry and Lawrence-Lightfoot, given the varied and nuanced nature in which each type of narrative is used, I have relied primarily on one conceptualization of "narrative," narrative inquiry.

Narrative inquiry, a term first used by Clandinin and Connelly in 1990, is one method that is well suited for an investigation of remembered experiences. Clandinin, Connelly, and others who have written about narrative inquiry, have published widely on this method's theoretical underpinnings, as was described earlier in this chapter. They have also written extensively on the particulars of this methodology. The vast body of scholarship provides a solid foundation from which to reflect on individual decisions, utilizing their suggesting or forming critiques as is appropriate.

Clandinin and Connelly (2000) propose a relational three-dimensional narrative inquiry space: interaction, temporality, and situation. The first dimension, interaction, is an exploration of experiences that looks inward and outward. Participants and researchers look inward toward the personal, toward "feelings, hopes, aesthetic reactions, and moral dispositions" (p. 50). Participants and researchers also look outward toward the social. The second dimension, temporality, involves looking forward and backward to develop an understanding of the past, present, and future. The third dimension,

situation, focuses on place. As described by Clandinin, Pusher, and Murray Orr (2007), the three dimensions provided the researcher "places to direct one's attention in conducting a narrative inquiry" (p. 23). How the three-dimensional approach to inquiry impacted the data collection process and representation of the data is discussed in greater detail in a later section.

Feminist Methods

Feminist research is not a monochromatic idea. Each feminist researcher has a unique interpretation of what it means to be a feminist researcher. However, there are some overarching principles that are generally agreed upon. These include challenging the assumption of necessary separation between the researcher and the research participant and a goal of empowerment of the oppressed or transformation of oppressive systems (Cook & Fonow, 1986; Hughes C. , 2015). These overarching principles have implications for research practices that are expanded upon throughout the description of methods. Although all feminist researchers do not agree on the implications of these principles, I used these principles to reflect on my research practices.

One of the implications of a feminist research agenda is in the overall method used. Although there have been arguments that feminist scholars in the social sciences should use both qualitative and quantitative methods, qualitative methods are by far more commonly used (Scott, 2010). More specifically, narrative is a means of scholarship frequently used by feminist social science researchers because, as previously described, it is particularly well suited to uncovering the experiences of those who are typically silenced, in this case women in science. Cotterill and Letherby (1993) articulate the importance of narrative in both data collection and representation: "The narrative technique allows respondents to 'tell the story' in whichever way they choose and,

importantly, validates individual experience and provides a vehicle through which this experience can be expressed to a wider audience" (p. 74). The accounts of the women who participated in this study are represented with full attention given to the individuality and nuanced nature of each woman's experiences, an emphasis that is vital in feminist research.

Narrative accounts also allow for a plethora of detail that paints a full and complex image. The storied accounts go beyond a focus on just human intra-actions and human understanding. The detail provides a description of experiences that is more-than-human. Asberg and Braidotti (2018) argue that storied accounts meet the new material feminist agenda of capturing a multitude of entanglements. They state, "the project of redefining the embodied posthuman or more-than-human subject enlists not only cognitive practice but also the resources of the imagination, affects, and ethics" (p. 14). The detail and artistry in storied narrative accounts allows the reader to begin to feel the human and nonhuman intra-actions present and the implications of those intra-actions.

One particular way in which narrative inquiry strongly aligns with a new materialist belief is in the idea of becoming. According to new materialism, since a phenomenon is based on entanglements that exist in that moment, a phenomenon is always changing, always unfolding, always becoming (Gries, 2013). Likewise, an important component of narrative inquiry is the idea that narratives are constantly unfolding through a comingling of the researcher and participants and comingling of stories of pasts, presents and futures (Craig & Huber, 2012). As described by Asberg and Braidotti (2018), "it [posthumanities research] is about materially embedded story-telling practices, about daring to acknowledge being, not in the center, but in the midst of the

world" (p. 17). New materialist feminism advances a belief in phenomenon as always becoming; narrative inquiry is used to explore experiences that are in a state of perpetual becoming. Researchers and research participants are in an entangled and ever-changing existence and thus any representation is incomplete, tentative, and storied. In that way the method of narrative inquiry is appropriate for new materialist research.

Agential Realism

One specific new materialist method is diffractive reading. Karen Barad (2007) describes diffraction as the method of agential realism. As previously described, Barad's theory of agential realism stems from the theoretical writings of Bohr. Bohr's writings regarding the two-slit apparatus showed that the use of particular equipment impacts the very nature of substances. Bohr built on this finding to argue that all findings are based on the intra-actions that exist in a specific moment. He argued that scientific truths are not universal truths, but are phenomena that occur in very specific situations based on specific interactions. Figure 3 shows a simplified representation of the two slit experiment that is revisited throughout this document to visually represent the various phenomena that are relevant to this study. The series of intra-actions in this study are also shown in Appendix D. Although the representation might evoke a sense of a cause and effect relationship, in fact, it represents multi-directional entanglements or intra-actions. The representation is also a snapshot in time, a representation of the entanglements that exist in the moment but change through the progression of time.

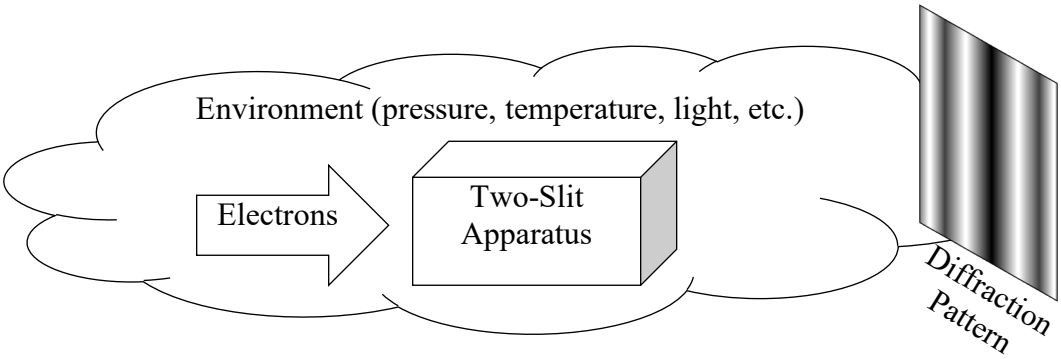

Figure 3. Simplified representation of two slit apparatus. This image shows a simplified representation of the two slit apparatus that will be used throughout to represent various phenomenon present in the study.

Barad applied Bohr's argument about what is true at the microscopic level, to argue that phenomena must also be all that can be known at the macroscopic level. Agential realism is Barad's theory that all that can be known is phenomena, and phenomena come into being through intra-actions, or entanglements between things. The idea of research revealing a phenomenon that exists due to current intra-actions aligns with the goals of narrative inquiry. As described by Clandinin and Rosiek (2012), "[narrative] inquiry is not a search 'behind the veil' of appearances that ends in the identification of an unchanging transcendent reality" (p. 41). They continue by explaining that inquiry emerges through a "stream of experiences" (p. 41). In other words, phenomena emerge through ever changing intra-actions.

The idea of agential realism has several implications for this research that will emerge as I explicate my methods. One implication is a need for reflection on the researcher as part of the research. As stated by Gannon (2012), when using Barad's theory, "analysis must therefore focus on entanglements, relationalities and 'intra-actions' of all sorts of matters and agencies, including the singular entanglements of data-

researcher-method" (p. 134). Of primary importance, if all objects emerge through intra-actions, those intra-actions must be made clear, including those of the researcher.

To understand women's relationships with science, I needed to develop an understanding of salient intra-actions that the women had with science. This included exploring intra-actions with humans and with nonhuman agents. For example, one woman with whom I spoke, Visha, talked about calling her dad on her cell phone to tell him that she was not going to go to medical school. The cell phone gave her distance that she needed, as she was anxious about talking to him. It also allowed her to search for a location that felt right for the conversation, in this case a public place. The phone had agency over her and intra-acted with her to create that moment, as did the agency of her father, the place the conversation took place, and an infinite amount of unknown and unexplored entities.

Of primary importance to this research is intra-actions between the women and human and nonhuman science-related agents. The phenomenon of women's intra-actions with science is represented in figure 4 (also found in Appendix D). There are moments of resonance, where the women's epistemologies constructively interfere with the culture of science that they have experienced, and moments of dissonance, or where the women's epistemologies destructively interfere with the culture of science that they have experienced.

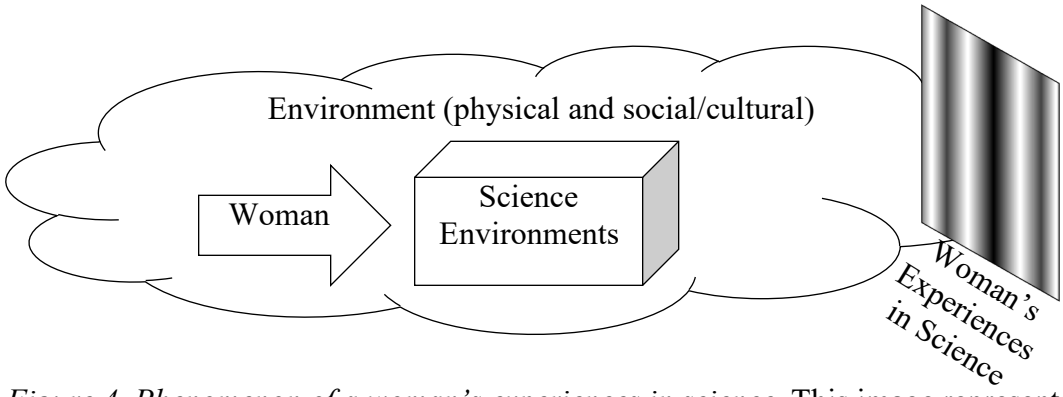

Figure 4. Phenomenon of a woman's experiences in science. This image represents the phenomenon of a woman's experiences in science when the woman intra-acts with science environments and with other aspects of her life.

Narrative inquiry is well-suited to representing the diffraction patterns produced from the intra-actions between women and science for several reasons. First, the three-dimensional approach to narrative inquiry takes into account the material concerns of human intra-actions by looking inward toward the personal and outward toward the social. It also takes seriously a consideration of space, one type of intra-action with nonhuman entities. Additionally, narrative inquiry locates experiences in time and explores temporality as an important characteristic of research. Likewise, temporality is an important component of agential realism. As stated by Barad, "reality is therefore, not a fixed essence. Reality is an ongoing dynamic intra-activity" (Barad, 2007, p. 206). In order to understand the dynamics of reality, all experiences need framed within specifics of time and place and since time and place shape the experiences, they need to be taken seriously as components of research. Lastly, narrative inquiry provides a means of aesthetic representation that is arguably necessary in diffractive analysis. As described by Bozalek and Zembylad (2018), "a turn to diffraction . . . will make us investigate and do educational research and write our analysis in a very different way, using quite different language that is more evocative and perhaps poetic" (p. 56). Unlike other forms

of representation, narrative is a platform that embraces the sort of visual and emotional language that moves a reader.

Narrative Beginnings

A researcher's subjectivity statement is typically written as a rather small part of a method section, sometimes as part of a conversation about limitations of the study and/or ethical considerations. However, in narrative inquiry, the researcher's experiences and beliefs are not addressed as an afterthought and are not things that should be bracketed out of the research. According to Clandinin and Connelly (2000), "one of the starting points for narrative inquiry is the researcher's own narrative of experience, the researcher's autobiography" (p. 70). This section first explores the importance of a researcher's narrative beginnings and then provides my own autobiographical account as a researcher.

Importance of a Researcher's Narrative Beginnings

In narrative inquiry, the reason that it is so imperative for the researcher's narrative to be fully explored is two-fold. First, the researcher lives narratively with the participants during the research and thus is part of the narratives told and produced. Secondly, exploration of the researcher's autobiography makes her more aware of the "bias" that she may impose on the research. Clandinin discuss this during a 2016 interview:

> Unless you're willing to actually do the autobiographical narrative inquiry, you can't possibly begin to understand someone else's story, because I think what happens is, perhaps unknowingly, that you start to just impose your story or a dominant story on a participant without really saying "look at the complexities in

my own story, now I'm more awake to the complexities that might be in another's life (7:02-7:32).

Recognizing the complexity in one's own story allows a researcher to be more attentive to someone else's stories. It allows the researchers to become more wakeful in their inquiry (Dubnewick, et al., 2018).

An in-depth exploration of the researcher's subjectivity is also central to many feminist approaches (Clandinin & Connelly, Narrative Inquiry: Experience and story in qualitative research, 2000; Hesse-Biber, 2007; Rayaprol, 2016). According to Rayaprol (2016), "one of the significant contributions of feminist work has been self-reflexivity in research, by urging social researchers to critically examine one's own social location and its possible impact on the conduct of research" (pp. 379–380). All writing and all research are subjective. Making that subjectivity obvious through the inclusion of the author in the text is more authentic than the author hiding behind a veil of third person accounts.

Additionally, self-awareness is a vital component of agential realism. Just as Bohr's two-slit apparatus determined whether the light was a particle or a wave, the researcher determines the nature of the research. Intra-actions between particles and apparatuses, along with other environmental factors, determine the phenomenon observed. Likewise, in social science research, intra-actions between the researcher and the research participant(s), along with other factors, determine the phenomenon. The intra-action between a woman's experiences in science and the researcher is represented in figure 5 (also found in Appendix D). Because of the entanglements between particles and the apparatus Bohr found it of vital importance to describe any apparatus used in

great detail. Likewise, the description of the researcher should go beyond a mere subjectivity statement. I aspire to make clear who I am as an educational researcher and as a scientist and therefore begin with an autobiographical narrative.

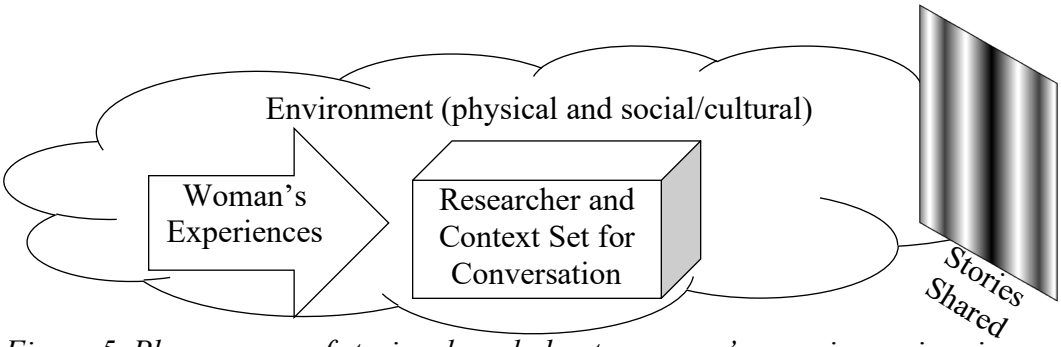

Figure 5. Phenomenon of stories shared about a woman's experiences in science. This image represents the phenomenon of the stories shared about a woman's experiences in science when the woman's memories of experiences in science intra-acts with the researcher, the contexts set for conversations, and with other aspects of the conversations.

In addition to beginning this exploration of women's experiences in science with an autobiographical reflection, I include my voice throughout as a co-creator of the narratives produced. According to Clandinin and Connelly (2000), "It is not only the participants' stories that are retold by a narrative inquirer . . . . it is also the inquirers' stories that are open for inquiry and retelling" (p. 60). I walk you through my experiences and thoughts as I narrate the experiences of the women with whom I spoke. The process of this writing is described in further detail later.

Cotterill and Letherby (1993) describe an autobiographical inclusion throughout research as an important component in feminist research: "Feminist scholarship involves understanding how one comes to understandings, not merely the end product of the understanding obtained. This should include the coming to knowing of both the participants and the author(s) of research" (p. 68). They describe feminist research as a weaving together of the researcher's and participants' stories. Through speaking with the

women in this study I gained moments of wisdom regarding women in science and I describe my intellectual journey along with those of these women.

My Narrative Beginnings

As I think back to how I got to where I am today, I realize that it was not a straight path. There were many moments that caused shifts in my goals, moments that irrevocably altered my trajectory. One of these moments was during the summer of 2002. Let me take you back to that time.

I am sitting by myself on the second floor of a science building at Penn State University. The sun is getting brighter outside and other students are starting to roam lazily around getting a late breakfast and meeting up with friends. The piece of equipment that I am using takes up half the room and drowns out the music, which I am futilely trying to hear. Despite it being the weekend, I am lucky to have use of the equipment that I had signed up for over a week ago. The research project that I was invited to participate in involves fascinating science and, if we succeed, could make the world "greener" by making the use of hydrogen as a fuel more viable.

The days are getting shorter and so is my time at State College. After three months participating in this research internship, I long to get back to life-as-normal. I miss my friends and I miss my classes. I miss feeling excited and not apathetic about getting up in the morning. This is not just my reaction to this lab. This is my third internship and they all have seemed to deplete my excitement for working as a research scientist.

Research, from my experiences, involves working in isolation. When work is interrupted with a personal question such as "how was your weekend" it is greeted with:

first a confused look, second a friendly grin and pleasant but brief response, third a return to work. Even when you are standing a mere three feet away from a colleague, a social and intellectual wall exists between you. Everyone in the room, in the hall, in the building is focused on his own work, which is related to, but separate enough from your own, so continued scholarly dialogue is unnecessary.

There is often upfront deep, critical and collaborative thinking that goes into creating a theory, followed by long periods of individualized and specialized work. The enjoyment and elation that is imagined to come with scientific work, the "eureka moments," are few and far between. The excitement and fulfillment of the first three meetings with my mentor felt like the classic portrayal of science in movies, the way I imagined it be. He told me about the possibility of making the use of hydrogen as a fuel more viable, with the only byproduct being water. I felt invigorated and could not wait to get to my apartment, pull out a lawn chair, and read more about fuel cells. He explained the complex chemistry involved in the research. The ideas were challenging and stimulating. I peppered him with questions and we quickly filled sheets of loose-leaf paper with sketches and formulas. He explained the innovative lab procedures, which I enthusiastically practiced under his guidance.

The novelty of the chemistry concepts, the lab procedures and the idea of being able to better society quickly dissipated. Unlike in the movies, rather than science being a string of innovative thoughts, surprising discoveries and world-changing successes, real labs are redundant and involve much more failure than success. As anticipated, my first experiment—the large, loud piece of equipment indicated—was unsuccessful. This did not come as a surprise and therefore was not upsetting. The fruitless attempt resulted in a

very small change in the procedure that was planned as a next step long before I arrived. I had to brush myself off and start the same process, altered slightly, over again, and again, and again. The once exciting possibility of making the world a cleaner place through novel science got lost in redundant daily activity.

As I sit waiting for the results on my twelfth try, listening to music, looking out of the window, I am not enlightened, excited or inspired. Being a scientific researcher is not what I thought it would be. It is not making me feel like I am experiencing or doing something meaningful, it is not keeping me intellectually stimulated and it is not making me feel like I am working toward the betterment of a team or of the world. So, if I am not going to be a scientist, what am I going to do with my life?

While I wait for the results—inevitably that another attempted experiment is going to be unsuccessful—my mind drifts, filtering through the last few years of memories, looking for moments that motivated me in all the ways that working in a lab does not. A smile spreads across my face as memories surface of digging in soil looking for different minerals with a teenager wearing a Korn shirt, building molecules out of cotton balls and Q-tips with my roommate and pulling out my shoe collection as a visual while describing factor label method to a nursing major in her forties. I realize that some of my best moments with science have happened while tutoring.

One experience with the nursing major—let's call her Becky—was a turning point for me. She sought out help feeling completely hopeless. It took a great deal of courage for her to go back to school only two years before her only daughter would enter college. She had sacrificed a great deal of time, money and humility to return to school at this point in her life. Intro to Chemistry is a required course for all nursing majors and

is known to be a huge deterrent. Becky was an intelligent and driven woman who worked hard to understand chemistry but felt completely defeated. She was seriously contemplating if all the classes she completed up to this point were for naught. I felt that she—as a pragmatic and worldly person—would make an excellent nurse but she did not see the practicality of calculating the number of molecules in a gram of carbon dioxide. The challenge for me was not explaining the "how to" of the calculations, which had already been done by her professor; it was explaining the relevance. Until she understood the why, she would not get the how. I had to connect with her personally and show her how to connect with the subject that I loved.

One day it dawned on me to teach the chemistry calculations—known as factor label method—using pairs of shoes. The concrete relationship of one pair meaning two shoes, stood in for the abstract relationship of one mole meaning $6.02*10^{23}$ molecules. It worked. A light bulb went off for Becky. A light bulb went off for me. She understood what she needed to do in the calculations, she understood how what was written in the calculations represented what was happening in the reaction and I understood both the calculations and how to explain them more thoroughly. We moved around pairs of shoes, modeling different examples and she began crying. Tears of relief flooded her eyes as she hugged and thanked me, contagious tears of joy. This moment of intellectual stimulation, of experiencing something tangible and of connecting to someone else surpasses any experiences that I had as a research intern.

As I wrap up my research from a summer at Penn State, I itch to get back to tutoring. Although every day as a tutor was not as dramatic as my day with Becky and

the shoes, tutoring always enlivens me in a way that conducting research does not. I realize that what I want to do with my life is to be a teacher.

Now it is 16 years later. I have spent the last 14 of those years as a science educator, science curriculum writer, instructional coach, and an education faculty member. Over the last several years I have also been pursuing a doctoral degree in curriculum and instruction. The experiences that I had in my professional work and academic studies have caused me to reflect more on my past and analyze the decisions that I have made. I have come to see my experiences as storied accounts that have evolving meaning. I have come to see my experiences as an intra-tangled web of factors. I have come to see "reality" as based on this web of relationships, and as such as continually emergent. As these commitments greatly align to those of new material feminist, I have come to see myself as a new material feminist (Parikka, 2010). I also see that at different times and in different situations, a variety of epistemologies have proved fruitful for me. This led me to a personal commitment to the valuing of multiple epistemologies. Agential realism is one of many epistemologies that I navigate between when making sense of the world.

Currently I am working with undergraduates in a program called GWTeach. GWTeach is based on the UTeach model from the University of Texas, Austin. Students in the program are pursuing majors in science, technology, engineering or math (STEM) while completing one of GWTeach's pathways: a minor in STEM teaching or a teaching certification in their STEM discipline. The GWTeach classes are typically small and involve a great deal of group work. Throughout the program students have me as a teacher or co-teacher in at least two courses. We also have a student work space attached

to our offices where students plan lessons, study, and hang out. My trips to the water cooler and coffee breaks involve catching up with students. In this context I get to know my students very well and form a relationship with them that is closer and more personal than a typical teacher-student relationship.

Although The George Washington University is similar to other institutions in the underrepresentation of women in most science degrees, GWTeach is mostly women—approximately 75 percent. Something about becoming a teacher attracts women at a far greater percent then it attracts men. I have had many conversations with my students regarding what draws them to education but few conversations explicitly regarding their experiences in science. When students do share their experiences in science with me, many of the experiences resonate with my own.

The Women

I met with three students who identified as female, were pursuing degrees in science, and were also interested in becoming teachers. My goal was to present the narratives of few enough women that each story could be explored and developed fully, yet enough women that the narratives provide a rich picture of the variances that occur between women's experiences. This goal aligns with what is common in qualitative research. As stated by Hesse-Biber (2007), "the logic of qualitative research is concerned with in-depth understanding and usually involves working with small samples" (p. 119). Women were recruited from the GWTeach program, as GWTeach students are in the fairly unique position of pursuing studies in science but are considering becoming teachers rather than research scientists. Also, GWTeach was started after the women began their studies at George Washington University (GW), so they did not start their science degree intending to simultaneous study the art of teaching.

The criteria for participation in the study were that the students were 18 years of age, identify as female, were science majors, completed at least two education classes, and were considering becoming teachers. I defined "science majors" as including the following majors that are offered at GW: biology, biophysics, chemistry, and physics. All active GWTeach students who met the participation requirements according to GWTeach records received an e-mailed invitation to participate in the study. Four women replied to the email, three of whom met the criteria. Those three women agreed to participate and continued through to the completion of the study: Visha, Mae, and Nathalya. They were pursing degrees in a variety of sciences, and had different ethnic backgrounds, linguistic backgrounds, immigration statuses, and socioeconomic statuses. Visha was a biology major and second-generation Indian immigrant who grew up speaking English but understanding some Tamil. Mae was a chemistry major of Italian ancestry who grew up speaking English. She did not mention when her family first came to the United States. Nathalya was a physics major and first-generation Colombian immigrant who grew up speaking Spanish.

The women were not selected based on their varied degrees of study or cultural backgrounds. They were the only three women who met the criteria and expressed interest in participating in the study. Also, the women were not explicitly asked about ethnic backgrounds or socioeconomic background. All of the information in this vein that was included in the narratives was done so because the women spoke about it as important parts of their stories. For Nathalya and Visha, their Colombian and Indian heritages were an integral part to many aspects of their narratives. For Mae, her Italian

ancestry was only mentioned in passing and was not as woven into her recollections the way that heritage was for the other two.

Relationships

According to most social science research methods, knowing the participants before the study begins would be a detriment because it would decrease my ability to objectively analyze the information provided. However, in narrative inquiry, forming a close relationship with participants is essential. Clandinin and Connelly (2000) indicate that relationships are something that need to be continually worked at and strengthened. They state that, "moving into close relationship with participants is necessary work in narrative inquiry" (p. 82). As an instructor in the GWTeach program, I actively work on fostering friendly relationships with all the students in the program. My pre-existing relationship with them was an asset to the narrative work.

In order to empower female research participants, one of the most important features of feminist research is that researchers should try to decrease the hierarchical relationship between themselves and the research participants (Campbell & Wasco, 2000; Hesse-Biber, 2007). One way to do this is to approach the relationship with mutual trust rather than a researcher/researched relationship.

In one of the most cited articles written about feminist social science research, Ann Oakley (1981) critiqued interviews, questioning if there can be such a thing as a feminist interview. She refers to interviews as "pseudo-conversations" since researchers are taught to be "friendly but not too friendly" in order to "manipulate" the participant into opening up without removing one's own objectivity (pp. 32–33). She argued that not only does this go against a feminist objective of eliminating hierarchy, but also it is not the most effective way of obtaining meaningful information. As stated by Oakley,

"Finding out about peoples' lives is much more readily done on a basis of friendship than in a formal interview" (p. 52). The interviewer should not attempt to stay an "objective" outsider but should engage with participants in a companionable conversation.

One of the ways Oakley (1981) recommends that a researcher can build relationships and trust with participants is counter to what most interview guides recommend; reveal yourself, your thoughts, your experiences, your opinions. She argues that, "in most cases, the goal of finding out about people through interviewing is best achieved when the relationship of interviewer is prepared to invest his or her own personal identity in the relationship" (p. 41). Oakley was interviewing pregnant women who were, at times, anxious about the future. When the pregnant women asked Oakley questions about giving birth and raising children, most interview guides provide the guidance that she should direct the interview back by responding with a question directed toward the participant. Oakley felt that it was cold and detached to not answer the questions that the women had about her experiences as a mother. Likewise, my students are going through a transition that I went through. To see my conversations with them as one sided is an unnaturally detached approach to hearing about their experiences. Thus, as Oakley did, when the women with whom I spoke asked me questions, I answered them. For example, in the context of meeting for the research, I spoke with the women about how to learn about different available teaching positions and about free online classes that I have taken to learn more science after graduating.

Not only are relationships important in narrative inquiry and feminist research methods, relationships are also considered unavoidable and thus an important area of exploration in agential realism. As previously represented in figure 5, the intra-actions

between myself and the women with whom I spoke impacted the phenomenon of the conversations. As the researcher, I was the apparatus through which the women's experiences were being viewed. Just as Bohr's two-split apparatus determined whether the light was a particle or a wave, researchers determine, to a great degree, the nature of their research. Therefore, I described as fully as possible the intra-actions between the women with whom I spoke and myself. In order to do this, I made myself, as the apparatus, evident in the narratives.

One barrier to the type of relationship that I have argued is important to have, is the fact that the students had me as an instructor in multiple courses. Instructor-student relationships are implicitly hierarchical. However, the relationship with my students is different than what is typical. I have already described that my courses are mostly small and guided by group work. Additionally, the guiding principle of the courses is to provide feedback for growth rather than evaluation for grading. I view myself as a co-learner in the classroom and I view my students as co-teachers. Also, I have many opportunities to interact with the GWTeach students outside of course-related experiences as GWTeach hosts events and gatherings on a regular basis.

The way my students interact with me outside of class provides some evidence that my relationships with them are more trusting and less hierarchical than typical instructor-student relationships. All of the students are provided my cell phone number for emergencies related to teaching experiences. Students use this to text me questions and in some cases just to say "hi" with no apparent hesitation. Additionally, when students have a semester without a GWTeach course they often stop by my office to catch up, telling me about their courses and friends. Although I cannot speak for the

students, I feel that many things indicate that they are comfortable with me and that we have relationships that go beyond our teacher/student dichotomy.

Although it is my belief and hope that my role as an instructor does not predicate a hierarchical relationship between me and my students, I did not take this for granted. In addition to analyzing the conversations in the manner needed to create the narratives, I also analyzed the conversations for evidence of hierarchy. According to Dini and Hammer (2017) an open structure to an interview allows for analysis of how participants are framing the interview. Although not what Dini and Hammer were looking for, I looked for evidence of a hierarchical relationship based on the students' approach to our conversations. For example, if students were overly apologetic at times or if they didn't ask me questions, these might indicate that they viewed me as someone in a higher status than their own. The women did apologize if they were late to a meeting but quickly moved on. Also, all three women asked me questions at times. According to Jennifer Coates (1997) the primary feature of friendly conversation between women is that both speakers construct the conversations together. This type of dialogue contains co-constructed utterances and overlapping speech. There were instances of overlapping speech in my conversations with all three women. And although there were long periods of the women doing all of the talking, there were also periods of back and forth dialogue more typical of friendly dialogue. Coates (2007) also suggests that laughter is an indicator of intimacy in conversation. The conversations I had with the women contained a great deal of laughter.

Conversations

First, let me explain the use of "conversations" instead of interviews. Not only did I use an open-ended approach to the "interviews", but the time together took the form of conversations. According to Clandinin and Connelly (2000):

> Research interviews normally have an inequality about them. The direction of the interview, along with its specific questions, are governed by the interviewer. However, researchers who establish intimate participatory relationships with participants find it difficult, if not impossible, to conduct such interviews with participants. Even when they begin with the intention of conducting an interview, the interview often turns into a form of conversation. (p. 110)

The relationship that I already had with the students made it uncomfortable and not pragmatic to approach the meetings as formal interviews. A conversational approach is recommended by narrative inquiry researchers and feminist researchers in order to decrease the hierarchical relationship and learn as much as possible about another person's experiences.

Conversations differ from interviews in several ways. In an interview a researcher tries to maximize the focused time. In the conversations it was important to take time for small-talk. For example, greetings and pleasantries that are typical when acquaintances get together for coffee were an important part of the conversations. Most of the conversations started with and ended with long periods of catching up that had nothing to do with the intended purpose of the meeting. Sometimes we would spend upwards of 30 minutes talking about our current lives before or after focusing on their experiences in science. Nathalya and I typically started the conversation talking casually. Visha usually seemed to want to be focused on her experiences in science at the

beginning of our conversations but we would drift into small talk for a while, often walking out of our meeting place together before parting ways. Mae and I would drift in and out of casual conversation throughout our time together.

In an interview a researcher typically directs the conversation through questions. In these conversations the woman primarily directed the conversation. My participation was more of a give and take rather than directive questioning. Just as one might ask a friend for details or clarification of a story that she is telling, I did ask questions. Questions were asked at pauses in the conversation in order to keep it going rather than being interjected to redirect the conversation and the questions were based on and built off of the direction of what the women were saying. At times I hardly spoke beyond, "wow," "uh-huh," and laughter. At other times the conversation was more of a give and take, a mixture of comments and questions from me and recollections and some questions from them.

The three women were asked to meet for a series of face-to-face conversations. The overarching purpose of the meetings was to provide the women an opportunity to share about experiences that they had in science, an opportunity to tell their stories. When describing conversations with participants, Clandinin and Rosiek (2012) state, "experience is storied both in the living and telling and that can be studied by listening, observing, living alongside another" (p. 43). We lived together through them telling about their experiences in science. The conversations were open-ended and lasted approximately one hour each: the shortest was just over thirty minutes and the longest was just under an hour and a half. A minimum of three meetings was initially requested; however, I ended up meeting with each woman between five and six times. Although the

"interviews" were open-ended, an initial purpose for each was described at the beginning of each conversation.

Three-interview approach

In a pilot study conducted in the spring of 2016, it was found that the women interviewed wanted to provide a background of their experiences in science before describing specific experiences in detail. This background information was also found to be useful in contextualizing the stories of the women. This sequence aligns with the approach outlined by Irving Sidman in *Interviewing as Qualitative Research* (2013), thus Sidman's three-interview approach was utilized although not necessary fitting into three conversations.

As outlined by Sidman (2013), the focus of the first conversation or first set of conversations was to gain information about the women's past in science and general demographic and background information. For example, I said to Nathalya, "What I want to do, is just get a picture of who you are and what's important to you." I said something similar to both Visha and Mae, but I already knew Visha particularly well, so to her I specified to tell me things as if I did not already know them. Mae began by telling me where she grew up. Immediately the conversation was a back-and-forth with me asking things like, "is that a small town?" and "did you start out in private school?" Our conversations continued with my asking a question every minute or two. Visha began by telling me about her Christian faith. She spoke for three minutes before pausing, at which time I asked, "but you grew up in the church?" She would typically speak for three to five minutes in between my asking questions such as, "what do your parents do?" or "you haven't done much writing for enjoyment for the last while?"

Nathalya began by telling me that she had recently written an autobiography. She often spoke for five or more minutes before I would ask a question such as “was she always a beautician?” or “how old were you then?”

The focus of the second conversation or set of conversations was for the women to share details about specific experiences related to science. For example, I said to Visha, “I was hoping today that you could just tell me anything and everything about your experiences in science from the youngest age that you can remember thinking about science or experiencing science until tutoring chemistry now, everything in between.” I said something similar to all three of the women. Mae and I switched to focusing on science in our second conversation. With this focus she shared more stories, speaking for longer periods of time, about three to five minutes, before I would ask a question. Some follow up questions included “like Bill Nye?” and “do you remember any of your teachers specifically?” Visha and I also switched to focusing on science in our second conversation. The pattern of our conversation did not change noticeably with the change of topic. Some questions that I asked her included, “did you have pets?” and “when do you think you were having these thoughts.” Nathalya and I switched to focusing on science at the beginning of our third conversation. With the change of conversation, I asked questions slightly more frequently. Questions included “what was your teacher like?” and “what year did you take chemistry?”

The focus of the third conversation or set of conversations was for the women to reflect on the intellectual and emotional meaning they attribute to the experiences shared. This part involved more direct questions than the other parts of the conversation. For example, I said to Nathaly, “you've talked about some experiences of women in

Columbia. Like your mom getting hired for a job because she had big hips . . . . And I'm wondering how you feel, if that upbringing has impacted how you perceive women." I also asked for specific five senses descriptions of places and people who were previously discussed. Some of these conversations did not have an introduction, flowing from casual catching up to reflecting on things we had talked about. Some of them were prefaced with statements such as "I have some really specific things that I wanted to follow up with you about, so sorry if I bombard you with questions."

The purpose of the second interview or series of interviews blended with that for the third interview or series of interviews, so it is difficult to pinpoint where one ended and the other began. After switching to focusing on science, I ended up meeting with each woman four more times.

Having a focus for each conversation allowed the women to reflect forward and backward, inward and outward as is needed for a three-dimensional narrative approach. According to Campbell and Wasco (2000), one of the four defining features of feminist research is "recognizing and reflecting upon the emotionality of women's lives" (p. 783). The women inevitably did this throughout, but the third conversation or set of conversations in particular allowed them to reflect on the emotions and meanings they attributed to or associated with experiences.

After I established the general purpose of the conversation, the women mainly determined the direction that the discussion progressed. As mentioned, follow-up questions were asked as needed in order to elicit further detail about each experience that was shared. I also interjected my own experiences when appropriate. Clandinin and Connelly (2000) suggest that it can be productive for researchers to interject their own

stories and experiences in conversations. An example is when Nathalya was talking about the many places that she has traveled overseas, I said that I had only been to Egypt and Jordan. This led her to sharing that her research advisor's son was currently in Jordan and she had several friends who studied abroad in Jordan.

The conversations were audio recorded as I have found in other circumstances that taking notes detracts my attention from fully engaging in a conversation. Video recording was not used because it can cause more uneasiness, which is discussed further in the section on material concerns. In between meetings with the women, I listened to the audio recordings in order to obtain a holistic sense of the women's accounts and to determine potential topics and questions for subsequent conversations. Throughout the conversations, the women would periodically share photos with me that were saved on their phones or that they pulled up on Google. The photos were typically of places they were describing such as their church or high school. Nathalya also shared a diagram that she made as part of her work assisting a professor. Both Nathalya and Visha talked about pieces of writing that they had done that I casually asked them to share with me. In both cases I requested sharing the writing twice but did not ask again as they seemed unsure where they saved the documents and I did not want it to be an inconvenience.

Although some images were shared, I did not use multiple data sources for the purpose of "triangulation." As stated by Vagle (2014):

> I do not think that one needs to triangulate across [data] moments in order to say something meaningful. Sometimes a single statement, from one participant, at one moment in time is so powerful that it needs to be amplified. (p. 97)

Sources of information beyond the conversations were used when appropriate to add detail to the portrayal of the women's experiences, but the goal was not triangulation. The stories are valid as they are the women's re-membering of their experiences not because of methods like triangulation being used to "validate" their "truth" (Hendry, 2010, p. 75).

Material Agents

New material feminists argue that nonhuman material objects have agency. Intra-actions occur between everything, human and nonhuman, impacting the phenomenon being studied. Therefore, nonhuman agents need to be considered when designing a research study. As stated by Eaton (2018), "the politics and power dynamics of inquiry constantly demonstrate that even when we listen to the voice(s) of participants there are many other nonhuman resonances to which we should be attuned" (p. 94). Three nonhuman factors that I anticipated would impact my participants were my attire, the recording device used, and the physical space in which conversations took place.

Clothing is one way in which hierarchies can be reinforced. Parkins (2008) argues that fashion choices are "material and discursive phenomena" that should be paid attention by feminist scholars (p. 502). One way that I minimized any potential hierarchy between myself and the women with whom I spoke was through my attire. When meeting with the women, I dressed in a manner that is similar to what their peers may wear, thus not reaffirming my role as an instructor or as a researcher. Of course, my physical body, that of a white, female, who was about 15 years older than the students, also creates material conditions that impact the students in unknowable ways (Marn & Wolgemuth, 2016).

Since everything in the environment during the conversations intra-acted to form the phenomenon of that moment, the recording device used is also an important consideration. Nordstrom (2015) used interview data that she collected using a recording device to reflect on particular interruptions the device caused and how the human-nonhuman entanglements between recording devices and participants affects the findings of research. Nordstrom's article highlights the importance of having the recording device as unobtrusive as possible. For this reason, I chose to forgo video recording in favor of audio recording. Although, at times, I wished that I could look back at the body language of the women, a video recording device would have changed the dynamic of the conversations and would have eliminated our ability to meet in public places without calling attention to ourselves. I used my phone for audio recording. Phones are out on café tables most of the time that friends gather and therefore is a common material reality. As such, the intra-actions between my phone and the women with whom I spoke are likely to be less obtrusive than those with a less familiar recording device. Many times, the women's phones would be out on the table next to mine. I would periodically see their screens light up with a message or reminder, but they seemed so used to notifications that their eyes did not even drift to their device. They also seemed unphased by the presence of my phone.

Many researchers, who discuss interviews, write about the importance of location (Creswell, Research Design: Wualitative, Quantitative and Mixed Methods Approaches, 2014; Herzog, 2005; Maxwell, 2013; Seidman, 2013). Discussing social boundaries and hierarchies, Herzog (2005) stated, "the physical location in which the interview is conducted is one of the most concrete expressions of this process of boundary-crossing"

(pp. 27–28). My office is an extreme reminder of the women's place as a student and my place as faculty. Public and outdoor locations are spaces with little social context that reasserts power to either member of the conversations. In her research, Herzog (2005) found that many participants had difficulty selecting locations. I wanted to allow the women with whom I spoke to select a meeting location while decreasing any challenges with this selection process. Therefore, when scheduling the meetings, I asked the women to determine a comfortable and relatively quiet place for us to talk. I provided examples including a coffee shop, the library, or an outdoor seating area. I ended up meeting Mae and Visha in various coffee shops. Nathalya and I met outside, except for once when it was raining.

I also met once with Mae and once with Nathalya in a virtual environment. When completing their narratives, I had a few follow up questions and they already graduated and were living elsewhere. These two virtual conversations felt much more formal and less free-flowing than other conversations. Perhaps this was due to the nature of the follow-up questions or perhaps it was the agency of a virtual space not allowing us to *be* together in the same manor.

Field Texts

Immediately following each conversation, I recorded detailed field texts in order to capture my sense of the human and more-than-human intra-actions that occurred. In narrative inquiry, field texts are a way to record important details about the experiences of the participants and to reflect on the researcher's transforming thinking through the research experience. Clandinin and Connelly (2000) state, "field texts slide back and forth between records of the experience under study and records of oneself as a

researcher experiencing the experience" (p. 87). According to Clandinin and Connelly field texts are more of a journal than a formatted text. They slide from fact to feeling, from literature-based analysis to memory-based reflection, from self to other, and from prose to poetry. Field texts were used as a way to capture, negotiate, and make sense of the narrative experiences the women and I shared.

Composition of Narratives

In order to create the written narratives, I intra-acted with, reflected upon, and re-storied the experiences shared during the conversations with the women, as is represented in Figure 6 (also in Appendix D). Just as a researcher is entangled with a woman's experiences during conversations, a researcher is also entangled with the data during analysis. This intra-action is what determines the phenomenon of the stories produced. As stated by Taguchi (2012), "data is often treated as passive matter to be interpreted by an ontologically separate researcher in a self-reflexive way" (p. 269). She continues by highlighting how a diffractive method requires a researcher to become entangled with the data rather than reading it from a distance. One example of how multiple agents entangled to create the presented narratives is from Visha's narrative. By allowing myself and other texts with which I was engaging to intra-act, I made sense of Visha's fears of not pursuing medicine through Michelle Obama's (2018) description of her motivations for studying law.

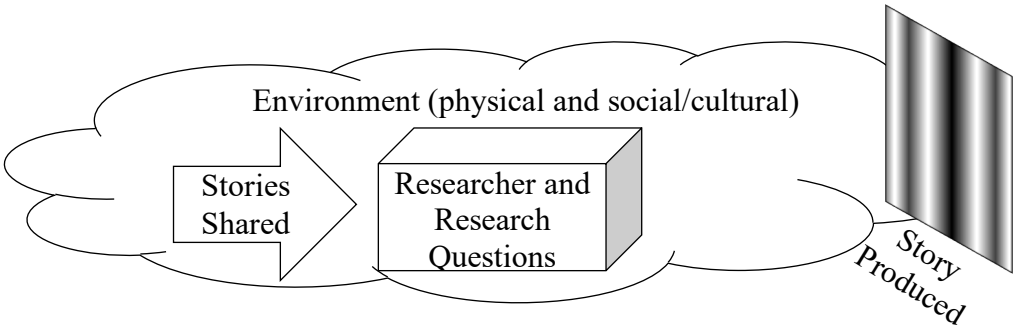

Figure 6. Phenomenon of stories produced about women's experiences in science. This image represents the phenomenon of the stories produced by the researcher about women's experiences in science when the recordings, transcripts, and notes about the women's stories intra-act with the researcher, the research questions, and with other aspects of the research environment.

I transcribed the conversations with a broad focus on the words spoken, not on capturing every utterance. However, overlapping speech and laughter was recorded. As part of the transcribing process, the recordings were listened to multiple times. I open up to experiencing literature more when I am listening to it than when I am reading it. Therefore, one of the reasons for listening to the audio recordings several times was to promote a more corporeal entanglement with the data. Also, I found that the act of typing silenced what Hendry (2018) calls dual conversation. She said, "Listening to stories we are often engaged in a dual conversation. One conversation with the interviewed and one in our own head where we are constantly engaging in a meta-analysis of a story" (p. 58). Similar to how the physical act of driving or showering allows some people to form their best thoughts, I found that the physical act of transcribing allowed me to really listen, with suspended analysis, to what the women were saying.

Hendry (2018) goes on to describe needing faith, as researchers, that through the stories that participants share, meaning will be made if the researcher just listens. Suspending all formal methods of coding or analysis, I transcribed and listened to the

conversations. After an interval of time the conversation would switch from one topic or one memory to another. In these moments, the story shared in that segment would coalesce and I would write. The act of listening shaped the story and the transcription provided the details.

Three Dimensions

Once the initial draft was written, the transcripts were reexamined for the three-dimensional space of narrative inquiry and for resonance and dissonance between the women's epistemologies and the culture of science they experienced. As previously described, the narratives were written in story segments. Each story segment's corresponding transcript was analyzed for the temporal (past, present, and future), interactional (personal and social), and contextual (place) dimensions. As described by Clandinin and Connelly (2000), "following the notion of the three-dimensional narrative inquiry space, the writer tries to compose a text that at once looks backward and forward, looks inward and outward, and situates the experiences within place" (pp. 139–140). The three-dimensions were used to help create coherence for an outside audience and were used to identify further questions for the women. This practice often highlighted that I needed further information about when an even took place, how an experience made the women feel, or how a moment related to other moments shared.

Resonance and Dissonance

According to Gannon (2016), when Barad's theory is used in research, it is imperative that analysis focuses on entanglements and intra-actions. This focus can be accomplished by looking at and trying to make sense of the diffraction patterns produced. Therefore, transcriptions were analyzed for moments of resonance and dissonance

between the identities of the women and the experiences they had in science, and the narratives mapped the *effects* of those differences (Barad, 2007, p. 72). In that way the entanglements between the women and science were explored.

The resonance and dissonance emerged in several ways. Sometimes the women would expressly say that they felt comfortable or uncomfortable in different environments or that they liked or disliked certain scientific practices. For example, all of the women talked about how different college labs were conducted and what they did and did not like about them. Also, various linguistic indicators may point to moments of dissonance in the women's recollections. For example, Susan Scott (2002) indicated that there are several linguistic indicators that are used in moments of disagreement. These include using absolute terms such as "all" and "every"; using negotiating terms such as "no," "but," and "well"; and using emphatic terms such as "a lot," "most," and "really." An example of when a linguistic indicator inspired me to ask a follow up questions is when Nathalya said that she liked her high school chemistry class. The statement went up in pitch at the end, like a question would. Through further conversation it was revealed that there were cultural tensions in the class that did not allow her to feel comfortable as a student.

I analyzed the audio recordings and transcripts for moments of resonance and dissonance and made sure to include those moments in the narratives. I figuratively painted a representation of the diffraction patterns produced from the intra-actions between women and science.

Epistemologies

One specific area in which there were areas of resonance and dissonance was in the epistemologies of the women and the culture of science that they experienced. As previously described women have, to a large degree, been enculturated to think certain ways. Science, on the other hand, has been historically positioned in a particular light that is often opposite the ways in which women are perceived. Exploring the diffraction pattern between women and science can shed light on why some women choose not to pursue science as a career. I looked for instances of the women discussing what scientific knowledge is and how we get that knowledge and how science was talked about and operationalized by others in their accounts.

Based on the work of those studying practical epistemologies, I looked for examples of when the women did or did not seem to believe that scientific knowledge is constructed, scientific methods are diverse, there are different forms of scientific knowledge, and scientific knowledge varies in certainty (Sandoval, 2005). One area that was discussed by all three women was the belief or disbelief that scientific knowledge varies in certainty. This is explored in Chapter 7. Based on the work of those proposing feminist epistemologies of science, I looked for examples of when the women emphasized embodiment, affect, and community (Anderson E. , 2015). Relationships and engagement with material agents emerged as particularly important to all three women. This is also explored in Chapter 7. Epistemic moments are discussed along with the usefulness of the moment to the women. Although the epistemologies of the women and those of the people they shared about were not analyzed using the methods typical to that area of inquiry, epistemological moments are evident in the narratives produced.

Nonhuman Agency

In order to better understand the entangled and intra-active nature of all things, one of the primary emphases for new material feminists is exploring the agency of nonhuman entities. While discussing the importance of researchers paying attention to the material, Scantlebury, Danielsson, Hussenius, Gullberg, and Andersson (2019) state:

> Researchers rarely describe the space and matter involved with the interview. Were the interviews conducted in comfortable chairs, with an informal setting, or with chairs situated across from each other with other material objects also as part of the process? Was there an audio recorder? Paper with a list of questions which provided an interview protocol? Or did the interviewer use other devices such as an iPad or a computer? How different is the data collected and knowledge produced if interviews are conducted using video recorders? What entanglements occur with these instruments/ apparatuses? (Scantlebury, Danielsson, Hussenius, Gullberg, & Andersson, Communicating Through Silence: Examining the Unspoken, the Unsaid, and the "not Done" in Science Education, 2019, p. 240)

Without making explicit the material entanglements occurring during the interview process, those intra-actions cannot be explored. Many of these questions I thought through and previously described in the section dedicated to describing the conversations. Otherwise, I described material agents that acted on the women and me during our conversations as part of the narratives and that acted on the women within the stories that they shared.

Rosiek and Snyder (2018) point out that new material feminists were not the first scholars to focus on the idea of nonhuman agency. They state, "Indigenous studies' scholars have taken nonhuman agency as a given in their social and philosophical

analysis and, thus, have more experience working out its practical and performative implications" (p. 3). They continue by outlining three aspects of indigenous scholarship regarding nonhuman agency that are relevant to narrative inquires: what kinds of agents are considered, what characteristics of the agents are considered, and what the ethical reciprocity is between the inquirer and the nonhuman agent. When considering the representation of nonhuman agents, the characteristics of those agents are particularly salient. Rosiek and Snyder point out that indigenous cultures, such as Native Americans often personify nonhuman entities in their literature. Animals, plants, and abiotic entities are believed to have a spirit - personalities and souls. They wrote, "it [spirit] is a tendency to act in a directed, though not mechanical, manner with other agents with a particular style" (p. 4). In other words, everything has agency.

Personification is not quite the correct word to convey the agency that is attributed to nonhuman things. In *Breading Sweetgrass* Kimmerer (2013) explains that in her ancestral language of Potawatomi, words that are nouns in English, are verbs (pp. 53–58). For example, wiikwegamaa is translated as, "to be a bay" rather than "bay." This way of speaking mirrors the indigenous respect for the life of a bay, the way it smells and moves and sounds. Trees, nuts, rocks, water, fire, and stories are all seen as animate beings and thus are verbs. Kimmerer points out that the English language does not allow for the description of things as animate without personifying them. She stated, "In English, you are either a human or a thing" (p. 56). She later continues, "the arrogance of English is that the only way to be animate, to be worthy of respect and moral concern, is to be a human" (p. 57). In the narratives, I did not strive to attribute human

characteristics to nonhuman entities. I strove to be attentive to nonhuman entities as agential beings. Rather than attending to personification, I attended to being-ification.

One way to communicate the agency of nonhuman entities, is to write in a manner that makes clear that objects are acting on humans, not only that humans are acting on objects. This way of writing is not common in Western culture and did not feel natural to me. Often it involved needing to intentionally get into a particular way of thinking and then rewriting sections of narrative. An example is a sentence from Mae's narrative. It was first written as: "We tucked ourselves into one of the many private nooks against a large plate glass window facing a busy city street and made ourselves comfortable on the upholstered chairs." Considering the agency of the many entities in this moment yielded a subtle but significant rewriting. It now reads: "One of many private nooks provided us some privacy while large plate glass windows allowed us to watch people walking by and cars speeding by on a busy city street. The upholstered chairs encouraged us to sit back and get comfortable." Rather than us acting on the nook, the window, and the chairs, they were exercising agency on us; they were acting on us as much and sometime more than we were acting on them.

Another example is from Nathalya's narrative. The sentence was first written as: "She loved the freedom to explore Boston during her free time, she loved that staying on campus gave her a feel for what college might be like, she loved hearing the talks about medicine, but most of all she love the structured debates that were part of the program." Once the agency of all of the aspects included in the sentence were consider, the sentence was rewritten as: "She loved the call of city waiting to be explored during her free time, she loved the dorms which made her feel like she was getting a taste of college life, she

loved the talks about medicine that captured her attention, but most of all she loved the structured debates that were part of the program." Each entity in this experience acted on her in a meaningful way.

Agential Cuts

Throughout the composition of the narratives agential cuts were made when deciding what was and what was not included in the final text (Barad, 2007). Overall, I made sure to include every major discussion topic in the final narratives. As described, the women's conversations would typically progress in storied chunks. Attention was given to including each story in the narratives. Inevitably, based on my own experiences and interests there were details that were unknowingly highlighted and other that were unknowingly excluded. However, by focusing on the main idea or purpose for each section of story shared by the women, I was able to ensure that the purpose of each story shared was conveyed. As described by The Personal Narratives Group (1989), the researcher should pay particular attention to the purpose of each story shared.

By paying particular attention to the purpose of what was shared, I ensured that what was important to the women was included in the narratives. However, as mentioned, details that were important to the women may not have seemed important to me. For this reason, it was particularly vital that the women felt the narratives depicted what they shared. This is discussed further in the section titled "member checking".

Once the narratives were written, the transcripts were reread line by line. Every line that was represented in the narratives was marked as such and every section that was not included was labeled based on the topic of that section. There was one theme in the transcripts that was not included in the narratives, some details about family members.

Both Mae and Nathalya shared a great deal about their parents. Nathalya also shared about her grandparents and other extended family. Often these stories made clear how their family members' experiences shaped the women's experiences. These instances were included in the narratives. Other times the stories of family members were not clearly connected to the experiences of the women. These stories and details were often left out of the narratives.

Order and Sectioning

Often narratives and stories written in Western culture are presented linearly, moving through time sequentially. Reflecting on agential realism in relationship to narratives, Rosiek and Snyder (2018) challenge this way of writing:

> If time, however is not understood as linear, but instead as the contingent product of spatial and material relations, then offering chronological narratives can become self-deceived naturalizations of unified linear temporality. Stories can, in other words, become ways to convince ourselves that things are simpler than they are. (p. 3)

In other words, since the women's lives are entangled and continually evolving stories, they need to be represented as such. To present a story as a continual, linear sequence gives the impression of causation: "since A happened, then B" and "since B, then C." To write narratives in this way would give the false sense of life unfolding due to time rather than due to entanglements that occur through space and time.

As someone raised in Western culture and being trained to write for a Western audience, particularly a scientific audience, the notion of thinking outside linearity was challenging. I also struggled with an idea presented by Rosiek and Snyder, that a story

should have "an identifiable *being in future*—a purpose—that organizes its movement and activity" (p. 6). They state that this structure gives the text purpose within the academy. I struggled with this idea because it seemed to prioritize my agency as a scholar over the agency of the women telling their stories. My research questions guided the conversations that we had. Beyond that, I wanted the women's own patterns of narration to guide the narratives produced. Often the women told their stories in semi-linear ways, but each woman had her own style of narration and sequencing method. Therefore, rather than determining sections based on my interpretations of the stories and rather than attempting to purposefully sequence events through time, I focused on being attentive to the experiences the women shared and the connections through time that they made. The sequences the women told their stories in were used to guide the sequence I used to share the narratives.

The headings within the narratives were also based on how the women approached the telling of their experiences. Visha organized her story around moments of insight. She would often start and end recollections with overarching statements regarding their significance. The sections of her narrative are titled with these statements. Mae tended to focus on one time period in her life at once. She talked about one class before moving on to reflect on another. The sections in her narrative are titled with things like "High School" and "Physical Chemistry." Nathalya's recollections were less chunked, moving from one moment to the next. Her story was filled with action. The sections in her narrative are titled with what we see her doing in that section, such as "Making Herself Dinner" and "Buying a Book by its Cover."

As previously described, in order to prioritize the stories shared by women and the meaning they attribute to those stories I listened to and read the transcript of one story segment or chunk of discussion that seemed to center around an event or theme. I would write about that chunk with attention given to all the connections the women made throughout time and space. The resulting text read as, what one of my writing group members called "puzzle pieces." She said that each piece of text adds to the other pieces in a way that is non-linear and never fully complete.

Aesthetics

While remaining true to all of the above aspects, I also kept the aesthetics of the composition in mind. As stated by Clandinin and Connelly (2000), "In writing narrative research texts, we must be mindful of balancing the tensions of writing within the three-dimensional narrative inquiry space, of writing in ways that narratively capture the field experiences, and of balancing these with audience" (p. 154). The audience is an important aspect of the research that cannot be ignored. Reading narrative inquiry should evoke a story within the readers, in this case individuals who are interested in the puzzle of the underrepresentation of women in science. The intra-action between the text and the reader is a meaning-making process and part of the research. This is represented in Figure 7 (also found in Appendix D). Based on agential realism, the ideas represented in a text are living and breathing. They should be reborn with each intra-action with a reader. The reader's life experiences and other influences should entangle with the narratives to create moments of wisdom for the reader. Therefore, the narratives were written in a way that will engage readers and will evoke new and continually evolving insights.

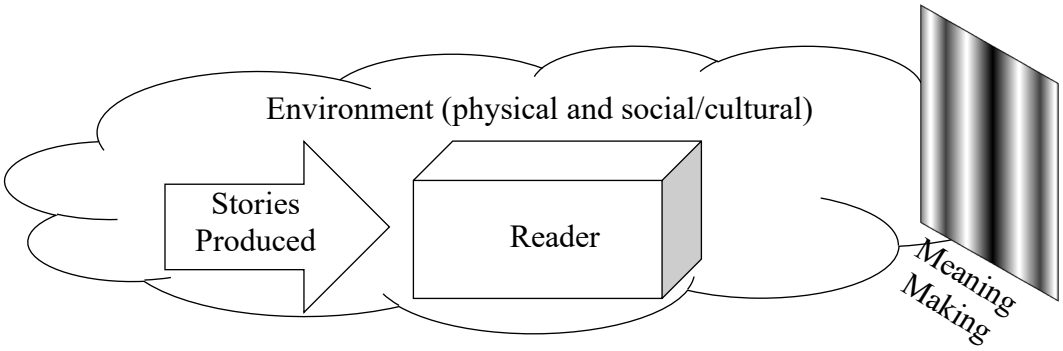

Figure 7. Phenomenon of meaning made by a reader. This image represents the phenomenon of the meaning made by a reader when the stories produced intra-act with the reader and with other aspects of the reader's life.

In order to focus on the aesthetics of the writing I used several strategies. I reread some of my favorite fiction and nonfiction books in order to analyze aspects of engaging writing and to get into the headspace of an engaging writer. I used "snapshot" writing, or writing that provides a great deal of detail about one moment in time, in order to create a picture in the reader's mind (Lane, 1993). My most important tool for focusing on the aesthetics of the narratives was my writing group. I wrote with three other women, two of whom have advanced degrees in language arts and all of whom are wonderful writers. Their feedback helped guide my writing in many ways. One of the most important things that they did was to ask questions of the narrative, pointing me to areas where more detail was needed and was of interest to a reader (Lane, 1993).

Ethical Considerations

The research followed all considerations outlined in the Internal Review Board application which was accepted on February 27, 2018. All data was kept on a password-protected computer that can only be accessed by me. I also did all transcribing myself and therefore was the only person who listened to audio recordings of conversations. All physical papers created during conversations and analysis were scanned and the physical copies were destroyed.

During the pilot study that I conducted during the spring of 2016, one of my surprising findings was how uncomfortable I was with selecting a pseudonym for the women. Names are meaningful to people. They hold importance within families and within cultures. Multiple studies show that people attribute characteristics to others based purely on their name (Lahman et al., 2015). It felt presumptuous to assume that I could select a name that has similar connotations to participants and readers. It also felt presumptuous to assume the women would want to be referred to by a pseudonym. Stemming from critical race feminism, Lahman et al. made the point that some people who have been Othered want their identities to be associated with their stories because it provides them with honor. Therefore, at an initial meeting the women were asked if they would like to use a pseudonym or their own first name in any published materials. If they chose to use a pseudonym, they were asked to select what pseudonym they would like to use. All written records used the women's selected pseudonym. If a woman initially chose not to use a pseudonym, I confirmed that she still wished to use her own first name after she read the narrative produced. The women were also asked to choose pseudonyms for all other individuals named in their narratives.

Despite my belief, as described, that my pre-existing relationship with the women with whom I spoke is beneficial to the research, it does create an ethical concern. They are or have been students in my classes, which creates an innately hierarchical relationship. In addition, the researcher–research participant relationship is innately hierarchical despite all attempts to make it otherwise. For these reasons, the women may have felt obliged to speak with me and to reveal more than they would in general conversation. Therefore, the women had all potential risks described at least twice: at the

beginning and end of their participation in the study. I also clearly and repeatedly told them that they could choose not to answer any questions that they prefer not to answer and that they could stop their participation in the study at any time. The ability to discontinue participation was available up to and including the point where they read the written narratives.

Trustworthiness

According to Clandinin and Connelly (2000) the most important component of a trustworthy narrative inquiry is "wakefulness" or an ongoing reflection. Researchers need to be wakeful during interviews, analysis, and writing. Beyond wakefulness, several other considerations for trustworthiness are addressed in the following sections.

Subjectivity Revisited

As mentioned, I maintained an obvious insertion of myself in the narratives created. This is not to remove any focus from lives of the women, but rather to make clear that the stories are produced through intra-actions between the women with whom I spoke and me. As articulated by Cotterill and Letherby (1993):

> Their lives are filtered through us [the researcher] and the filtered stories of our lives are present (whether we admit it or not) in our written accounts. Surely it is better to acknowledge them and explore it analytically. (p. 74)

I acknowledged and explored my presence in the research, making clear that the narratives are told through me as the instrument. I made clear my perceptions by, for example, sharing what I observed in the environment in which the conversations took place. I also made clear my thought processes, using the field texts as guides.

Since I am an intra-active, agential aspect to the research, the narrative produced would be different if a different researcher did the same study. As stated by Clandinin

and Rosiek (2012), "Narrative inquirers work with an attitude of knowing that other possibilities, interpretations, and ways of explaining things are possible" (p. 46). They continue by arguing that the existence of other possibilities is not a deficit of narrative inquiry, but is more authentic to the reality of human experience.

One text that I used as a model of how to capture myself as part of the emerging narrative, is *The Immortal Life of Henrietta Lacks* by Rebecca Skloot (2011). In this text the reader is walked through the intellectual journey of Skloot and is constantly reminded that the presentation of information is through the author's eyes. For example, rather than opening the book with a description of Henrietta Lacks as if the description captured a singular, stagnant, and unbiased description, Skloot starts the book in a way that makes it clear that she, as the author, is giving her perception:

> There's a photo on my wall of a woman I've never met, its left corner torn and patched together with tape. She looks straight into the camera and smiles, hands on hips, dress suit neatly pressed, lips painted deep red. It's the late 1940s and she hasn't yet reached the age of thirty. Her light brown skin is smooth, her eyes still young and playful, oblivious to the tumor growing inside her. (p. 1)

Skloot did not say, "my subjective interpretation of Lacks is . . .," but it is clear to the reader that the description is Skloot's interpretation. The weaving of the author's story with the subject's story creates a very different text than a third person account would have created. It creates a much less omniscient sounding text that is truer to the reality of experience. Utilizing this method of writing helped me to avoid the pitfalls of absolutism and to create narratives that are more authentic representations of the co-creation process.

Writing Group

Following the writing of draft narratives, they were read by my writing group of three other women. Each member has a different set of skills and different life experience; therefore, they each provided different feedback. The members of the writing group were asked to read the narratives and reflect on them based on the list of elements for consideration that can be found in Appendix C.

The writing group functioned similarly to response communities which are recommended by Clandinin and Connelly (2000):

> As narrative inquirers, we share our writing on a work-in-progress basis with response communities. By this, we mean that we ask others to read our work and respond in ways that help us see other meanings that might lead to further retelling. (p. 60)

Revisions were made to the narratives based on insights from the writing group.

Member Checking

Following multiple rounds of revisions, the narratives were sent to the women who shared their stories for member checking (Guba & Lincoln, 1981). The women were asked if they felt the narratives were an authentic portrayal of them and if there was anything they would not like to be included. Clandinin and Connelly (2000) describe why this broad type of questioning is more suited to narrative inquiry than more specific questions:

> When narrative inquirers return to participants with text, their question is not so much, Have I got it right? Is this what you said? Is this what you do? Rather, it is something much more global and human: Is this you? Do you see yourself here? Is this the character you want to be when others read this? These are more

> questions of identity than they are questions of whether or not one has correctly reported what a participant has said or done. (p. 148)

The question is whether the narrative produced tells their story, not if every minute detail was fully and accurately captured.

In addition to allowing the women to have final say over how they are represented, Clandinin, Pusher, and Murray Orr (2007) argue that keeping participants in mind while writing keeps researchers ethical in their representations. By writing for yourself, your audience, and your participants an author is more likely to avoid narcissism, being unethical in representations, and writing without a clear a purpose. Since I was writing as much for the women telling the stories as I was for anyone else, I always kept them in mind and was always working toward creating texts that they would feel represent them and their experiences ethically.

According to Patti Lather, a prominent feminist scholar, member checking is an important component to any ideological or emancipatory research, particularly feminist research (Lather, Issues of Validity in Openly Ideological Research: Between a Rock and a Soft Place, 1986; Lather, Research as Praxis, 1986; Lather, 1988). Lather warns that indoctrination into homogony can lead to false consciousness. Therefore, analysis cannot rely solely on participants' perceptions to determine validity (Lather, Research as Praxis, 1986). Theory needs to be taken into consideration alongside participant's perceptions. On the other hand, Lather warns against presenting participants with findings that are too full of theory and "alienating jargon" as participants will not know what the findings are "getting at" (Lather, Issues of Validity in Openly Ideological Research: Between a Rock and a Soft Place, 1986). The narrative inquiry approach is perfectly situated between

these two issues, allowing participants to determine if they see themselves in the text without having to slog through heavy theory and jargon.

The women with whom I spoke were asked to share with me their thoughts on the narratives. All three women had different responses to their narratives. Visha only said that she felt weird that someone wrote so much about her. Mae, who often described our conversations as therapeutic, chose not to read the final narrative. Nathalya thanked me for writing about her saying, "I laughed, thought, reflected, and even cried." She pointed out several moments where she felt like I wrote as if I had been at that place with her because the physical description was so accurate and other times that it was like I was in her head because I so accurately described what she thought and how she felt.

Overall, one participant asked for one small change to be made because she felt that it was too revealing of a family member's life. Otherwise, no further edits were made following the member checking. The women had the last say on the document.

Stories as Agents

The purpose of narrative inquiry is not to be used to dictate specific solutions to problems. As described by Clandinin and Connelly (2000), "the narrative inquirer does not prescribe general applications and uses but rather creates texts that, when well done, offer readers a place to imagine their own uses and applications" (p. 42). Rosiek and Snyder (2018) echo this sentiment when writing about agential realism and narrative inquiry. They state, "an agential realist narrative research practice would have to relinquish some part of a hierarchical claim to authority that the project of revealing hidden realities implies" (p. 7). The usefulness of the narratives produced is not in their ability to show previously unknown "truths." Rather, the usefulness is when the

narratives intra-act with readers. A reader will feel particular resonances and dissonances with his or her own experiences. A reader will make sense of the narratives in a way that is particular to his or her context. The readers of the narratives presented in this research will be able to transfer what they read to the unique contexts that they experience in productive ways.

Narratives speak to and act upon people in a way that is different than that of other forms of research. Stories have agency. They have a life beyond the publication date. Rosiek and Snyder (2018) explain that the real goal of narrative inquiry should be for the stories to ethically exercise their own agency. As they state, "narratives are often thought to get into our heads, change the way we think and feel, whether we want them to or not" (p. 9). Narratives awaken people to the intricacies of situations and allow people to see situations in new and insightful ways. Barone (2007), while talking about arts-based research, of which narrative is one example, stated, "They [texts] may transgress against the reader's comfortable, previously unquestioned ways of viewing and acting within the world" (p. 25). Narratives have the potential to break down assumptions and allow new questions to emerge for readers.

I am asking that you, as a reader, allow yourself to intra-act with the narratives presented. I ask that you allow the narratives to exert their agency on you by allowing them to act on and awaken you. I also ask that you exert your agency by purposely allowing your life experiences and the literature with which you have previously engaged to inform your reading of the narratives. Through this intra-action, just be with the text. As stated by Rosiek and Snyder (2018), individuals who read in a manner that does not silence the agency of text should "not just dissect the content of the stories but also…

[be] good companions to the stories" (Rosiek & Snyder, 2018, p. 5). Be with the story, acting on it and allowing it to act on you.

In order to provide structures to support and a visual reminder to intra-action with the text I borrowed a practice for traditional Arabic texts. One of the members of my reading group is an Arabic Language Specialist. When we were speaking, she introduced me to the idea that before the printing press, Arabic scribes would use only three quarters of a page. Ellabbad (2006) stated, "they left this blank space for the readers, giving them the entire length of the page so they could make notes as wished: comments or criticism, explanations, ideas that came to them as they were reading the text" (p. 26). He continued by pointing out that the many future published texts came from or started from what was written in the margin of a different text. The blank space on the page encouraged intra-action between the reader and the text and facilitated the unfolding of new insights. I have, likewise, provided a large margin for you to note your intra-actions and new insights as you read.

Narratives can speak to and awaken a variety of stakeholders about a topic that they might otherwise have been blind to or uninterested in. In a 2016 interview, Clandinin discussed the impact narrative can have. She described the universality of the texts and indicated that a narrative text can be "picked up" by multiple interested parties including parents, school district employees, policy makers, and more. The narrative presented can awaken multiple people to the complex issue of underrepresentation of women in science and the narratives can intra-act with people in a variety of contexts to create new, unique, and fruitful moments of wisdom.

Summary

This research addresses the puzzle of the underrepresentation of women by presenting narratives that were co-created with women who were getting a degree in science and were planning to teach rather than becoming a research scientist. The research used the theory of agential realism in combination with narrative inquiry to explore the ways in which the women's epistemologies and the culture of science that they have experienced have resonance and dissonance with each other. The research also considered feminist concerns, such as researcher/participant relationships, and material agency. The narratives will intra-act with readers, awakening new wisdom that is useful in their particular work.

Chapter 4: Visha

"I think a lot of science for me was engaging with the natural world around me."

For the first seven years of Visha's life nature surrounded her. Her home sat at the top of a hill. At the bottom of the hill a lake glistened with sunlight and bustled with wiggling sunnies just under the surface. The mountains that grew out of the earth behind her "farmhouse preschool" waited patiently for the next adventure. The miles and miles of endless forests played hide and seek with bugs, birds, and other animals. Visha engaged with all the wildlife Vermont had to offer.

Inspired by Visha's love of the animals that made their home in the trees of the forest, her grandpa, who she referred to by the Tamil term "Thatha," gave her bird books. She loved to watch the birds as they showed off outside and look them up in her books, memorizing their common names and scientific names. She had a knack for remembering that sort of information. After watching the movie "The Land Before Time" she also learned the name of every type of dinosaur possible.

Visha's recollections of her Vermont home were a montage of childhood memories, more recent memories of vacations in the home, and memories of how she described the home in a seventh-grade essay that earned high marks from a strict teacher. Wandering out into the huge, sloped yard between her house and the lake, Visha would mostly ignore the swing set in order to dig up worms at the set's base, displacing them from their everyday life into mud houses that she and her sister, Sasha, built. Although Sasha, who was 18 months younger, was not a fan of bugs she did not mind getting dirty. Under the distant but watchful eyes of her grandparents, Thatha and Gama, Visha would collect insects. Gama, a jean shirt protecting her saree, would garden; Thatha would

stand with his hand behind his back, humming a hymn and watching the world go by; and Visha would periodically bring them bugs to share what she found. At certain times of the year caterpillars would cover the bark of trees. Visha would carefully move them from the trunk of the tree to her arm, encouraging them to crawl and race. Some days Visha and her family would wade through the thick foliage that created a barrier between the yard and the lake to visit their little dock and the welcoming, cool embrace of the water. Once there they would feed the fish, go fishing, swim, or kayak.

Noticing her interest in bugs, Visha's grandpa and grandma bought her a plastic insect kit with 3D examples of insects from around the world. Her maternal grandparents and maternal great-grandma would spend half of their time in their home three hours away in Canada and half of their time in Visha's home in Vermont, watching the girls while their parents were working. Gama was light skinned and very short. Thatha was dark skinned and very tall. Regardless of their physical stature, both of them had a huge influence in Visha's life. Visha and Sasha did not play with many toys. Mostly they chose to play outside, but one of the toys Visha does remember that enticed her to play was her set of plastic insects. Visha would look up the insects' names, of course, scientific and common names.

Often Visha's 90-some-year-old great grandma would call the girls to come and visit with her in her room. Sasha would run and hide but Visha would eagerly go. Visha called her Bigga, short for "big grandma." Sometimes Visha would take a plastic bug from her kit and it would spark a memory. Bigga would pick up the bug in her wrinkled hands and prop herself up against her pillow at the head of her bed in her tiny but comfortable room. Visha would sit at her feet. I can picture Visha as a little girl with

rapt attention as her great-grandma verbally painted a vivid picture of the bright colors of the India of her youth. With voice crackling and raspy, the beloved elder would tell thrilling stories of snakes and scorpions. As she talked her hands, which normally had a small tremor, would start moving in bigger and bigger gestures and her eyes would bug out, the whites starkly contrasting her dark skin. She would tell of a scorpion maliciously crawling on the wall toward the sleeping infant that was Visha's mother and the whole family, particularly Visha's grandma - the infant's mother, being frantic over what to do. The stories made Visha think, "Wow! These things are way cooler than I thought, and they're only plastic." The plastic insects come alive to Visha through the stories.

The times that Visha visited India made these stories even more realistic. Her family saw a lot of cockroaches, which Visha found gross, and lizards, which she found cool. One lizard would crawl in and out of her uncle's piano, playing peek-a-boo, something that Visha never thought would happen in the states. She told herself, "This is a different place with different creatures." She realized it was not unlikely for a scorpion to crawl on the wall of an infant's room.

At her preschool in Vermont, Visha and her friends would go on great voyages into the mountains, finding all sorts of insects and snakes. Miles of uninhabited wilderness dwarfed the small yellow building with a small sandbox. Venturing into the wilderness, the students often saw one species of harmless snake that was adorned with bright green. All of the other children would be afraid to touch the slithering forms but Visha would pick them up, gently placing them in a bucket for closer observation once the class descended from the mountains. She said, "[I] Just really engaged with what was around me and what was around me was a lot of insects and animals." When stuck inside

the preschool, Visha would try to sneak off to find the two cats that lived there. Knowing that she was allergic, she would wrap one of the cats in a thick blanket and hold it like a baby, telling herself, "I'm not that allergic. I just can't kiss it too much." Visha would come home from preschool with a craft for her parents to add to their collection, covered in dirt from the fun she had with the snakes and head back outside her own home to find some hiding worms and caterpillars.

Visha was telling me about her love of nature and animals while we sat outside a café in downtown Washington DC. It was one of the first days in October that actually felt crisp enough to believe that fall was on its way. The recording captured the sound of the wind and of birds more frequently and with greater clarity than the never-ending city traffic. An umbrella over our table provided us a continually moving shade with harsh lines that starkly contrasted the dappled sunlight that I imagine illuminated Visha's youth. Small flower boxes provided spots of pink against the backdrop of roads and buildings.

Of all of the women that I spoke to in order to hear about their experiences in science, I knew Visha best. We have spent countless hours talking about her love of people and her love of God. However, I had never before heard about the love for animals that permeated her youth. She said that through her early exposure to nature, she "grew a deep love for animals, which continued through my entire life really." This love was the reason why Visha decided to be vegetarian throughout her entire college experience and plans to continue being vegetarian.

Two of Visha's favorite movies growing up were "Free Willy" and "Flipper," movies about dolphins and the friendships that they formed with people. I can picture her

and her sister on the couch being cuddled by a big, warm blanket. While a thick layer of snow covered the natural world that she loved so much, the TV allowed her to enter into another world under the sea. She was fascinated by the idea of being so close to animals and having a real relationship with them. "They weren't just these things in the ocean that were far away, but you were up close and getting to know them." Wanting to form partnerships with animals like dolphins, Visha decided that she wanted to be an animal trainer or zookeeper.

In fourth grade a book opened Visha up to seeing the movie "Free Willy" in a new way. She often read a series of books that told about adventures a group of kids went on that involved animals. One day she went into the school library to see what new book appeared on the shelves and there was a book in this series that had dolphins on the cover. "Wow! So Exciting!" She could not wait to read the book. Although the book was interesting it was not what Visha expected. It showed animal training in a way that Visha had not thought about and changed the way she thought about it. She recalled thinking, "I don't want to hurt them. I don't want to keep them in captivity." Just like that, her goals for the future shifted. She said to herself, "I don't want to train animals. I want them free in the wild."

From an early age Visha was also interested in medicine. When she was in first grade her parents got her a doctor's kit. The kit allowed her to frequently give her sister full examinations. Sasha was a year younger and was her best friend from as early as she can remember and remained her best friend throughout the times that we spoke. Visha would have her sister lie on one of their beds, which transformed into an examination table, with her knees hanging over the edge. Visha would then give her patient a full

workup: tapping her knees with a little hammer, looking in her ears, and looking into her eyes. Visha would be sure to use every instrument in the kit and to say "doctor-like things." She said to me, "I remember wanting to really play the part of a doctor." Despite her attempt at professionalism, fits of giggles would often take over both her and her sister. Her early interest in medicine faded throughout elementary and middle school but resurfaced later in high school as she developed a fondness for science.

I found it interesting that, to Visha, her love of animals and love for medicine never converged in an interest in becoming a veterinarian. When I asked her about this, she shrugged it off as if it was never a consideration. She explained that despite loving animals, she has allergies to many of them including cats and birds.

At seven years old, and about a year after Visha's great grandma passed away, Visha moved from the open country in Vermont to a cul-de-sac in the suburbs of New Jersey. Visha and Sasha piled into a car with her grandparents while her father drove a truck. The car made it to the house a long time before the truck, so the four riders transitioned from the car to a bed with nothing but blankets. A big, empty, cold, unfamiliar house surrounded the bed making the girls feel lonely, but Thatha and Gama talked to the girls till they calmed down and finally went to sleep. The next day, and the day after that, and the day after that the shower provided Visha with a private space to cry since she was too proud to let her family know how upset she was. She would also use drawings as a conduit for her emotions, creating images of, "the Vermont house, of my friends that I left behind, the lake, snakes, all these things that I was leaving behind."

Gradually the business and joys of suburban life eased Visha's discontent. Visha's dad surprised the girls with bikes, a perfect gift for their new surroundings. Also,

after years of begging, the girls' got their perfect gift for suburban life. One day when they came home from school, they were greeted by their father carrying a video camera, which was capturing every moment. They asked "what's going on," before seeing a black fur ball of a puppy run from the shelter of one couch to the shelter of another. They had always had fish and continued to, but that dog started a trend for getting more and more pets. After getting the dog, a rabbit joined their family, then one parakeet, then more parakeets for a total of four. Luckily the parakeets did not trigger Visha's allergies because they stayed in their cages all of the time. Visha described their collection of animals as "like a zoo." The outdoor Vermont animals that she used to love being around were replaced with indoor New Jersey pets.

Despite not wanting to become a dolphin trainer, Visha retained a love for the ocean and she showed this love in her new bedroom. Her room was covered in dolphins and whales, both of which "compelled" her because they were so "large" and "majestic." The room was painted blue with a dolphin boarder. She had a dolphin lamp and a shelf of life-like marine-themed stuffed animals. A new marine animal friend showed every year for Christmas. Each friend had a button that would tell Visha about the animal when pressed. Her room stayed an underwater wonderland until high school.

Even though her love of nature was being displayed in her room, Visha's outdoor life became more typical to her suburban surroundings. The outdoors still called to the girls more than inside toys did, but time surrounded by towering trees was replaced with time surrounded by sidewalks and manicured lawns. After school they would ride bikes, play soccer, or play hopscotch with other neighborhood children rather than digging for

worms. When Visha saw a bug, she was more inclined to think, "I don't really want this in my space" than she was to look the bug up in a book.

"Writing was what took over that time."

In elementary school, literature filled Visha's mind and heart, flowing out of her pencil and mouth in the form of poetry and journal entries. She liked to read but she loved to write. Visha thinks that one of the reasons that she loved writing so much was the support that she had from her teachers. She said, "I do remember having teachers that really encouraged me." Her third-grade teacher taught her students how to write essays and held them to really high expectations, making sure the students knew they could meet those high expectations. Her fourth-grade teacher had them do many "creative projects" including creative writing.

Visha's favorite type of writing became poetry. She would share some of her poetry with her school's librarian who told her that she should make it a goal to publish a book of her work by eighth grade. Recalling this support with a tone of fondness and pride, she asked me, "who tells a fourth grader that they're going to be published in eighth grade?"

Visha wrote poems for every occasion. Her work became gifts for birthdays, Christmas, and any other occasion that came up. This practice yielded many accolades, particularly from her grandma who would say, "wow! This is really good. You should write more." Just like the encouragement from her teachers, Visha felt this encouragement was a large motivator for why she enjoyed writing. She told me that she sees herself as "pretty self-deprecating," explaining that even when she was good at something, she often didn't see it in herself until others point it out. After receiving

outside recognition, she still finds it difficult to acknowledge her own talents and strengths.

In addition to writing for gifts, Visha also wrote poems for her book. The idea for her book was to write a poem about every animal in her encyclopedia of animals. The encyclopedia was a Christmas gift from her grandpa in the guise of Santa. The book was her favorite book for years and something she still had and treasured during the time she was telling me about it. Power Point slides provided the format for Visha's book of poetry. She described her writing process: "I would literally go in this encyclopedia and look at the name of an animal, Google a picture, put the picture and the title, and leave a space for the poem and then go to the next one."

Visha wrote poetry for several years but then switched to journaling. When her grandpa passed away when she was in sixth grade, journaling allowed her to write to him and tell him everything about her life. Eventually she stopped addressing entries to "Thatha" but she continued writing.

Other than a continued interest in animals, science was a part of the school day, not a passion. The most memorable elementary school science activity was not part of the regular classroom science instruction. Every year Visha's school would set up a mobile planetarium in the cafeteria. Every class would have a designated time to come and the school would host a parent's night so that the whole family could visit outer space. For an entire week the kids would see a boring looking plastic bulge in the middle of their cafeteria. During their class's day to visit the bulge, they discovered that it was a teleportation device. Visha said, "It was just like stepping into another world."

One moment students would be in a large room with overly bright overhead lights; the next moment they would be in darkness so complete that they could not see the child next to them. Kids would slip in and out of the bubble, fascinated by the sudden transformation. Once settled enough to sit down, the students would look up and realize that the small bulge somehow transported them from their school into the infinity of space. Visha described the feeling: "It really is like you're looking at the night sky but with clarity." When Visha's parents came in the evening, she excitedly pointed out the constellations and made them experience going in and out of the busy and bright room, through the teleporting door, and into the never-ending expansiveness of space.

Visha's grandparents prioritized their grand daughters' educations and worked closely with the girls to make sure that they were successful. Starting in third grade and through some of high school, Gama would sit with Visha after school to do her homework with her. The dining room table would provide a solid surface if writing was involved. The front porch would provide fresh open air if Visha was studying. Gama would quiz Visha with flash cards while neighborhood kids played and birds sang. Over the years Gama's beautiful, curly hair went from black to streaks of grey and then to snowy white, but her high expectations and willingness to support Visha never wavered. She had been a teacher in India and loved to learn. So that she could better assist her granddaughter, she would read and take notes from all of Visha's textbooks, which Visha referred to as "our textbooks." Gama would talk to her and teach her about everything from science and history to making good life choices and the stories of Jesus.

Thatha seemed to take the more active role during the summer. Visha explained that, "he basically homeschooled us every single summer in elementary school." She

then said, “It was amazing.” He was both strict and silly. He commanded respect but knew how to have fun. He meticulously planned the girls’ summer days and they loved it. Appreciating the planning behind it in retrospect, with awe Visha said, “He would structure a full week’s worth of curriculum in every subject including gym.”

The day might have started out with mathematics, Visha’s least favorite subject at the time. Thatha, calling himself Mr. McFall after the elementary school principal, would sit at a chair and the girls would sit on the bed in Sasha’s room. Inevitably, shortly after the day would begin there would be a knock at the bedroom door by Gama, carrying a plate of cut apples and peanut butter. “Mr. McFall, it’s snack time. The girls really need to eat.” “Mrs. McFall, you can’t keep interrupting us.” After the snack reenergized them, the girls would get back to work.

Throughout the day the girls would practice math, practice typing, read assigned books and write book reports, do research projects on other countries, and memorize the hymns that Thatha loved to sing with his “strong, deep, rich voice” in the shower and hum all day long. The hymns provided an opportunity for Thatha to expand the girls’ vocabularies, patiently explaining the meaning of acclamation and adoration while working on “How Great Thou Art.” Visha said, “He would make sure we knew exactly what we were singing.” The memorization of hymns was something that Visha has appreciated as she has become more devoted to her faith and she recalled it with great fondness.

The day was not filled with all serious study. Thatha valued their physical health as much as their mental health. At 70 years old he would play every bit as hard as they

did to win monkey in the middle in the hallway during the PE. He also let them take an occasional break to watch Animal Planet, the only channel they were allowed to watch.

The influence of her grandparents extended through Visha and Sasha's time at GW. From the time the girls were born they set aside money for college. This money allowed the girls to attend their dream university. Visha said, "she's the reason that we're going to GW." Gama would tell her not to worry about money but to focus on school.

When I asked Visha if she remembered "doing any science in elementary school," she told me about her "favorite lab ever" that she did in fifth grade. The students were given owl feces and instructed to reveal the mysteries hidden inside by picking the feces apart. What had the owl eaten? When I went back to ask Visha more details about this lab she explained to me that she actually had to miss the day of class that the students were doing this lab because of a doctor's appointment. She was so upset. Later the teacher showed her the fragments that the other students found, but she didn't get to go through the feces herself.

There seemed to be two reasons that Visha was so upset that she missed the owl feces lab. The first was that the lab was so different from any other labs that they had done in elementary school. Visha explained, "I feel like in elementary school, a lot of it is 'you pour this one thing and it causes bubbles' or 'you do this and it causes that'." This lab was different from all of the others. Visha felt that it was really engaging in the act of science. She said, "A teacher could have easily said, 'this owl eats that' or 'that owl eats that', but we were visually looking at owl feces . . . and making those discoveries on our own." The students were acting like scientists.

The second reason that Visha was so upset that she did not get to do the lab was that it put her behind her classmates, one in particular. One of Visha's three other lab partners was her academic rival and good friend. They would tease each other about who got a better grade on assignments but mostly they pushed each other to do the best that they could academically. Visha felt this competition was a positive motivator for her. She recalled feeling, "really challenged by the people around me and feeling excited about that." Having a classmate who pushed her to do her best made Visha more excited to learn.

After telling me about the owl feces lab, Visha told me about some of her other favorite labs, all of which were about identifying the parts of living things (or living things' feces). Her seventh-grade frog dissection was the next science lab that was memorable to Visha. She was really excited leading up to it but disappointed in its reality. The smell of the preservative made her gag, she didn't actually get to do the dissection but observed and took notes, and it was hard to distinguish the intestines and organs.

Although the frog dissection disappointed, the pig dissection that Visha did during AP biology in her senior year of high school did not disappoint. The teacher reassured the class that the pigs died of natural causes and were not killed in order for them to do the dissection. Leaving any hesitation behind, she thought the lab was "so exciting" because "the parts of it were a lot more identifiable" than the parts of the frog since the animal was so much larger. The class had studied what to expect during the pig dissection in detail. In contrast to the frog dissection, Visha got to take the lead on the pig dissection as four of her classmates observed and took notes. Visha explained that

she was, “making really small incisions, picking things up, putting them back, and labeling them.” She said, “you enjoy those things so much more and you get so much more out of it if you’re the one doing it.” She also enjoyed a competition that her teacher set up to see who could maintain the longest small intestine. “I took the intestine out and it’s all curled up. So, we have to make surgical cuts to stretch it out without ripping it.” The whole class was invested in the competition arguing, “No, mine’s the longest!” Visha felt that this experience allowed her to really understand the different parts of animals and she therefore did well on related sections of assessments.

“I remember memorizing and having fun . . . with the projects.”

In one sentence Visha said that she “loved science in middle school” and in the next she said it “was kind of a joke.” Most of the instruction was some lecture and a great deal of bookwork and worksheets. Despite the class being structured around lectures and worksheets, Visha considered her seventh-grade teacher to be a good teacher. The teacher seemed to her to be very knowledgeable and enthusiastic about science. The class memorized biological things like the photosynthesis equations. This was easy for Visha because, just like when younger, she was “really good at memorizing things.” She thinks that she must have been “top” in the class. The class frequently watched Osmosis Jones, a cartoon character that teaches about biology on the microscopic level. Visha was shocked I had never heard of it. She also did “really fun” projects like making models of plant cells and animal cells.

Most of the projects involved putting materials together and painting in a way that was “really artsy.” Visha’s dad was good at art so he would sometimes help her with the projects. Visha recalled one specific project of creating a three-dimensional animal cell that she waited a little too long to get started on. She was a bit stressed about getting it

done and her dad stepped in to help. There was no annoyance or judgment from him, just kindness. She recalls feeling grateful for his help but also wishing that he would be that involved more often. Visha explained that, "he was always working." The day they worked together on the project, paint, buttons, and beans filled the kitchen table. The sound of the hair dryer that Visha's father was using to dry paint drowned out any other household activity. The final result met all of the class requirements but was too rushed to earn Visha's pride.

Visha's eighth-grade teacher was not as challenging or engaging as her seventh-grade teacher. Visha described him as "not put together" and "really scatter brained." The students were tasked with memorizing the periodic table but during tests "everyone cheated" by having a copy of the periodic table in front of them. "And he [the teacher] didn't care." Visha asked herself, "Why are we doing this?" The teacher did not seem to care about science and the students, in turn, did not care as much. Visha explained that if the teacher did like science, it really did not show in his teaching. The students in the class would just sit there passively and as a result a movie provided the most memorable lesson of the year.

Visha and her eighth-grade classmates were also assigned at least one science project that she recalls. The project involved making a "diagram of how clouds worked" with a partner. Unlike the seventh-grade projects, Visha felt these projects were "a joke." The very specific requirements of the cell project were in stark contrast to the seemingly absent criteria for the cloud project. Visha told me, "I remember just drawing a cloud, drawing a little bit of rain." The challenge and engagement that she felt in seventh grade was not there in the eighth-grade science classroom.

The eighth-grade science class was "all about earth science." I found it interesting that although earth science is about everything all around us, Visha did not feel that this class had real world applications. She said, "there was nothing that was directly correlated to medicine, nor for me, as application based as I would have like." This was the first of many times that Visha alluded to seeing the application of science being synonymous to the science of living things, particularly humans.

When I went back on a separate day and asked Visha what she meant when she said her middle school science classes were not application based, she said, "I was treating a lot of things as facts, but not as facts with some kind of purpose attached to them." She explained that in seventh grade she memorized the equation for photosynthesis without any understanding of what was actually happening in the plant. In eighth grade she memorized the periodic table without knowing why she was doing it. She recalled saying to herself while studying, "I need to memorize these things." Visha was not sure how much of her emphasis on memorization was her own and how much was instilled by her teachers.

In high school Visha took two years of biology: ninth-grade biology and AP biology during twelfth grade. She loved the classes and loved the projects saying, "I can't even think of a subject in biology that I really didn't like." One project that was particularly memorable was a viral project completed freshman year. Visha studied pink eye. She found it fascinating that pink eye is something most people know about but very few people really understand. She learned about how it spreads and what happens on the microscopic level.

"I think I appreciated biology so much because it's so applicable to us."

Visha was very studious in high school. She described herself as, "basically enslaved to my studies and enslaved to good works." At that time, she believed that God would punish or reward her based on how hard she worked. Her childhood church instilled the idea of righteousness and her parents focused heavily on the value of good grades.

All of Visha's family valued academic success. Her father would often say things like, "You're so smart." To Visha's chagrin he would proudly tell her GPA or SAT scores to anyone who would listen. Visha felt a great deal of pressure to do well in school. "I just wanted to please them. I wanted to give them something to be proud of." She felt a heavy weight on her shoulders trying to do her best at all times.

One example, besides academics, of how trying to please her parents impacted Visha's young life was her involvement in dance. During elementary and middle school, Visha and her sister were part of a Christian Indian dance group. The group would perform at churches in the area and for events like weddings. Once she got into middle school, Sasha had lost interest in dance. Visha would say to Sasha, "we need to do this because mom and dad really value this. Everybody talks highly of us. Everybody talks highly of them because of us. We need to keep doing this because of them." Every class started with a "pep talk" from Visha and a reminder to make their parents proud. Eventually, however, the girls did stop dancing to pursue other activities.

Visha's group of friends in school were also very academically motivated. She mostly spent time with four other girls who were also Indian. They went out of their way to invite anyone who was sitting alone at lunch to eat with them, so their group expanded

and contracted, but those four girls remained Visha's closest friends. Visha explained, "these girls were geniuses, all of them." So, they all pushed each other to excel in school.

Visha particularly loved her high school biology classes. This was mostly because she could see how the information related to the real world. She said, "I could see so many direct correlations between what I was learning and how it applied to our lives, that it just made it all more interesting to me." Although she felt that "you can make that case with so many of the sciences," the applications of biology were more obvious to her.

One application of biology that Visha noticed was medicine. When reflecting on her interest in biology, she said that this interest was one of the reasons that she began thinking about becoming a doctor. She recalled thinking to herself, "this [medicine] could be interesting. This is good application of biology. This is a job that is going to pay well. Oh, your parents would be so excited." She considered her interests, her future income, and her family's approval when thinking about her future career. She also wanted to care for people. Visha said, "I think I do just have a heart that wants to help people and wants to care well for people." She also explained how proud it made her father that she wanted to go to medical school saying, "every Indian family wants their daughter to be either a doctor or lawyer or engineer." Medicine seemed like a path where she could apply all of her interests while making her family proud.

Thoughts about studying medicine began solidifying during ninth grade when she took her first biology course and continued gaining strength throughout high school, particularly during advanced placement (AP) biology. Visha felt that AP bio was extremely application based and that there was no way to do well in the class without

focusing on the applications of the content. She said, "in order to do well on the AP exam you had to be able to do application-based questions." She continued by explaining that students could not do well on the questions by just understanding the content. They had to apply their understanding to different contexts. This was one of her favorite aspects of the course.

In addition to being able to see how the content of Visha's high school biology classes related to the real world, she also felt the labs were directly relevant to what they were learning and to what biologists do. "We were doing labs and experiments that . . . replicated what we were learning in the textbook and what actual scientists are doing." However, other than the pig dissection, which I already described, she did not share about any specific labs done in AP biology.

"Some of the concepts were a little bit harder for me to put together."

When Visha shared about all of her experiences in science, her experiences with biology were in the forefront. The only time that she mentioned other high school science classes was in passing. For example, while talking about receiving AP credit for biology she mentioned also getting credit for chemistry despite never talking about taking two years of high school chemistry while sharing about her high school science experiences.

When I asked her more details about her high school chemistry classes, Visha said, "I did well in it, but it wasn't as enjoyable to me." She went on to say that she had not previously thought about why she did not enjoy chemistry, but that she would "guess" that the concepts were harder for her. She assumed that she did not enjoy the class because she found it so difficult. She made this assumption about chemistry based on her experiences with physics. Visha took one year of high school physics, which she

found tough and did not particularly enjoy. Visha said that when she took physics again in college, “I put a lot of time into it and I loved it.”

Visha felt that the content of biology was much easier to grasp than that of chemistry and physics. She said, “I think biology, for me, was a lot more straightforward than chemistry and physics.” Providing the example of electron theory and orbitals, Visha pointed out that physics and chemistry concepts are “more abstract.” She said, “I think my mind does better when concepts are more concrete than abstract.”

Visha contrasted the abstract nature of physics and chemistry with the applicability of biology. She said that she had tried to find areas in which the physical sciences were relevant, but struggled. For example, when Visha was learning about magnetism, she recalled thinking to herself, “when are we going to use this? I know they're used in MRIs and we need to know all these things, but this is really abstract."

I asked Visha if her teachers pointed out the real-world applications of concepts, such as the MRI machine, or if she tried to make those connections for herself. Laughing, she said, “I think that was me.” Making it clear that she didn’t want this point to reflect poorly on her teachers, she said that she wished teachers made more explicit real-world connections to content. “I feel like the majority of students are not good at building those bridges on their own.” Later Visha did indicate one college physics professor who she felt did a good job making the application of the content clear and stated that medicinal biochemistry had clear applications. Other than that, most of her classes taught content outside of any context and she “could not think about the topics outside of that [the lecture’s] context.”

Visha connected her thoughts regarding the real-world relevance of concepts to the idea of transference that she learned about in one of her education courses. Visha felt that her skills of being able to make connections between class content and context improved throughout college with more experience.

"I think students should ask for help when they need it."

Visha didn't take any science classes the first semester of her freshman year of college because she had credit for most of the required introductory courses from her high school Advanced Placement (AP) courses, which she felt was "really God's kindness." She was also advised against taking upper level science class before getting acclimated to college life. She did take physics the second semester. However, first semester of sophomore year was her first experience with taking multiple college science courses at once and it was "so rough." She struggled in organic chemistry one (orgo I) and in the second semester of physics.

Orgo I was a mass lecture required for all chemistry, biology, and pre-med students. The class was notoriously difficult and Visha's experience was no different than what she felt was typical. She needed help but did not feel comfortable seeking that help from the professor. She told me, "I was so scared to go to my professor." She also did not ask questions in class. She would think to herself, "I'm going to go to this professor and I'm not going to know what I'm talking about and he's going to think I'm stupid." Visha said that if she does not know a person very well, she does not like admitting that she needs help, so she only asks questions of people with whom she was comfortable. During the second semester of orgo, Visha "stepped it up" and studied more. This made her feel more confident asking her professor for clarification. Since her

questions were not really admitting that she was not understanding, but were more a seeking of clarification, she was less anxious.

The way that Visha perceived her peers was that there was a group of pre-med students who were "cut throat" and would "do anything to get the grade." These students readily asked for help and frequently asked questions in class. Visha seemed to admire their self-advocacy but thought their purpose was misguided. She said, "I think students should ask for help when they need it, but I think they're pretty motivated to get what they want when they want it." Of Visha's friends, half would ask for help from professors and half would not. She told me of one friend of hers who exemplified those who asked for help. During lectures he would ask, "can you clarify that?" He would reword what he thought professors were saying to make sure he understood while still in class. Visha indicated that other students would "rather just look online" if they needed clarification.

In addition to orgo I, Visha also took physics II first semester of her sophomore year. She told me, "that's probably the class where help from a professor was the most impactful for me." The class was one of the smallest science classes she has had, with 25-30 students. Visha took a quiz where she felt completely unprepared and felt like she guessed on every question. Somehow, there was a "miracle" and she got a B on the quiz. The professor would frequently encourage his students to come to his office hours for help. He would say, "I want you to succeed. If you leave class and you are not sure of a concept, then ask me." Unlike the organic chemistry professors who were not visibly distressed when 75% of the students in the class were failing, this physics professor "doesn't enjoy giving out bad grades." Feeling lucky about the B on the quiz and certain

that she would not be so lucky again, Visha emailed him saying that she had rugby practice during his office hours. He replied that they could meet anytime that fit into her schedule. She said, “my halfhearted effort was really met by his full effort of wanting me to do well.”

When they met, Visha was direct about guessing on the quiz and told him, “I don’t understand anything going on in your class right now.” He suggested that they go through the quiz together. This was not the last time that Visha went to him for extra help and as the semester went on, Visha “started loving physics.”

“I would pick a study partner in every single one of my science classes.”

In addition to feeling that getting help from a professor was a great way to be successful in science classes, Visha felt that working with her peers to study was invaluable. When she took organic chemistry and was not as successful as she wanted to be, earning her first ever C+, she knew she needed a new strategy. Reflecting on her studying experiences for the class, she said, “I studied alone. I didn't have anyone to check over what I was doing. I didn't have anyone to bounce my ideas off of. No accountability.”

Second semester of organic chemistry (orgo II), Visha had two friends in the class that she would sit next to during class. They would all also study together by making and doing their own practice problems and quizzing each other. Visha earned an A during that semester’s course. Visha thought to herself, “wow this is really helpful to have people who I'm bouncing my ideas off of rather than trying to study alone and watch videos on YouTube.”

Every semester after orgo II, Visha would find a study partner on the first day of class. She preferred studying with other females because she would invite them to her

place and often the studying occurred at night. Most of the time she would already know someone in the class and would ask her if she wanted to work together. She told me, "I would pray before every class that I would have at least one person that I could either start a relationship or a person that I would know." In one class there was no one that she knew. A girl sat next to her on the first day of class who Visha had seen before but not talked to. After an internal pep-talk for confidence, Visha said, "Hi, I'm Visha." They became study partners and friends from that moment on.

By the time Visha was in her junior year, underclassmen would ask her "how to survive being pre-med." Her response would always be, "Don't study alone!" She would advise students to work together to make their own practice problems and to think through ideas together. She would tell them that this strategy made studying more effective *and* more fun.

In addition to having the learning benefits of working with others, Visha saw her work with study partners as part of her ministry. She would get to know the girls well by working together weekly, and she would get to share with them about her relationship with God.

One of the reasons that studying with others was so helpful to Visha was that it gave her opportunities to explain her thinking. Through study groups and through her required teaching experience in her education courses, Visha learned that explaining science to others got her more excited about science and helped her to understand the concepts more deeply. Before developing a passion for explaining science, she would think to herself, "I just need to understand this concept so that I can do well on the test." However, teaching others changed her focus to understanding ideas enough to be

able to clearly articulate those ideas to other. She said, "I think it takes skill to be able to take a complex idea and change it so that your audience is going to understand it." In order to explain a concept to others she had to be able to manipulate the ideas in new ways.

Being an extremely self-reflective person, Visha used the discovery that she learns best by teaching others to develop an innovative method for studying for the Medical College Admission Test (MCATS). She reminded me of her method saying, "to study for the MCATs I came up with a lecture series." Visha would have friends or family sign-up on a color-coded Google Doc to learn about a concept. Some of the lectures she gave via Skype but most she did in person. She would often meet her "pupil" at the Science and Engineering Hall, where the whiteboard walls of the study rooms allowed her to visually convey ideas. I had previously known about this strategy because she gave one of the lectures to my colleague, bringing her own large whiteboard with her to our offices. This method kept Visha excited about learning since she found planning and delivering the lectures fun. She said, "I didn't want to sit with my book and read it, but I wanted to be able to teach and articulate it to people." Visha felt that, because it was holding her interest and forcing her to synthesize her thinking, the method would help her to be more successful on the test.

"All this stuff we were learning for the 17th time in greater detail."

Visha took her two favorite biology classes during her senior year: marine ecology and insect biology. She felt that both of these classes, particularly insect biology, were like entering completely different worlds. She took both classes with two students who she knew from her GWTeach classes. I happened to be teaching all three of these students in an education course at the same time that they were in insect biology. I

recall a day in class when a chemistry education student was sharing about a lesson plan that she was developing. A bug landed on the presenter, causing her to jump a little bit. She raised her hand to squash the intruder when the three biology students said "stop," "wait," and "no" at the same time. The three students opened their bags, pulling out plastic vials to capture the insect specimen. I believe that Visha allowed her classmate to take possession of the sample because she already had a similar one. Once their bags were zipped back up with the prize intact, the class continued as normal.

The enthusiasm with which my students approached gathering insect specimens surprised me and made me curious. A year after this experience, when Visha and I were meeting for her to tell me about her experiences in science, Visha said, "I was just immersed into a whole new world." Visha described insect biology as one of the most impactful biology classes that she took in college. It changed the way she looks at the world around her. The class would go to places like Roosevelt Island, a natural space surrounded by the Potomac River that can only be reached by foot, and the University's green house. The professor would direct his students to sit and stare at a plant, a new idea to Visha. She explained to me how surprised she was by the amount that could be seen with the naked eye when you really looked.

Visha quickly developed a fondness for Roosevelt Island. A location that started as a mandatory destination for class became an inviting oasis to which she would invite friends and fellow Bible study members to walk through while catching up. Visha would often sit on a bridge next to a wooded area, her feet hanging off of the edge, her net sitting beside her, and vials for specimens easily accessible in the bag on her back, and she would just pay attention to everything around her. Sounds filled the air. She could

hear insects fluttering their wings, leaves rusting when crawling critters were creeping over them, and mosquitoes softly plopping onto the water. The warm humidity of early fall embraced Visha in a hug of reassurance that the conditions were perfect for her small friends.

The final assignment for insect biology was to display over sixty mounted specimens that they had worked all semester to accumulate. As the due date approached, the weather started getting colder, forcing the insects to hide and allowing the students time to work on mounting their specimens. Visha loved curating her collection. She explained, "It's such a continued time of being out in the field and learning all these things, but then we're seeing them in front of us." The delicate wings of butterflies that provided little resistance to pins but threatened to rip were in stark contrast to the heavy resistance of the pentatonidaes' exoskeletons. In a last competitive push Visha and her sister went to the basement of all of the dorms on campus to search under washing machines for silverfish, a specimen that was missing from her collection. Despite already amassing enough critters to earn an A, she searched until she found one silverfish for herself, one for her friend, and one to trade with a classmate. She described herself and her classmates as "so intense" about the project.

It was months after the semester ended that Visha stopped looking under every leaf that moved to see what treasure lie underneath. However, the way of seeing the world that she learned in the class never completely went away. She said, "instead of looking in front of me, I'm always looking at trees and bushes and trying to see what I can find, or even just slowing my gaze." Visha also finds herself using what she learned to explain nature to her friends. The last time that we met, she had gone on a hike with

some friends and found herself explaining that the pesky things flying around them were not going to sting. They were flies that protect themselves from predators by mimicking a bee. She explained, "Seeing insects, I have to restrain myself from wanting to catch them, and from being excited, and not yelling out the scientific name." She laughed off her continued interest in bugs saying, "I'm such a nerd." Adding in, "but you understand these things." She knows me well enough to know that I empathize with over-excitement about science. According to Visha, her insect biology professor had the same "nerdy" tendencies as the two of us.

Marine ecology was not as fascinating to Visha as insect biology was, but it was still a class that took her out of her regular university experience. They went on several trips as part of the class. Many of the trips, such as one to an oyster farm and one to a center doing research on carbon dioxide in the atmosphere, primarily involved listening to experts talk about their research. Visha recalled thinking, "this is really unique research," but she also recalled feeling a little bit confused and overwhelmed by the volume of facts being shared.

There was one marine ecology trip that was very hands on, a trip to the Chesapeake Bay. The beautiful, sunny day elevated all of the students' moods which were already high as nature pulled them away from their regular classroom. They assembled crates with fake oysters, kayaked about a half mile into the calm, cool water, dropped the crates and came back to shore for a while before repeating the trip to collect their crates. While left alone for a few hours all sorts of creatures inhabited the crates and it was the student's task to find and record them. Elbow-deep in mud, the students found shrimp and things that looked like transparent underwater worms. Visha said, "[it] was

really cool because we were really just looking to see what we would find." The class also tested the water for things like salinity, but Visha explained that this aspect of the experience was less engaging to her than "looking at creatures and really getting our hands dirty."

Both marine ecology and insect biology opened Visha up to seeing the world in new ways. In comparison all of her other biology classes seemed to address the same concepts in greater and greater detail. She told me "literally almost every class that I had taken talked about transcription and translation and cell biology." These two classes were also unique because they involved lab components, which was not part of any of the other biology courses.

Before these classes Visha did not have much experience doing biology research. Many of her classmates got jobs in professors' labs starting their freshman year but this was not something that interested Visha. She did not feel that research in biology was as "practical" and "application based" as medicine. This was one of many times that I struggled to fully understand Visha's use of the word "application." As mentioned earlier, for her, application often seemed synonymous with medicine.

One day I pushed Visha to think about her own definition of application. She said that it is, "something that I could understand, or do, or change based on what information I'm getting." In other words, application involved her being able to actively use the information. I struggled with understanding how her definition fit statement that labs do not involve the applications of science, so I pushed her to further explain. She responded that, "in my head I'm defining it more as making a difference." Through further conversation she acknowledged that her marine ecology professor made it very clear how

one change impacted many other things and therefore how his area of research could make a very significant difference to people.

Visha then had an epiphany. She realized that for her, application means whether or not there was a clear human interaction involved, if the science would allow her to serve and care for people. "I definitely have a love for science, but I think, this is the first time that I'm discovering this for myself, of how closely it is coupled with caring for people." Visha realized that part of what she loved about science was seeing how it could be used to directly help people. It was her interest in directly relating to people that made it challenging for her to recognize some application. For example, she explained, "doing marine ecology, were impacting people, right? But, indirectly . . . . Medicine I was learning and actually getting to interact with the person and diagnose them or cut them open and fix them." For Visha, part of her love of science was being able to use it in direct relationships with other people.

Visha expressed a slight regret for not having worked in a lab because, as she said, "maybe I would have liked it and maybe I would have wanted to keep going." She questioned if having more experience doing biology would have impacted her interest in pursuing the field. Visha followed this slight statement of regret with dubiousness regarding if she would have actually liked research. She explained that hardly anyone she knew who worked in a lab actually enjoyed their work. For example, she knew several students who "hardcore did research freshman and sophomore year," but once they got accepted into the seven-year medical program, they immediately quit. They seemed to be participating in the labs as a resume builder, not to pursue their interests.

"I really honestly struggled to care about learning for the sake of the subject because it was so stressful."

After Visha told me about her wonderful field experiences in marine ecology and insect biology, I asked her what other college lab experiences stood out to her. She explained that there really were no other biology labs, so the only other college lab experiences that she recalled were in organic chemistry. She said that organic chemistry labs were "pretty challenging." In the first semester students were "just trying to figure out what you're doing."

In the second semester of organic chemistry the labs were tightly sequenced. They were long, four-hour lab sections where the results were what mattered. Visha explained that, "you're literally just trying to do what's right and get results because otherwise your grade is going to suffer." Visha said that for four hours students would tirelessly try not to mess up which created a "high stress environment." Adding to the stress, Visha's lab teaching assistants refused to answer questions and help students to understand procedures, which was not the case in some of her friends' lab sections. The emphasis on results and grades made it difficult for Visha to focus on learning. She would say to herself, "ok, I need to do what I need to do, because I need the results because otherwise, I'm going to fail this."

"I didn't want to be glued to the sciences which I loved."

When Visha entered college, she had several goals. She did want to be an outstanding pre-med student but she didn't want to be one-sided. She wanted to be a well-rounded individual and to stand out in her future medical school application. She also just wanted to try different things, "like almost every freshman does." At the recommendation of a girl in her Spanish class, one of the new things that Visha tried and ended up loving was playing rugby. Another new thing that Visha tried was taking GWTeach classes.

Visha told me about how she first found out about GWTeach. It was the end of a physics class period near the end of the semester. She was in what was called a scale-up classroom where students sit at tables of about eight students. A professor came to her class to talk about the program. She said, "I didn't even turn around . . . . It was a Friday. I didn't really want to listen anymore." The professor said, "even if you're pre-med . . . teaching is something that you are going to use for every single thing you do . . . . If you want to be a good doctor, you have to teach your patient." In Visha's head she added, "if I want to be a good Bible study leader, I have to be a good teacher. If I want to be a mom one day, I have to be a good teacher." She began thinking that teaching was a skill she could use to be a more well-rounded individual.

Visha turned around to the board and took down the email address that was provided. She sent an email requesting more information immediately after the class. The following semester Visha taught three lessons in a third-grade classroom and loved it. She felt that the class helped her to grow. She said that the class helped her to get better at "planning, organizing, being able to understand where students are at, [and] being able to communicate clearly." She also felt that the class helped her to be less fearful of "getting up in front of people." All of these skills, Visha felt were useful inside of and outside of the context of teaching, so she kept taking more GWTeach classes.

"I want to invest in relationships . . . whatever career I choose."

By the first semester of Visha's junior year she had completed three education courses, two of which involved teaching. She was also in the middle of an education independent study, was teaching Sunday school for five-year-olds, and was leading a peer Bible study. Through the GWTeach teaching experiences and teaching at her church she was developing a passion for educating and being with kids. She felt challenged and

gratified figuring out how to convey complex ideas to people, such as explaining Christianity to five-year-olds. She told me, "I was growing huge love for interacting with students, for teaching, for building relationships." Seeing the difference that she was making in people's lives brought her joy.

Every week Visha's church had a Sunday evening prayer service. One of these weekly services caused Visha to look at her future differently. The prayer services were smaller than the Sunday morning services, which were typically a full house with 1,000 to 1,500 people in attendance. At prayer service, about 400 people congregated in the front of the huge sanctuary, choosing to be close together and leaving the balcony and back pews empty. Evening light filtered through the tall stained-glass windows that were probably original to the early 1900s red brick building. Visha described the service as family coming together to share what was going on in their lives and what prayers they need. People go to the front of the huge sanctuary and stand at the podium to share. Then the pastor will "call out" some members of the congregation to pray aloud into the microphone that was passed to them about the things that were shared.

One week, a principal of a DC public school shared about the "horrid" things children in her school were experiencing and asked for prayers for her students. She talked about a student who got pregnant and got kicked out of her home. The girl's family was "basically telling her to abort the baby." The student was living in the street, dealing with her changing body, and trying to go to school. The principal took her into her home and took it upon herself to help her with school. Visha said the principal "basically saved this girl's life." According to the woman speaking there were "many girls who are in similar situations."

Visha mostly remembered that her eyes filled with tears and she felt "overwhelmed with emotion." Visha told me, "My heart broke for the things she was saying." Her heart broke and her heart drove her to want to do something. She felt that she was beginning to develop skills that could be used to help young people and that perhaps she should be putting those skills to use.

Visha always wanted to help people. Hearing about the hardships that many of the students in DC face made her want to help these students. For the first time she asked herself, "What if I didn't do medicine?" It was an epiphany. Visha told me, "that was the first time in a long time that I thought of something other than being a doctor."

Visha could not concentrate for the rest of the prayer service due to the all-consuming thoughts of "what if I just became a teacher? What if I could just go serve in that way?" Following the service, Visha got a ride with her friend who was "discipling" her. She started the ride silent and distant, looking out the window at nothing. Eventually Visha asked, "Can I tell you something?" Visha knew she had to talk about her feelings because, as she told me, "I'm such an introspective person that my thoughts, I would have been consumed by them."

Despite knowing that she needed to say something, Visha was so scared that she was shaking. She started to conversation with, "I don't think you're going to be friends with me after." Visha explained to me that this was half a joke and half a real concern that people would not accept her if she did not become a doctor. Visha's personal identity and the identity as a future doctor were so entwined that it scared her to think of herself as anything different.

I really struggled with understanding Visha's immense fear regarding not becoming a doctor. She talked about how proud her family had been of her being in medical school but she also said that her family had not told her that she *had* to become a doctor. Several months after talking to Visha about resistance to changing her career trajectory, I was listening to *Becoming* by Michelle Obama (2018) when I felt I finally understood what Visha experienced. Obama beautifully described a similar experience to Visha's. She started a pathway toward law school and just kept going, mostly because others were so adamantly affirmative of this trajectory. She said:

> I can admit now that I was driven not just by logic but by some reflexive wish for other people's approval, too . . . . This may be the fundamental problem with caring a lot about what others think: It can put you on the established path—the my-*isn't-that-impressive* path—and keep you there for a long time. Maybe it stops you from swerving, from ever even considering a swerve, because what you risk losing in terms of other people's high regard can feel too costly. (p. 91)

I believe that Visha did not want to consider swerving from the direction of medical school because of subconsciously not wanting to disturb others' high regard. Her fear of telling her friends seemed to validate my thinking. And her fear about making a change did not stop after that conversation.

Visha had to give herself a pep talk to tell anyone that she was thinking of not becoming a doctor. After telling the friend that had "discipled" her, the next people that she told were her sister, Sasha, and another friend. Visha also said to them, "I have something that I want to tell you guys but I don't know if you'll be friends with me after it." Their response was, "why wouldn't we be friends with you?"

After Visha revealed to Sasha and her friend that she was not sure if she wanted to pursue medicine, she told herself not to do anything rash. She continued in her MCAT class, continued waking up a 4am to read a passage of the economist (to improve critical reading skills) before studying, and continued giving lectures on MCAT topics. She also continued "pursuing education hard." She described it as, "turn[ing] from one track to just being really open minded."

During the second semester of Visha's junior year, she was on the phone with a friend who later became her boyfriend. They were talking about a religious ski retreat that they were both planning to attend. Visha told him that she was planning on staying inside and studying for the MCATs rather than skiing like everyone else who was going. In a laughing tone he responded, "you don't need to study for that. You're not really going to take them. You're not really going to go to med school." He must have known from the change in her voice that Visha was upset by his comment. Perhaps she became silent or curt with her responses. Whatever the cue, he Facetimed her so he could apologize face-to-face rather than over the phone. Despite this being an upsetting conversation, it planted a seed of thought in Visha.

Before this conversation Visha had been feeling pulled between the paths of medicine, teaching, and ministry. She had been praying that one door would shut. Her friend bluntly stating that he thought she would end up not going to medical school felt like a door being pushed shut that she had been holding open. She said, "the next couple of days, the next couple of hours, that was all I could think of."

A few days later Visha was sitting with Sasha and trying to figure out why she felt so consumed with thoughts of the conversation with her friend. She ended up laying out

what she wanted to accomplish in life. She told Sasha, "I want to invest in relationships . . . . I want to get to know people. Of course, I want to help people. And I want teaching to be a huge thing of what I'm doing." Sasha gave one final push on the door of medical school by saying, "I don't think med school is what you want to do if that's what you want to do with your life." Visha just needed to hear that. She knew that, but was not willing to admit it to herself until someone stated it clearly.

After talking to Sasha, it was clear to Visha that medical school was not what she would have been happy with. She wanted to start investing in people's lives immediately, not after four or more years of school. She wanted to really get to know and help people, not meet with them for 15 minutes before providing a diagnosis and a prescription and sending them on their way. She said, "I like relating to people and sharing my life with them, sharing religion with them, sharing science with them." Visha loved any opportunity to teach in both secular and non-secular contexts.

"I need to understand that . . . [my dad] was investing everything in this."

As described, Visha had a hard time admitting to anyone, even herself that she did not want to go to medical school. Despite how hard it was to say to anyone, the hardest person to tell was her dad. Although Visha felt like the dream of becoming a doctor started out as her dream, it was one that her father readily adopted. He wanted her to become a doctor and Sasha, who was the "talker," to become a lawyer. It became clear early on that his dreams for Sasha were not what she wanted, so it was not a huge disappointment when she studied something different. But for Visha, her pathway had been feeding into her father's dreams for a long time and the seemingly sudden departure from that path would be hard for him to take.

One of the reasons Visha had such a hard time talking to her father about whether or not to become a doctor was because their reasons for valuing the profession were so different. Visha explained, "he just wanted fame and prestige and I didn't want those things. I never did. Still don't." Trying to explain to him that she was giving up renown to care for people in a more personal way was like talking in a different language.

One day Visha realized that her mind was made up to not become a doctor and it was not going to change so it was time tell her dad. She left the comforting familiarity and privacy of her dorm room and sought a more public space, thinking that the space would force her to stay brave. With dread she picked up her cell, a device that provided the distance that she needed for comfort, but still seemed to exert a heavy weight in her hand. In the end the distance provided by the phone and the social pressure provided by the public space were not enough to keep Visha from dissolving in tears. "I started crying. And I was like 'why am I doing this in a public place. I'm so dumb.' And I ran to the bathroom."

That conversation changed Visha and her father's relationship for a long time. She explained, "He said some awful things to me." He could not understand why she wouldn't do medical school when she *could* do medical school. She had the grades and was "smart enough" to be successful. He told her, "I've worked my entire life so that my daughter could be this prestigious doctor." He could not believe that she was "settling" to be a teacher or go into ministry.

After this conversation it was a long time before Visha's dad would talk to her. Once they did start talking, he would reassure himself by talking about how she could at least get a master's degree in education. He was even more upset when Visha explained

that she was deciding between teaching and the ministry. This upset him because she would likely not be pursuing further education if she went into the ministry.

Visha had stopped talking to her father partly because she felt hurt over his harsh words, but she also just didn't know what to say to him. She felt that the only things in her life that he had shown interest in were her grades and her med school related experiences. As an example, Visha recounted her homecoming from a summer of mission work a year earlier. Visha spent every day that summer "discipling" younger Christians. She also spent two days a week volunteering as an intern in an emergency room. At the end of the summer, she flew home, where her dad picked her up at the airport. She said, "I just spent my whole two months pouring out and seeing these women grow spiritually. And I get in the car and he says, 'So how was your time in the ER?' I almost cried." Moments like this made Visha feel like the work that she was dedicating herself to was something that her father had no interest in, didn't value, and didn't want to hear about.

A few months before Visha and I met to talk, she was struggling so much with her relationship with her father that she sought out the guidance of the family counselor at her church. This was a man whom she respected greatly, had a personal relationship with, and shared cultural similarities. She told me, "You have to read some of his work. He's phenomenal. He's pretty famous. And he's my friend slash counselor. He's also an Indian male so he kind of understands, too." The counselor explained to Visha, "You need to understand that your dad literally came to this country, got a job, put all his money towards your education so that his daughter could become a doctor. And you just crushed all of his dreams." At first Visha continued to feel angry, telling herself that he

needed to get over it and change his dreams and support her. But over time, she developed some sympathy for her father's perspective and developed some strategies to rebuild a relationship with her father by getting him invested in the work that she was doing.

Visha's dad was a businessman and a salesman. Numbers were something he understood, valued, and enjoyed. At the time that Visha was seeking to rebuild a relationship with her father, and the time that she and I met, she was fundraising to support her own mission work. The family counselor recommended that Visha involve her father in the financial aspects of her work and seek his advice. Despite not really needing his help, she asked her father to go out to lunch with her and to assess her finances. I can picture them sitting down over food, her showing him how she raised 40% of the funds that she needs to support herself in three weeks, and him glowing with pride over her accomplishment. She told me, "He was so shocked. He was like, 'this is actually insane. You're working so hard . . . . You're good at what you're doing.'" During that same lunch he asked her about teaching and why she chose to student teach. As the meal progressed the tension between the two of them eased to a point where they could begin to rebuild their relationship. His disappointment over Visha not being a doctor continued to resurface periodically over the time we met, but it was not a stifling presence between them.

Visha's mom was more immediately understanding about her decision not to become a doctor but was still reserved about such a drastic change. Visha recalled her mom saying, "I understand that you don't want to be a doctor, but you like so many things about this field . . . . Don't make a rash decision, just think about other options in

the health field." She went on to reassure Visha that she loved her and to suggest being a doctor missionary. Eventually, once convinced that Visha would be financially stable, she "came around" to supporting what Visha wanted to do.

Visha's extended family spent a great deal of time when they saw her, trying to convince her that she was making the wrong decision. But, as usual, Visha's grandma was nothing but supportive. When Visha told her that she was not going to go to medical school, she broke down in tears of joy. She believed that God had other plans for Visha and that Visha was listening to God and following his plans.

Visha's Final Thoughts

The last time that Visha and I met to talk about her experiences in science we met in the GWTeach office. She chose to meet there because she said that she missed spending time there. It was during the summer, so we were the only ones around. The space provided a much quieter and more intimate environment than the cafés that we met at every other time. Visha graduated a year early and it had been about half of a year since we last met. We spent about half an hour catching up before I asked some clarifying questions about what she told me previously.

After I had asked all of the questions that I had for her, Visha asked me to remind her what my research question was. I told her, "my research topic is the underrepresentation of women in science, but I'm addressing it from the perspective that hearing women's stories… there's a lot that we can learn." Visha then summarized what she thought were the most important aspects of her experiences.

"I think so many of my experiences were really fueled by the environment around me . . . . Just living in an environment where I was surrounded by wildlife and animals and that piqued my interest at a young age. Then the first time I said I wanted to be a

doctor; everyone was like, ‘Wow. Go towards science’ . . . . Can you imagine if they hadn't said that? I think my story would be very very different . . . . I’m definitely a person that’s very heavily influenced by people, or by people who I respect and know and love . . . . I just remember so many conversations with either parents or teachers or childhood friends or my grandparents were a huge influence on me . . . . I’ve had a lot of impactful conversations with you and Dr. Q specifically . . . . Can you imagine versus an environment where people are telling me that ‘you should go into history’ or ‘you should go into literature or English’? . . . . I think I probably would have done that . . . . I’m just so heavily influenced by the people in my life who have really just encouraged me towards this.”

Chapter 5: Mae

Changing Majors

Mae and I sat in a café with a distinctly Parisian feel. The aroma of dark, rich coffee and the drone of many conversations surrounded us. One of many private nooks provided us a retreat from those around us while large plate glass windows allowed us to watch people walking by and cars speeding by on a busy city street. The upholstered chairs encouraged us to sit back and get comfortable. This was the second time that we have met to talk about Mae's experiences in science. Relaxing into her chair, and pouring steaming water out of a small teapot into a mug, Mae told me about the moment she decided to become a chemistry major. She started by saying, "I remember when I had this epiphany that I wanted to transfer out of the business school." I can picture Mae during this moment of revelation.

Mae sat on a brick wall outside of "Thirsty" Thurston Hall, a freshman dorm known for being loud, fun, and *slightly* unsanitary. The rough brick might have scratched at her legs while the sun warmed her hair and shoulders. The fresh outdoor air, carrying only muted noises, allowed her to breathe more deeply and think more clearly. The phone held up to her ear made her mom's voice sound like she was sitting next to her, despite her being at work several states away. Mae always called her mom for organizational things like "to book flights or a life question." She and her mom discussed all of the possible pathways in the business school. As a student ending her freshman year of college it was time for her to make a decision regarding what type of business she wanted to focus on. Her mom was a very practical and methodical person so was probably approaching the decision in a systematic manner. When Mae enrolled in

school, she chose to enter the business school because, “I just checked the box on the application.” Business school “seemed like a safe bet.” Mae explained this reasoning by saying, “my mom is in business and she is very happy.” Both of her parents had studied business. But after a year in the business school, the safe bet didn’t seem like the right fit.

Sitting there on the wall, she was probably twisting and untwisting her hair into a low bun, something I have often seen her do even when not stressed. Dejectedly Mae told her mom, “the only one that I feel like I would be interested in would be the hospitality one. But I don't want to work in hotels. I just feel like that's a good one because I get to interact with people and I don't have to be in the office all the time.” At the other end of the phone, Mae’s mom was in her office working like she was almost all of the time. She picked up on and reflected back Mae’s lack of enthusiasm. Mae felt like she would be choosing something just to choose something, not because it was really what she wanted to do. So, she made a completely different choice, deciding, “I'm going to do chem. I’ve always loved chem.”

When Mae told me about this memory, with the café buzzing around us, it was three years after she switched her major to chemistry and about a month away from her graduation. She had accepted a position teaching chemistry at a private school in her home state for the next two years. I had known Mae for the past two years and taught her in four classes. I first met Mae during the fall semester of her junior year when she was a student in my introductory STEM education class. Her seemingly perpetual style communicated that she was both trendy and comfortable. This almost always involves distressed skinny jeans, a baggy sweater, and canvas slip-on flats. Her long, light-brown

hair usually flows loose halfway down her back. Since my classes are small and are based around group work, Mae and I have spent countless hours talking about teaching and lessons, sometimes in groups, sometimes one-on-one. In the last few months before she graduated, we met three times for her to share with me about her experiences in science. As we talked each time hot tea warmed her hands as she held it and warmed her from the inside out as she sipped it. She talked with very few pauses, leaning forward when particularly enthusiastic.

The sights, smells, and sounds of the café drifted into the background as Mae told me more about deciding to switch her major. After getting off the phone with her mom, Mae called her dad at their family home. She always called her dad when she needed to talk through things. Growing up, her mom usually lived out of town during the week to be closer to work, and her dad was the one that was always around to talk to about her day-to-day life. While away at school he always reminded her: "Call me. Check in with me." So, it became a habit to call her dad when she wanted to talk about how things were going. Mae told him, "I think I'm just going to do chem and try to go to dental school. And that will just be my path." She loved chemistry but knew she didn't want to work in a lab. She recalls that her father's response was, "OK. Yeah. Do it. Sounds great."

Mae said to me that she thinks that her parents would have been supportive of anything that she decided to do, but her dad was particularly enthusiastic of this decision because he knew that she always liked science and it was one pathway to dental school. He had a lot of friends who were dentists and orthodontists and told Mae what a great life style they had. He would tell her that, "they have a good source of income and are not

working all the time." He also felt that it would be a good fit for how outgoing Mae is. She told me, "he knows me and he knows how social I am." She takes after him with her extroverted personality.

Science Interest from a Young Age

Mae seemed to agree with her father that dental school was a viable ambition, and she always had an interest in science. She told me, "I think a lot my interest in science in general comes from when I was younger and just playing around with things." When Mae went to her grandmother's house she would "make lotion." During holidays like Thanksgiving and Christmas her grandmother's fairly small condominium would be filled to bursting with about sixty boisterous Italians. Every seat on the first floor of the condo was occupied by an adult. The running and shouting of kids interrupted conversations. Mae would inevitably climb the stairs to the second floor. The stairs were like a portal, not only to a place of quite solitude, but also back in time. Wicker furniture and retro bed covers decorated the three bedrooms that remained mostly unoccupied since their inhabitants moved out to start their own families. The "cool" but "weird" bed rooms only held Mae's attention for a short period of time. It was the bathroom cabinet that called to her. The space underneath the bathroom vanity was s treasure trove of rejected and forgotten lotions and powders. In small Dixie cups Mae would mix together everything that she found such as lotion and soap or baby powder and Listerine. She told me, "I just liked working with my hands and actively combining things and seeing what happened." After competing her "masterpiece" she would descend the stairs and make all of her cousins and aunts try it out. The scent of baby power and lavender from her creation would mix the pungent scent of roasting garlic and the tangy scent of stewing tomatoes. According to Mae, her father said that one of the reasons he thought that she

loved making lotion at her grandmothers was because of the attention that she got by having everyone try out her creations.

Mae's parents encouraged her interests by doing things like buying her a microscope from National Geographic one year for Christmas and getting multiple slime kits. The cabinet under the sink in the kitchen was dedicated to slime-making recipes and ingredients. Mae was able to make slime whenever she wanted. I picture her rushing in from the bus, not wanting to wait to try a new recipe. While her sister Alex would pull out crayons and paints, Mae would sit on the floor in front of the sink and open the door. Old bottles that used to contain cooking ingredients such as olive oil now contained the chemicals needed to make new concoctions. The tangy odor of Elmer's glue wafted out as components were selected. Did she want to make the mixture that turned out chalky and at one moment would pour out of her hand and the next moment would clumped together? Or today did she want to make a mixture that was smooth and stretchy and sometimes had water run out when squeezed? Mae tried over and over to make the perfect blue slime but the mixture refused to be anything but stark white.

Mae went to a science summer camp at the local recreation center. At camp she mixed salt and pepper with water to see what would happen. The salt seemed to disappear while the pepper floated to the top. She also learned about types of rocks and was given a container with rock samples which allowed her to compare and identify types of rock when the camp was over. After the camp, she and her father would look for rocks at the beach when they were staying at their cottage. Mae and her family would spend all day on the beach. The hot sun would make her sweaty but her surfer top would protect her skin from getting burned. The seaweed filled waves would tousle her hair and cover

her in a briny residue. At the very end of the beach was a rocky area with stones of all different sizes. After hours of playing in the surf and sand, the rocks would call to Mae, asking her to spend hours having fun in their midst. Mae would look for rocks about the size of an adult's fist. Rocks with layers held her interest the most. She would throw them at larger rocks but they would refuse to reveal their secrets, potentially shedding only one small sliver. "I would have to go fetch it and bring it over to my dad and have him do a hard throw." The rocks would surrender to the tall, athletic man's throw and would break open. The peaceful lapping of the waves must have contrasted with the periodic loud clack of rocks hitting into each other.

The first day that Mae and I met to talk about her experiences in science, we met on the outskirts of campus at a trendy, modern café attached to a public library. The café was filled with professionals and students. Glass bottles of water on each table allowed the patrons to hydrate at their leisure and white linen napkins keeps crumbs off of their business suits and name brand jeans. On the other side of the building the public library provided a roof for individuals who are homeless to get out of the rain and bathroom sinks for them to wash off the worst of the grime. The cafe was one large room that was filled with conversation and music.

Mae didn't seem to get distracted by anything around us. She kept eye contact with me not breaking her conversational stride when our waitress spoke with us or when a new born baby next to use cued and gurgled. Hands wrapped around a wide, warming mug of tea, she told me about many of her early experiences with science, saying that she was always curious but she was not sure specifically what prompted her interest in science. In the week between this conversation and the next, she asked her dad about

what he remembered regarding her early interest in science. He said that since she had an interest in seeing what happens when things are mixed, they geared a lot of her activities in this direction. Alex, on the other hand was more interested in coloring and painting. He also said, "I think when you and your sister were growing up, all the TV shows and all the childhood activities were trying to get people more into science." Both of his daughters ended up studying science and he was not sure if TV made a difference, but did remember that they watched a great deal of science related television, like Zoboomafoo, a show about animals all over the world. Mae also was unsure if television had an impact, contradicting herself in saying, "I don't know if that had an effect. I'm sure it did."

Mae's father reminded her that she also loved to mix things together through cooking and making up her own recipes. She and her sister would have Iron Chef competitions. I can picture Mae on a chilly Saturday at maybe six years old and her sister, who was three years older, at nine years old. The warmth from the oven, soft lighting, and the smell of garlic and baking dough enfolded them from every side. Stools probably provided them a boost, allowing them to see what big mixing bowls contained. The hardwood floors would have made cleanup a lot easier, gifting the girls with the freedom to make a huge mess, spilling flour and sugar everywhere and dirtying every dish. Mae recalls wearing an oversized tee shirt and socks that allowed them to slide from place to place rather than walking. Mae's dad was probably sliding around the kitchen with them, taking a break from one of his many interior design projects around the house. Her mom, who would have been home for the weekend, was most likely sitting at the kitchen table. The open laptop would have demanded half of her mom's attention while the family's silly antics would entertain her and get her laughing. Mae

mixed things like milk and lettuce and paid attention to how the lettuce wilted and the sour odor the mixture emitted. Alex, on the other hand, followed recipes to create perfect plates, often of calzone, that were as beautiful as they were tasty, and that were as much artwork as experimentation.

Elementary School Science

After describing her love of mixing things together at home, Mae told me that this interest was not something that she recalled being part of her early school experience. "I think elementary school and middle school, I lost that interest in it [science]. I was just caught up in growing up and my friends and stuff." She did remember loving when she was assigned school projects, like when she had to build a bridge out of toothpicks or when her class made cookies and decorated them to look like cells. Mae's early school experiences were within a smaller community that was almost all Italian but was very diverse in terms of wealth. After she was born, Mae's parents moved to a larger house that was out of the more prosperous community they had been living in. They found where they had been living "a little bit stuffy" and felt the people "took themselves a little too seriously."

Mae did speak fondly of her fifth-grade teacher specifically, Miss A. Before being her teacher, Miss A babysat for Mae and Alex one summer. Miss A's black jeep liberty would blare out music for the girls to belt along with while chauffeuring Mae and Alex between the pool, the beach, and their tennis and soccer lessons. Miss A's cherry red nail polish adorned her hand while she steered the car and the wind from open window blew her blond hair. The sun shining through the window worked to darken her

already tan skin. Her perfectly fitting jean jacket sat on the seat next to her waiting for the cool evening air to be worn.

In addition to babysitting, Miss A also student taught in Mae's first grade class. One of the reasons Mae recalls her so clearly was how well she knew her from these various contexts. "I was so close with her. I think I was naturally a little bit more engaged in her class than maybe I was in a lot of my Elementary school classes." Mae continued to explain that Miss A's impact as a teacher was not purely because they had a previous relationship but also had a lot to do with her personality. She speaks in present tense when describing Miss A, as she was still in contact with her. "She's young. She's very vibrant." Mae followed this statement with a huge compliment saying, "she reminds me kind of like you."

Additionally, Miss A's impact was due to her pedagogy. "She's really into incorporating good teaching pedagogy into her classes." Miss A taught topics that she cares about. "Even now she, I know, is doing this whole healthy eating movement in our Elementary schools and really questioning the lunches that they give to her students, and teaching her students how to cook for themselves." Mae described her teaching as fluid. Every subject blended into each other. She didn't recall a separate time for math or reading or science. Every discipline was "linked" with all of the other disciplines.

Mae seemed to look up to Miss A as a role model. She recalled that Miss A had them journal when she was a student, saying "I think that's why I'm so into that and doing that in my class." Mae related Miss A's investment in student journaling to her other interest related to self-care such as mindfulness, yoga, and fitness. Mae respected the teaching practices and priorities of Miss A and reflected on how to use similar

practices when she becomes a teacher. She explicitly recognized the impact that Miss A has had on her life. "She was, just in general in my life, very formative for me."

Middle School Science

When I asked Mae about middle school science she said, "I'm trying to think if I remember. I don't know if I even took science in sixth grade. Do you take science in sixth grade?" She did remember one teacher who was a "super bubbly" lady, but didn't remember what grade she was in or what specific science class it was. "I just remember she had an energy about science that I thought was really engaging." This was the teacher who assigned the students to build a toothpick bridge. The class was the first time that Mae recalled doing experiments.

Overall, Mae did not feel challenged in middle school. She remembered the building as just being brown and boring. She said that she understood the content better than most of her classmates but didn't feel like the there was any emphasis on trying to engage students. Using her recollection of middle school history to showcase what school was like she said, "that was really the first time that I remember sitting in a history class and just having someone show and read off of a Power Point. Every single day. For a year!" Not being challenged by her peers or teachers was one of reasons that Mae thought her middle school science experiences were not very memorable. "I don't really remember what we do in middle school. It [science] was at my public school so it was never really pushing me. Nothing really was too challenging." It was not until high school that science challenged Mae.

High School

Alex was three years older than Mae and the two girls didn't always get along. "We're so different. We always say that if we weren't sisters, we probably wouldn't be

friends." Mae said that she was outspoken where Alex always took time to think before talking. She describes Alex as "mindful," "peaceful," and even "angelic." "She's the kindest, just most thoughtful person." I got the impression that this was in contrast to seeing herself as high energy and perhaps spontaneous and slightly less patient. Also, Mae said that she has always had a wide variety of interests and Alex liked to go in depth with fewer things. Even their appearances were different. Alex had very dark brown, thick, curly hair, in contrast to Mae's light brown thinner hair. Alex also had "these crazy light green eyes." Although they were very different, they got closer in high school and Mae seemed to look up to her. Mae talked a lot about Alex, particularly the first time that we met. Just like when talking about her parents, Mae seemed to have a glint in her eye, a spark of joy that ignited when talking about her sister.

Despite Alex's early interest in art, she ended up getting an undergraduate degree in science and continuing to medical school, which fits her caring and academic nature. In an affectionate tone, Mae frequently described Alex as a complete "nerd" although at other times she called her "so cool." According to Mae, Alex was pursuing medicine in order to help others, not for the money. Despite her father's suggestion that she do a form of medicine that will make her a lot of money, Alex thought she might want to do primary care. Mae often found herself following in her sister's footsteps. When reflecting on her decision to study science, Mae commented on her uncertainty about how much Alex's decisions impacted her own. "Sometimes I [wonder] . . . did I just inherently follow her because she's my older sister or did I actually like this [science]? I don't know."

One way that she followed in her footsteps was by following her to the same private school. Both Mae and Alex completed elementary and middle school in the public-school system and then went to private school for high school. Alex loved learning but felt like her middle school classmates didn't take school very seriously. Most of the students did just enough to pass a class. Mae told me that she thinks her middle school classmates mostly aspired to go to a local University and find a job close to home. "She [Alex] wanted to learn more. And it wasn't cool to be smart there. So, she actually approached my parents to go to private school for high school." Both of Mae's parents went to private Catholic schools, so they were open to the idea of private schooling. When Mae started high school, she was allowed to choose if she wanted to stay in public school or go to a private school and was allowed to choose what private school she wanted to attend. She chose to reside at home and attend the same school that Alex had been attending for the past three years. She said that it was a combination of factors that led her to choose that particular school. Her sister going there was "definitely helpful." Also, her club soccer coach had just started a coaching position there.

Mae described her private school to me with a loving, nostalgic and reverent tone. After talking with her about the school I looked it up online and pictures projected the same feeling of an idealized tranquil learning environment. "It kind of looks like a small college." Each subject had its own building. The building surrounded a sprawling green lawn and various sports fields skirted perimeter. "It's four blocks, the main campus. I think there is something like 700 acres total." Most of the buildings looked very similar to each other. Red brick walls with white trim around the windows, and white columns wrapped the exterior of the buildings. There were a couple more recently constructed

buildings that were all set in one area of campus. These buildings featured sharp angles that juxtaposed with curves and were primarily white, chrome, and glass. When we spoke, the most recent construction was the math building, which was not built when Mae was a student, but she worked in one summer while in college. Dorms provided housing for most of the students. The largest dorm accommodated all of the approximately 150 residential freshmen. Houses held approximately five upperclassmen each. Most of the residential facilities were between these two extremes.

A large pond adorned the front of the science building. A bridge over the pond connected the building to the courtyard. "It's kind of like a modern looking building. But it's not as modern looking as the new math building." Red brick wall formed many angles. From the inside, many large windows allowed students to see the beautiful exterior. The windows provided students views of huge evergreen trees, endless green lawns, or the reflection of a weeping willow on the pond. Classroom's white walls, charcoal black two-student tables, and metal lab benches gave off "sterile vibes." The building was well stocked with computers, probes, other scientific equipment, and even close-toed shoes for students who forgot to dress appropriately that day.

The tranquil physical environment of the school was not necessarily a reflection of the mood of the student body. Students at the school were competitive. Mae saw the academic environment both as a positive and a negative. She loved that there was a culture of learning, saying "it's the first the place that I went to school where it is really cool to be super smart." However, she didn't love how aggressive the students' ambition could make them, saying "I think that creates a lot of drama and insecurity among

people." Mae had a difficult time transitioning to this new environment. Speaking about her high school she said, "I was the smartest one in my middle school and I come here and I'm the stupidest one here." She said that students joked about how they were all the smartest kids in their old schools and all of them went through the process of getting "knocked down a peg." At first Mae got caught up in the competitive environment with everyone else, feeling intense pressure to do better than others. She eventually began to "unwind" after realizing that each student there seemed to have something that they were particularly good at, their own "niches." Mae provided the example of her best friend who "was in all of the musicals." Another friend was "a total economic nerd." Despite not loving the competitive environment, Mae loved her overall private school experience. She liked it so much that she decided that she wanted to teach in a private school upon graduation.

High School Physics

The first science class that Mae took in High School was physics. There were two pathways: a concept-based class and a mathematics-based class. She believes their previous math scores determined the students' placements. She took the mathematics-oriented class. Mae struggled a great deal with physics, but she felt like all of her classmates were struggling along with her due to their youth and inexperience with similar classes. "I think sometimes when you're a younger learner you don't really have the capacity to know even how to study something. And I think that's what happened with my physics."

Mae struggled with relating the physics concepts with the mathematical applications. "I literally would get a problem and would see what numbers they gave me

and would desperately try to plug them into any formula and I didn't know what the concepts were." Mae felt like she was really trying to understand how the concepts and applications of physics related but had a very difficult time. She said that sometimes things just click and physics was not one of those things. Mae did not feel like it was the teacher's fault. The class did experiments but she struggled to make the connections. She said, "I feel like physics is something where you really need to be able to link the physical phenomenon that are going on with the theories and the math." Mae recalled one time that the teacher took them into the hallway with ropes and springs in order to learn about and experiment with waves. Despite the use of engaging activities, the difficulties she had with connecting concepts impacted her interest in the subject. "I was just not getting it at all . . . I was just not engaged because of that."

There were several times in science that Mae struggled with applying concepts. Because of this difficulty she wanted to work hard to make that relationship explicit when she became a chemistry teacher. Referring to her own challenges seeing how the content was relevant in context, she said "I'm going to have to figure it out myself in order to link it for them [students]."

High School Chemistry

From the first time that we met until the last, Mae talked a great deal about her high school chemistry teacher, "Coop," short for Mr. Cooper. Both Mae and her sister played tennis and Coop was the coach. His multi-decade passion for sports showed in the classroom where he often limped from joint pain and on the court where he could not hold back from ripping shots at his players. Mae became close with him during her freshman year, connecting with his jovial personality on the court. Mae believed her

closeness with him greatly impacted her interest in his chemistry class. "I think I enjoyed the class because I knew him and I could go to him easily."

The summer before Mae took high school chemistry, she did a five-week residential summer school program about chemistry at her high school. Mae had done a two-week program as a commuter student the previous summer, the summer before beginning high school, because her parents wanted her to get familiar with the school. The summer before taking chemistry, one of her friends wanted to do the program in math so Mae thought it might be fun to do a program too. When deciding what program she wanted to do, she did not recall her exact thinking. "I knew I was going to be taking chem, I knew that I was kind-of interested in it, and I knew that Coop, my tennis coach, was teaching it." Mae associated her previous experiences making slime and mixing lotions with chemistry and "was really excited about it when it came time to actually study it."

When I asked Mae about the friends that she made that summer, she told me that most of the students in the program were not students who attended the school throughout the year. They were mostly international students attending for an enrichment experience. She seemed to use her experience teaching at her alma mater's summer school program while on summer break during college as her reference for this statement, not her own experience as an attendee. Her friend that had wanted to go ended up not doing the summer program and she recalled only one other student at the program who went to school with her during the year. The friendships that Mae did make that summer did not last long beyond duration of the program. For example, Mae stayed as a resident

for the summer program and had a roommate from Turkey who she had a great time with, but didn't keep in contact with afterward.

While Mae was trying to choose which program she wanted to do, Coop told her, "in the summer program we cover pretty much, obviously at a lower level, but we cover pretty much half of what you'll learn in chem throughout the year." That summer Mae spent half a day, about three hours a day, for five weeks studying chemistry, and loved it. Coop switched out sports attire for preppy clothing but his fun-loving personality on the court continued in the classroom. "He's one of those guys that always has to go for the cheesy jokes. He has all of these weird one-liners." I can picture Mae as she sat on a black lab table rolling her eyes while laughing at something Coop just said and animatedly discussing lab results with a small group of students from all over the world, really debating what the findings mean. Coop might have taken notes about what the students were saying on the smart board in his perfect, beautiful handwriting.

Mae felt that, unlike with most science classes, there was a large enough chunk of time for labs to be "fluidly integrated" into what they were learning. Coop typically followed the routine of teaching a concept, having the students do a lab related to the concept, and then explicitly discussing how the lab demonstrated the concept that they were learning about. Mae described this as having the concept "tied off with a bow." After spending half of her day learning about, doing, and discussing science, the rest of her day was filled with playing sports, learning study skill, and getting to know the other students.

Speaking about this summer program was one of many contexts in which Mae expressed to me the importance of having lab and class content closely integrated. She

valued having larger chunks of time daily, two or three hours, to experiment and relate the experimentation to concepts. “I could do the lab stuff and get it to work and then talk about it. I think having it more fluid with the periods was more conducive for me.” She considered it ideal when she felt like, "Oh. That's what something like that looks like."

When Mae took chemistry the following year, she had already done and thought deeply about almost all of the labs for the first half of the year. When the weather started to turn cold and they started getting into labs that she did not already have experience with, she found the labs much more difficult to make sense of. Coop noticed she was struggling and checked in on her asking, “Are you still doing ok?” She responded, “Yeah, I am just used to it being the second time I'm going through [the labs] versus the first time.” She ended up seeking out extra help from Coop and felt comfortable doing so since she knew him so well. She had not felt comfortable asking for extra help from the physics teacher the previous year. It meant a great deal to Mae that Coop noticed her struggling. “It's one of those things where I was like ‘Ok. He really is paying attention to what’s going on.’ But it wasn't in a confrontational way . . . and it was kind of nice to know that he had noticed that.” Despite hitting the point mid-year where chemistry became more challenging, overall Mae felt like she understood chemistry. She explained, “chem worked in my head. It made a lot of sense to me.”

Despite loving chemistry her sophomore year of high school, Mae did not take Advanced Placement (AP) chemistry. She took AP environmental science and marine biology because her friends took those classes. “The intent was so not to enrich myself; it was to take classes with my friends.” It was not until Mae was trying to figure out what

to major in after not wanting to be a business major that her love for chemistry influenced her decisions regarding what classes to take.

Mae did not speak much about her other high school science classes, but she did reflect on the test questions that her biology teacher would use. He focused on application rather than memorization and his test questions reflected that. The questions would relate to what they learned but would be unlike anything they had done in class or as homework. The students would complain that they didn't know what to do and he would reply, "Yes you do. You just need to think about it. Think about what you know and what the problem is saying." He focused as much on making the students better learners as he did on the content of biology. Despite liking the teacher and how he taught, Mae did not enjoy biology very much. She told me, "bio did not work in my head . . . . I didn't connect as much with the topic. It just didn't make as much sense to me."

College

When Mae chose what University she wanted to attend, she wanted a new experience from that of her private school. She explained that despite loving her private school, she wanted something new. "Once you're there for four years, you're ready to leave that kind of environment." Most of the schools that she visited were NESCAC (New England Small College Athletic Conference) schools and looked exactly like her private school. The "beautiful, remote campuses" were familiar. The vast outdoor space mirrored the endless green surroundings of her high school years. The intelligence and athleticism of the students felt routine in a way that was comfortable, too comfortable.

Mae explained that the similarities between her private school and the NESCAC schools were not unintentional as most boarding schools were modeled after these universities and were designed to prepare students to attend these universities. "We're

kind of the feeder for that." At one of the college visits, Mae said to her parents, "I literally can tell you today what the next four years of life would look like." She could see herself playing competitive soccer. The soccer team would become her family away from home with whom she would spend all of her time, and she would socialize with the boys' sports teams, just like she did in high school. When she envisioned her future self, she thought, "I already am you." She wanted a new experience, something that would challenge her. This led her to being interested in city schools.

When Mae visited George Washington (GW) she felt "relieved." The campus and the surrounding city were much lighter and airier and less stressful and chaotic than she thought they would be based on her frequent daytrips to New York City. A hot and "swampy" day hung over the city when she visited. However, the many open spaces on campus gave her a feeling of fresh air surrounding her. It was not that the city contained the University. The University sat within the city. It felt like an "actual" college that just happened to be surrounded by city. Mae knew this was where she wanted to spend the next four years.

A year after starting her college career at GW, and right after deciding to switch to a chemistry major, Mae registered for all of the classes that she thought a chemistry major should be taking. It took time for the paperwork to get processed, so she registered without having an advisor and without talking to anyone about what she ought to take. When she officially became a chemistry major, she met with someone from the department once and they mapped out the remainder of her required courses together.

Rather than finding the meeting with an advisor helpful, Mae found it frustrating. She was not sure how to request a meeting but found a website provided her with a phone

number. The voice at the other end of the phone directed her back to a website to fill out an online form, which didn't work properly. Finally, Mae searched for the physical office and told the person working, "I need an appointment." Finally, the calendar indicated it was the day that she would receive guidance but the dark room that met her did not feel welcoming and the advisor did not seem reassuring. Mae tried to tell the advisor about her concerns regarding starting late and not doing as well as she would have hoped during her first semester of college chemistry. The advisor just said: "What are you talking about? You're fine." This ambiance made it clear to Mae that this person was not there to try to understand what she was going through or who she was. She left the meeting realizing, "I'm going to have to do this myself."

Since she fit a four-year degree into three years, Mae had to condense the recommended schedule and took classes in an order that was not the order they are typically taken in. Mae indicated that taking courses out of the typical order might have caused her to be missing some expected prerequisite knowledge at times. After the one meeting, Mae never met with an advisor again. She told me "I don't know who my advisor is. I could not tell you. That's been such a shift for me here. That was really hard for me." At her high school Mae had an advisor that checked in with her. All of her teachers checked in on her and the other students on a regular basis. She had plenty of support from her teachers and a close relationship with many of them. It was a large transition for her to not have anyone checking in on her at college. She told me that the lack of support was "a source of shock and frustration" but also motivation to figure things out for herself. Although Mae found this challenging, she felt there was a silver

lining that not having supports taught her to advocate more for herself when she needed help.

Chemistry 1

During Mae's sophomore year she took her first semester of college chemistry. On the first day of class, she saw one girl in the class who she knew from her involvement in Greek life. It turned out that the girl had registered for the class accidently, so she quickly dropped the class. That first day Mae did not notice the twin brothers who were in her class that she also was acquainted with through Greek life.

One night early in the semester Mae was out at a party at a fraternity house. The house was home to many of her best friends, so she knew a lot of people at the party. The music "blasted" and people "screamed," drowning out all other noises. Mae's name was called across the room. "Mae. Come here." The beckon came from a fraternity brother named Gary who was standing with his brother. The brothers' Persian ancestry bestowed them with dark tan skin, dark hair, and dark eyes. Mae tentatively approached. The overfull room exerted a resistance that she had to nudge her way through in order to see what these boys, who she barely knew, wanted. They told her, "We're in your class. We need to study together." Mae wasn't sure how to respond so she just said, "OK . . . . Whatever."

For a while, chemistry provided a topic of conversation anytime Mae would see Gary out. Eventually these conversations gave way to genuine friendship. When Gary got to class on time he would find and sit with Mae. Often his lack of punctuality would necessitate a seat in the back of the lecture hall. In some ways he was always on top of

things and in others he was a mess. Assignments were always completed but were stored in a crumpled mess at the bottom of Gary's book bag.

After sitting together and studying together during Chem 1, Mae and Gary would plan their schedules so that they would have chemistry classes together. Gary continued to be late to classes on a consistent basis, which Mae says "stresses me out so much." Despite his tendency to not be on time, Gary was serious about his studies. Mae said, "he's also the most high-strung and stressed out" student she has ever known. He would ask Mae: "Are you reading today? Are you studying today? Let's do this today." They motivated each other. Mae said to me, "I honestly have no idea what I would have done without him."

Quantitative Analysis

During "quant" Mae had similar challenges to those she had experienced in high school physics. She struggled with applying concepts to application-based and mathematics-based problems. At test time she would say to herself, "I'm just going to try to do something with these numbers and hope it's partial credit. I don't know what I'm doing." Just like with physics, Mae felt she may have been too young and she felt she didn't know how to study for in-depth understanding. Mae described her professor as "so smart and such an actual scientist, out there doing science" but "not a teacher at heart." He would talk through power points without actually explaining the topic.

Mae would commiserate over how lost she was in chemistry with, Gary. Despite it being so challenging Mae loved chemistry. Mae and Gary often asked each other, "Why do we do this?" They felt like friends in non-science majors studied much less, had better grades, and would get higher paying jobs when they graduate. She was not

sure if this was true or just the idea that "the grass is always greener." She sympathized that some of her friends would have to write 30 pages or longer papers, which she thought "sounds horrible." But sometimes she wishes she could work on a paper over time rather than having to study for big tests. The answer that Mae came up with regarding why she kept doing chemistry was, "I think it's just what I'm interested in, what I like. I also kind of enjoy the torture in a really weird way." She explained that she felt so good when she was successful at learning chemistry because it's not easy. "I think I just like hard classes."

Mae had a different professor for the lab section than for the class section. The smaller class size allowed her to connect more with the lab professor. This was one of the only labs during her degree where Mae planned her own experiments rather than being told the steps to do and the professor facilitated their independence. "She has you design your own experiment to accomplish a certain goal." The students were given a problem, read how others had solved the problem, and designed their own way "to make it work a little bit better." Mae felt like the research was her own and she felt like the experience was authentic to what scientists do. "Nobody is revolutionizing one experiment that no one's ever done before. I feel like they're all piggy backing off of something else."

The professor facilitated autonomy in the initial design of the lab and in problem solving during the lab. Often when students would ask the professor a question, her response would be "it's in the readings." Although this made Mae fearful of asking questions, she also described it as a "great teaching moment." The professor's refusal to

provide the students with answers made Mae feel like she was being forced to become more independent.

Because Mae designed the experiments herself, she felt like she was not just following steps without understanding what she was doing, which was how she did feel in many other lab settings. However, designing her own procedure also led to many more mistakes than in other labs. Mae said, "we would be halfway through a period and we would be like 'we did this whole thing completely wrong' And we would have to start over." By the end of the semester, the experiences with failure taught Mae to plan out what she was going to do in labs more thoroughly. Although the students were not always successful, Mae felt the professor was really good at "steering us towards what would be most effective." She felt the professor created a productive environment of "guided helplessness."

Organic Chemistry

Mae took the first semester of organic chemistry simultaneously with quantitative analysis. She felt like second semester of organic chemistry was when she really learned how to study for chemistry. "I remember my orgo teacher, my second semester for orgo, talked a lot about passive studying." The teacher explained that just taking notes from the book and reading through the book or notes was passive studying. Mae realized this was what she had been doing. The teacher explained that active studying was doing practice problems in order to apply the concepts. After applying this active method of practice, Mae did much better in organic chemistry and applied that study method to her future classes. This was a turning point. "That's been a huge transformation for me

between the first half of studying chem here and the second half." Learning to study in an active way changed the way she was a chemistry student.

Mae always studied hard but the way she studied changed after her organic chemistry professor explained the difference between active and passive studying. Also, over time she studied more and more. "I feel like I've developed such a test anxiety that now I have to over-prepare to be like I won't feel like I could have done more. I never want to feel like, 'Oh, I shouldn't have gone to dinner that night. I should have stayed here and studied.'"

When Mae studied after learning how, she read everything she can about a topic. Mae felt like there were some students who understood chemistry just by hearing the professor go over it and she was not like that. "I still have to practice it. Look at it again. Connect it with everything else that we've learned." Mae would get out everything in front of her: an outline of the content from class, class notes, the assigned textbook reading, assigned practice problems, and her computer. She would start by making sure that she really understands the concept by reading everything including class notes, the textbook, and websites about the topic. She would trace ideas to other things that they have learned. "They expect you to have that background knowledge and sometimes I forget or don't have it really figured out completely yet." During all of this she would take notes while trying to make sense of all of the information. "So, I end up taking a lot of notes on it, drawing pictures if I have to, writing things in my own words . . . . The volume of notes that I compile for every single test is ridiculous." She would do this chapter by chapter.

Once Mae was done reading and taking notes, she would do all of the practice problems provided by the professor or by the textbook for that chapter. "And then I'll probably do them again if I'm not getting it." She used to just check her work in the back of the book, make corrections, and move on. After learning how to actively study, she would do problems over and over until she was sure that she understood. "I do things like six time." Mae would rather over-prepare than regret not having prepared enough.

As a tutor, Gary had the ability to reserve study rooms in the science building. He would reserve a room for them almost every day for two weeks before each test. They would meet up first thing in the morning and Mae would take a brief break only when hunger made her dizzy and she "literally couldn't see straight." Glass walls in the study rooms allowed studying students to be part of the common space while having privacy and quiet needed to focus. Despite the openness of being surrounded by glass Mae remembers feeling clammy while studying. Stress and coffee made her jittery and the coldness of the space encouraged her to wear multiple layers. The glass walls also provided large blank spaces for students to work. Mae and Gary would mostly study in silence, together in the space but working alone. When Mae would come across a problem that she had a question about or that she felt was likely to be on the test they would work through it together on the walls. Sporadically a joke that Gary saw on line would cause him to start laughing. Mae said, "I would always think he was working but I would find out he was not doing work." After two straight weeks of preparing for a test, Mae and Gary would go two weeks without seeing each other, until needing to prepare for the next test brought them back together.

Biological Chemistry

Mae took biological chemistry her junior year. She felt like she learned "so much" in the class. "I was learning interesting things like glycolysis . . . and I was really learning how they all interconnected." But she got discouraged when her grades did not reflect her learning. At test time, a "blue book's" blank pages waited to be filled with how the change of a functional group in one chemical process would affect the next process and the next—connections that Mae could not fully articulate. She indicated that Bio Chem was one of the first college classes where the test pushed her thinking beyond what was learned in class. She said, "I'm sure, if I could have stretched my mind that way, I would have gotten them right."

Despite not being as successful as she would have liked on tests, Mae felt good about the class. She worked hard and felt good about her effort and about what she learned. She elaborated, "I had to come to this understanding of myself that it's [grades are] just not what it's about to me." Mae also knew that Bio Chem was just a hard class. She would overhear other students whispering to each other about how hard certain tests had been. Mae felt that focusing on learning instead of grades after that point allowed her to do better both in terms of grades and in terms of how she felt about her learning. Mae partially attributed this shift in thinking to her classes in the field of education saying, "I think that was a big time where I was reframing my whole mindset on classes in general and studying." She said that the education classes focused on growing as a student rather than growing your GPA.

Physical Chemistry

Mae worked particularly hard at understanding Physical Chemistry (P Chem). There were two semesters of class and one semester of lab that occurred during the

second semester of class. Mae felt like the labs connected particularly well to the concepts learned in class, which she described as "really beautiful," a more grandiose description than was typical for Mae. One topic that she learned about during the first semester was cooling curves. She worked really hard to understand this topic that she felt involved a great deal of memorization at first. During the next semester she and Gary did a cooling curve lab. Mae was able to use what she learned during class to complete the lab analysis and really understood what happened. She said to herself, "We've studied this and now I'm seeing what experiment you would actually do to see this concept." In moments like this, she felt the most like she was doing what actual scientists do and felt really good about herself. She explained, "When it works out in a lab setting it feels really good."

Mae felt that the structure of having P Chem lab two days a week really helped her to be able to make sense of how the lab connected to the content that they had learned in class. "On the first day we do the experiment and the second day, the full day is on data analysis." She said that the lab instructors did a really good job of making sure that students got the important information from the lab and understood that information.

Second semester of physical chemistry, which she took her last semester at GW, was the first time that Mae felt like part of the GW chemistry community. This semester she felt like, "I'm a person here too." She felt that she was able to be herself with other members of the class. She and Gary were friends outside of school so they "gravitated toward each other in the major." Neither of them were members of chemistry fraternities or organizations. Most of the other chemistry majors were. Since she and Gary started the major late, all the other students seemed to have already formed relationships, so they

always felt like outsiders. The physical chemistry class was a small class, most of the student had been in the first semester of P Chem together, and Mae knew another student in the class fairly well from her education courses in GWTeach. She began to talk to people other than Gary during class, noting that "it was nice not to be scared to ask them how they were prepping for something or if they had started yet, or what they knew about the teacher and their assessments."

One of the reasons that Mae did not talk to anyone before that was that she felt like the other students knew more than her. "I guess I'm always one of those people that feels like everyone around me is smarter than I am. So, I always get shy about that." In hindsight she felt like she probably knew just as much as everyone else, but that was not how she felt in the moment. "Just in my head, I think I created that." She realized that the student she knew from GWTeach "probably was just as confused as I was." In her last semester she realized that "everyone is super nice." She felt she could text any of them if she had a question or wanted to talk through an idea. In her final semester Mae also learned that the other students who were in the chemistry fraternity had access to a test bank that provided them with more resources to use to prepare for assessments than she had access to. Referencing the test bank, she said, "I was missing out on a lot of things that other people have that make their life easier."

Mae believed that her distance from the rest of the students kept her out of most of the competitiveness that she was sure existed. She thinks that everyone, including her, did not want to feel stupid in front of others by admitting when they did not understand something. She did not know how much other students compared grades. She and Gary would compare test grades and she would typically do a little bit better than him. He

would say, “I need to get a better grade than you in some class someday.” He would get very excited whenever he got a better grade on an assignment. Mae felt like this was “friendly competition” and did not think that either of them really cared that much.

Inorganic Chemistry

In addition to taking p chem her last semester before graduating, Mae also took inorganic chemistry. She really liked the professor. Before this professor she felt like, “none of these teachers know who I am. None of them care what happens.” This was partially due to large class sizes. Mae’s inorganic chemistry professor was one professor who seemed to really care about chemistry and care about her students. Unlike many of the professors who use the same test that was taken from the book every time they teach a class; she made her own test. Mae felt this showed that she cared. During class her enthusiasm for the subject was palpable. She also made it a point to get to know her students. When going over the class expectations on the first day, she said to the class, “Come by. See me. Introduce yourself. I want to get to know you guys. I want you to feel comfortable coming to my office hours.” Mae had never gone to a professor’s office hours after the first class until her inorganic chemistry professor specifically invited. This initial introduction made Mae feel much more comfortable seeking out help during the rest of the semester. “When I have a teacher that I feel comfortable going to, it doesn't make you feel silly for your questions.” When Mae did come for help, the professor took the time to make sure that she was really understanding the concepts rather than trying to rush through things.

Mae also liked how “application based” the inorganic chemistry test questions were. “I think some teachers, their tests force you to study a certain level of

material. And then their tests push it a step further. But not in a way where you're banging you head against a wall." Like her high school biology teacher, Mae's inorganic chemistry professor wrote problems that went beyond what they had previously practiced. The professor provided many practice problems that required different skills and different ways of thinking about the concepts, but the test was never just like the practice problems. When Mae would first see the test problems, she would feel like, "I have no idea what this is asking me." Then she would try to look at the problem from "different angles" and would figure it out. Being able to figure out problems by putting together multiple things that she had learned made her feel like she really understood. She told me, "where I can connect practice problems to an application, I always feel really good."

GWTeach

Near the end of her sophomore year Mae began thinking that teaching might be a career that she wanted to think about. "I was thinking about dental school or something like that. Then . . . [a professor] came into my chem class and told us about GWTeach, the undergraduate STEM education program at GW, and I was like 'OK. Let's do it.'" A "drab" lecture hall provided the backdrop for the class. Stadium seating allowed the students to see the slide after slide of Power Point presentations. Then a "goofy" professor with a "good energy" woke up the class by "selling" GWTeach to the students. He emphasized the point that through the program students could get certified to teach while getting a degree in their field of study. Both Mae and Gary thought the program sounded interesting and contemplated taking the first class.

Mae remembered that in high school she thought that she might want to teach chemistry and be just like Coop but didn't know how to become a teacher. She hadn't really thought about it between high school and the end of her sophomore year. The first GWTeach class was one credit, which allowed her to "dip your toe in the water." The program ended up giving Mae direction. She said "it was a nice little beam of hope for me." It provided her a path but didn't limit her if she decided to do something different with her chemistry degree. Mae loved the close relationship that she had with her high school teachers and felt a real loss when she did not have that at GW. This made her want to have the impact on people that her teachers had on her. "I think it really made me appreciate good teachers and what it means to really know that a teacher knows what's going on with you."

Mae's parents were supportive of this decision but focused on potential paths beyond being a high school chemistry teacher. Mae's mom said, "If you're going to teach, you're going to become the highest level of a teacher that you can be . . . . You're going to go back to grad school. Maybe get your PhD or your masters . . . . You can become a dean or a professor . . . . I know you and I know you're not going to want to be a low-level high school teacher forever." Mae's response was, "maybe if I love it, that will be what I will do, but it depends." Mae clarified that she thinks her mom did not want her and her sister to become "stagnant" and that it was a fear of hers too. She wanted to travel and have unique experiences and did not want to get stuck in a "bubble." Mae said that one of her considerations was that a teacher's salary can support her as a single woman, insinuating that having a potential family one day may motivate her to seek a higher paying job. She indicated that getting a high-paying job was a point of

competition at GW but she did not feel the need to make a great deal of money. "I literally can go to the beach for a week straight and not do anything, not spend any money."

Mae started GWTeach her junior year. This was enough time for her to get a minor in STEM teaching but not enough time for her to get certified without staying an extra semester. She had to take about two teaching classes a semester to complete the minor by graduation. She found an academic community with the other students and the instructors in GWTeach and she felt like the teachers really cared about her. Mae said that another teacher in the program and I "have really been the first teachers that I have really been comfortable talking to after class about stuff." She felt it was the first time her professors looked out for her and cared about what the students thought. Mae also found that she really enjoyed teaching. "The more I taught in our classes; I just really like the energy. I really like how every day is different. It's never boring. You get to interact with kids." She loved getting to know what was going through students' heads and being able to explain something that she herself struggled with at times.

Given what she was learning in her education courses, Mae found herself evaluating her experiences in chemistry classes "from an education standpoint." When feeling frustrated in a class she would think to herself, "Why is this not working?" A universal answer to that question did not present itself because Mae only knew what worked for her, and knew that what worked for her will not work for everyone else. "Every learner is different." Mae could sympathize with how difficult teaching is and therefore found it hard to criticize her teachers.

The biggest critique May had of her science classes was something that was not the professors' fault, the class sizes. With 100 to 150 students in a class, "of course they're not going to be able to have an extremely personal connection with every single person." In hindsight Mae felt like if she had gone to office hours more, she would have done better in all of her classes. Mae also noted that most of her chemistry professors focused on doing their research, not on teaching. "Most of the time they're really here to be doing their research. Or sometimes it can feel that way." Professors gave off the impression that they cared more about their research by not showing up to class for several weeks and having a post doc teach instead. She pointed out that some professors, like her inorganic professor, did "important" research *and* gave off the impression that they cared about teaching.

Mae completed the minor in STEM teaching and did not stay longer to get a teaching certification, but she wanted to teach. She considered doing Teach for America (TFA) when she graduated, but decided against it. "It was really exciting to apply for TFA . . . . It was the first opportunity that I had to apply to a post. grad. job." She was excited about being able to really make a difference in struggling communities but felt unsure about how her upbringing would impact her ability to be successful. She thought to herself, "I don't know how I'm going to be able to handle these situations when I come from such a different background." She decided that she wanted to get some experience teaching and grow as a teacher before stretching her boundaries.

One teaching option that did not require a certification was teaching at a private school. This option was appealing to Mae. The school that she ended up accepting a position at was very similar to where she went to high school. Mae liked that she was

familiar with the structure of having many roles: being a teacher, an advisor, and a coach. Describing the structure to me, she said, “The expectation is that you coach two of the trimesters. You, obviously, advise in a dorm.” Familiarity was one factor in choosing where she would work, but it also was a two-year commitment where the school paid for most of her Master’s Degree and provided a salary while she lived and ate on campus. The school was in her home state, which she said was not necessarily a selling point. Her sister will also be at medical school in that state. They both have said to each other that they did not want to end up where they started and wanted to be in cities, but something pulled them closer to home. “I feel like my parents put it out in the universe to bring us home.” One of the best things for Mae about living so close to home was that she would have her Jeep, something that I have heard her talk about many times. “I love driving, you know. So, I’m happy that I’ll have that.”

Mae seemed more nervous about her graduate studies than about teaching. She said that she needed to spread out her work because she was not used to having to write as many papers as the program would require. Laughing, she said that she will “set Bitler deadlines,” referencing the structure that I use for writing papers in the classes that I teach.

Mae said that if she had not turned toward teaching, she might have tried to get experience working in labs in order to figure out what she ultimately wanted to do with her chemistry degree. Although she never felt like being in a lab was something that she was interested in, she indicated that she still might decide to do something other than teaching someday. “My friends and I have been talking so much about post. grad. jobs . . . . They feel like the first job that they get is selling them into one industry or one job or

one role. I don't really have that same feeling." Mae went on to say that she was not sure if she would love teaching because she had not done it for an extended period of time before. After her two-year commitment teaching, she said she may continue at that same school, or teach at a different school, or get a PhD, or go to dental school, or switch to a totally different field. The list of potential options seemed to have no limits. "I could easily be one of those people that's had so many different roles in her life by the time I'm 45. I could have had several different jobs in several different industries." She did not feel limited to one job or even one field. "I'm fine with that [changing jobs] if that's what ends up making me happy." To be happy Mae felt like she needed an environment where she was around people "My number one thing is just being around people. I love that." She also felt happier when she was physically active.

Mae felt that if she were to continue studying chemistry, which seemed to be at the bottom of her list, she would be most interested in going into pharmaceuticals or cosmetics. She believed that the role of a scientist was to try to "come up with solutions for really any type of issue." She was more interested in trying to solve people's health related issues than other sorts of issues. Mae said, "when you end up doing research it does end up being so specific to one thing that you have to be really interested in it or you'll probably drive yourself crazy." Mae would only want to study something that she was interested in during her everyday life, like make-up, lotions, or fragrances. "If I'm not interested in something, why would I dedicate my time to it?" Since she had not found one aspect of chemistry that she was that passionate about, she did not see herself continuing with studying chemistry.

Chapter 6: Nathalya

Writing on a Plane

"Nací en Bogotá, Colombia." "I was born in Bogota, Colombia." Nathalya once began writing her life story while between Austin, Texas and Washington, DC, returning from a conference. During the conference Nathalya attended a session titled "The Negro Scientist." The session focused on early Black scientists who were previously unknown to many including Nathalya and it inspired her to write about an unknown scientist, but the confinement of an airplane left her unable to do research. Then she realized that she herself was a scientist of color. She said to herself, "let me write about my life."

The view out of the window gave a place for her gaze to rest while reflecting on her life. The roar of the jet's engines drowned out the tapping of her fingers on her iPad's screen. The enforced confinement and sedentariness of plane rides between Colombia and DC or, like this time, to and from a school-sponsored conference has often inspired Nathalya to write. Writing was something that Nathalya enjoyed to do and used to do frequently for fun, but now tends to do only for assignments or while traveling. As she explained it, "I like writing a lot . . . . I used to write just because it was good way for me to talk about things that I maybe couldn't talk to anybody about." But during this plane ride, Nathalya had a purpose.

So, reflecting on her own life as a scientist of color, she started writing. "I was born in Bogota, Colombia." She then recounted many childhood memories, writing in Spanish as she does all of her non-academic writing. Although Nathalya never shared this writing with me, the act of writing seemed to solidify some of her early memories in a way that made the accounting of her life easy and freshly recalled. The words of the

stories she shared with me often flowed easily, wrapping me into the world she pulled together from memories, family stories, and more mature sense-making later in life. Her quick talking, punctuated with large hand gestures often pulled on my heart or left me in suspense. Previously meeting with me in my role as her teacher or as her advisor, intense eye contact would communicate her engagement in our conversation and passion for her academics, but during these meetings she usually had a distant gaze, as if her past was physically pulling at her.

The details Nathalya shared made me feel like I was with her on a journey. But, at other times heavy statements were vague, communicating that the topic was not something Nathalya was willing to describe in detail. It was possible that some of the time she didn't know more detail as they were recollections from her childhood. Her cool, calm, objective story-teller demeanor was in contrast to her fiery, deep brown, almond shape eyes and her exotic Colombian accent. We met five times during a hot DC summer. After explaining to her that I wanted to hear about her life and her experiences in science, her story flew out her with very few pauses or breaks, leaving me little chance to follow up with specific questions.

Nathalya's life story often melded with her mom's story and, sometimes, that of other family members. Her words and body language communicated that she felt her family's history and her early years shaped who she became later in life. She began by telling me how her father and mother met. Her mom had Nathalya's two older siblings with a man who eventually left for the United States and started a new family. She explained to me what happened after this man left: "My mom lived in this neighborhood and my dad lived across from them . . . . My dad had his family, house, apartment, he had

a good job, everything. And he had two kids who were five years older than my siblings . . . . They fell in love, whatever. His family fell apart. But he left everything for my mom." He started by helping her as a neighbor who saw the hardships she was facing raising two children as a single parent. Then they fell in love.

Nathalya was born almost ten years after her mom and dad met. She was born during a time of great upheaval in her parents' lives. As she said, "around the same time I was born, on my dad's side of the family, lost a brother. So, my uncle . . . . Crime, street crime, vandalism is a huge thing in Bogota." Her uncle went missing a week before she was born. Because her father was dedicating all his time to trying to find his brother, he was not there when Nathalya was born. The family later found out that he had been robbed and killed.

Nathalya's dad was one of 13 children but three of them died early in life. Only two of his siblings completed high school. Her dad did not, but he worked very hard and had several successful businesses over the years. Because he left his wife to be with Nathalya's mom, Nathalya was often treated as an outsider by his extended family. Nathalya never spoke specifically about her half siblings but did talk about family gatherings. She explained how it felt saying, "things that I remember vividly is when all those people would talk about me, that I had no idea what they were talking about." Later reflection helped her to recognize what she was too young to understand at the time; her father's family blamed her mom for taking him from the successful life that he was living before meeting her. That animosity bled into how they treated Nathalya.

After the first few years of her life, Nathalya's parents went their separate ways and her dad was not very present in her life. She told me, "He was never in the picture. I

just got close with him two years ago." During Nathalya's life he experienced financial difficulty and didn't help her mom out with money nor did he give Nathalya or her mom any emotional support. Any time her parents were together, they fought about his lack of support. At the time that we met, Nathalya had formed a better relationship with her father. She explained, "I don't like hating anyone because it's just not healthy for me because it's like, they don't know that you hate them. They're not going to gain anything or lose anything if you hate them. It's all within you. I like to be at peace. I like to just not have so much hatred in my life. I feel like that makes you angry and I'm sort of a happy person."

It was very clear talking with Nathalya that her early experiences were something that she reflected on and felt made her who she is. These experiences seemed to shape her into a caring, tenacious, resilient person. She did not, however, explicitly reflect on how these experiences shaped her later scholarly endeavors and career path.

Sitting on a School Room Floor

Most of Nathalya's elementary and middle school education was in private schools in Colombia. Her siblings, a brother who was ten years older and a sister who was nine years older, started their education in a public school in Bogota, the capital of Colombia. However, as Nathalya casually, while looking into blank space, told me, rape was common in public schools in Colombia's capital. The glossing over of the statement and quick moving on was a clear indication to me not to ask further questions. Nathalya's mom, therefore, moved her sister to an all-girl private Catholic school and her brother to an all-boy private Catholic school.

When Nathalya started kindergarten, she went to the same school as her sister. As someone who "didn't have an education," Nathalya's mom greatly valued her children's

education. She worked extraordinarily long hours in order to be able to afford private school for her children. Nathalya stated that, "I never saw my mom."

Nathalya's mom worked since she was five "washing shirts for a tailor or something." Nathalya's maternal grandparents were not very present in their daughter's life. Her grandparents, who died before Nathalya was born, were burdened with alcoholism, and raising nine children. They worked incredibly hard to be able to provide what they could for their children. Having parents consumed with work and their addictions, the children mostly raised themselves. Nathalya's mother was the youngest. The situation at home left her unmotivated to go to school, looking for ways to earn money during the day and seeking other places to sleep at night. At ten years old a family who lived nearby took her in. Nathalya explained: "They gave my mom housing, education. It was a public school but they took her in. They gave her food." Because of the support of this family, she was able to get a high school certificate and saw that children could make it further than the generations before them if they had the right supports and opportunities.

Although private schooling provided a great opportunity to Nathalya and her siblings it came at more than just a financial cost. Nathalya explained to me that being upwardly mobile in Colombia was not perceived well; it was seen as arrogant. "They have this mentality that if you were born poor, you die poor." For example, when Nathalya would get a nice toy at Christmas or would move to a better part of town, people, often in her extended family, would judge her and her mom for trying to live like they were more privileged than they were. This way of thinking was very new to me. My American upbringing instilled in me that the ultimate goal was to do better than your

parents, the American dream. A member of my writing group, who was raised in Egypt explained to me that elevating one's social class was also frowned upon in her culture. People saw these behaviors as acting white or acting Western and turning your back on who you really are.

Despite being raised surrounded by people who saw upward mobility as arrogance, Nathalya's mom did not believe that her children should be stuck in their current social and economic status, perhaps due to the influence of the family that took her in. She worked hard to give her children every advantage.

The one exception to Nathalya's private schooling in Colombia was one year, second grade, spent at a public school in a city two hours outside of Bogota. Nathalya had moved there with her mom in order to "start over." Her siblings did not come with them, but went to live with different members of their father's family. With family they would be away from boys and other "bad influences." Her mom could not take care of all three of them and work as much as she needed to. She kept the youngest, Nathalya, with her and found other alternatives for the other two. Nathalya said, "my mom couldn't really help us all three out, so she paid for my sister's education. She helped my brother a little bit, but she helped me the most."

They left to get a fresh start financially and because, as Nathalya said, "she fell in love with someone who was married, and didn't want to do that, so we moved out." When they got to the new town, they went to the local Catholic school. Sitting in a waiting room, Nathalya could tell that her mom was nervous. She didn't know what was wrong because she was confident that she would do well on any assessment that they gave her. She found out later that since private school was expensive Nathalya's mom

did not have enough money to pay the outstanding balance when they left Bogota. This meant the school would not release her records, which in turn meant that she could not enroll in a new private school in their new city. The nun they met with was very dismissive of their situation saying there was no way that Nathalya could be enrolled. Sitting in that waiting room, Nathalya watched her mom as she cried that she had to put Nathalya in public school, a school that engraved itself on Nathalya's memory.

At seven years old Nathalya sat on a dirty floor in an unfinished two-story house with a notebook. The teacher's chalk screeched on the blackboard that was a size better suited to individual work than class instruction. The teacher wrote the ABCs, trying to teach the students the basics of reading and writing, something Nathalya already learned in kindergarten at her private school. As the teacher drilled counting, Nathalya reflected on division, which her cousin had already taught her. I imagine her daydreaming, doodling, counting the cracks in the concrete ceiling, anything to keep her mind occupied.

Sweat soaked Nathalya's uniform and that of all of the other students. A longed-for but slight breeze periodically found its way through one of the "windows" which were better described as holes as there were no actual windowpanes. Sensing the need for some fresh air, the teacher would call a break. Nathalya would hurry outside, searching her pockets for the fifty cents her mom gave her that morning, to buy an empanada from a lady who made them fresh every day. Two classmates would join her buying a piece of cake, a sandwich or a piece of fruit. These same three kids ate a meager snack together every day while their classmates glanced at them out of the corner of their eyes, wishing they could afford something to eat, likely not having had breakfast that morning. By the

end of the day Nathalya ran home so that she could use the bathroom since she didn't like to use the one at school which was co-ed and had no running water.

Nathalya and I often met outside to talk about her experiences. It was summer time and other than a quick trip to visit her mom, she was on campus all summer. The day that she was recalling her experiences in the public elementary school we sat on a bench in the middle of grass filled courtyard shaded by trees. We paused our conversation to watch a group of daycare students walk through the space talking and laughing and enjoying the fresh air. We briefly commented on how cute the kids were without reflecting on or even seemingly noticing the stark contrast between their current experience and what she was describing.

Making Herself Dinner

After one year in the new city, Nathalya's mom said to herself, "If I'm just going to be a hair stylist, I'd rather do it in the capital because I know I'd get more money there." So, they moved back to Bogota. Once back in Bogota Nathalya returned to a coed private school that was not as good as the school that she spent her first two years in, but much better than public schools. In order to provide private schooling for her three children, Nathalya's mom worked a lot. After barely finishing high school, her mom got a "prestigious" job as a secretary. However, with a lightness and nonchalance that did not match her words, Nathalya said, "they hired her because she had big hips and a good body. So, people took advantage of that." To get away from being treated like an object she changed jobs a few times until she became a beautician. She would often work 18-hour days, seven days a week and Nathalya spent a great deal of time by herself.

By the time she was in third grade Nathalya would walk home from school alone, do her homework, make herself dinner, play Barbies or watch TV, and put herself to bed.

Nathalya's mom had strict expectations for her daughter. Nathalya explained her strictness saying, "She was the mother and the father and everything for us. She had to be so strong in life . . . . So, she was so strict all the time." Nathalya would clean the bathroom and wash her own clothes. She was supposed to listen to classical music on the radio rather than watch TV, and she was supposed to read. Despite not having much, her mom would make sure there were always books in the house. Her mom would say, "I'm not going to be home, but when I get home, I want you to talk to me about the book you read." When home, her mom would read aloud to her.

In hindsight Nathalya found it interesting that despite not having obtained higher education, her mom encouraged reading. She said, "This past semester in CI [an education course] we read an article about underrepresented, or minorities and how they learn versus parents who have been educated and how they read to their children . . . . She [mom] was trying but she wasn't able to formulate questions that were probing questions or could get me to think." She went on to describe how her mom would check that she understood the book but didn't know what else to ask. She reflected on the fact that both types of parents are trying to do what was best for their children but educated parents have an advantage.

Partying with "Friends"

Nathalya remembers feeling really lonely during third through fifth grade. She told me, "I guess that's where I realized that I was really lonely, that I had nobody there with me, that I had to do everything on my own." At the age of 12, the toll of being self-reliant had on Nathalya became evident. When she entered secondary school, she made some friends who were not good influences on her. Her two new best girlfriends were wealthy and had parents with very few rules. The fact that they showed interest in

Nathalya made her feel like, “wow, I'm cool.” The girls would go to one of their apartments after school. Nathalya explained the allure to me saying, “She had money. She had a nice house. She had a family. I was there. So, I felt more of a home there than my own house.”

Unfortunately, the apartment was not just a place to go, it was a place to party and drink. Nathalya’s parents never really drank or smoked, so it was totally new to her. Reflecting on why she drank, she explained, “I’d forget about things and that was great because I didn’t want to be in reality.” Her grades dropped and she started making bad decisions. She would skip school, sneak out, and go to parties. She explained, “For a lot of years I expressed my, I guess the lack of having a parental figure through just misbehavior and not doing well in school.” Nathalya’s new friends convinced her to think, “I shouldn't be so nerdy. Why don't I try to enjoy and be cool?”

Since she worked long hours, Nathalya’s mom didn’t notice right away that things were going downhill. In sixth grade Nathalya managed to maintain decent grades despite her afterschool activities. Her mom would ask, “what’s going on there?” and she would reply, “I’m just feeling tired.” However, in seventh grade, things started to slip more. She was failing five classes and was partying frequently. She explained to me, “I was also trying to get my dad's attention. . . and it was affecting my mom instead. It wasn't affecting my dad at all. He wasn't there. He wouldn't know what I was going through.”

One Friday night at midnight Nathalya’s mom came home from work and found her drunk. She grabbed some trash bags, threw open dresser drawers and started throwing all of Nathalya’s clothes in the bags. She said, “I’m done. Call your dad right

now." She then said to Nathalya's dad, "I'm tired because I've given her everything . . . . You just need to take her."

As mentioned, typically "conversations" between Nathalya's parents involved mostly yelling, no matter where they were or who was watching. Nathalya explained to me that her mom was often the fiery parent and her dad was usually "chill." Her dad seemed to realize that he needed to be serious and calm in this situation saying, "let's try to talk this out." He talked Nathalya's mom into letting her stay.

Unfortunately, the first time that Nathalya and I met I had another obligation, so we had to wrap up after an hour of talking while she was sharing about this pivotal time in her young life. I was so intrigued by her story, particularly knowing what a strong and outspoken person she became. I could not wait for our second meeting which ended up being almost a month later due to both of our summer plans.

Listening to Metal while Reading Philosophy

The next time that we met Nathalya picked up her story where it left off. In the week after Nathalya's mom found her drunk, both of her siblings made a point to talk to her about what was going on. They expressed concern and told her that they thought that she should get help. They said, "go to the guidance counselor at your school and talk to them." Nathalya did start to talk to people at school telling them about the drinking, about how she was feeling and what she was going through. Without any break in her story-telling flow or apparent emotion she said, "I think I developed some depression so I started getting suicidal thoughts and I had a few incidents." She told the guidance counselors everything, not specifying to me what "everything" involved.

There were some things, like her suicidal thoughts, that she knew the counselors would have to tell her parents, but there were other, again unspecified, things that she was

assured would be kept private. They were not. Nathalya explained to me that this experience made her untrusting of people. Even feeling like she could use support later in life at GW, she was unwilling to go to mental health professionals. Nathalya told me about these experiences and feelings on a hot summer day. Limited shade encouraged us to sit facing each other on the same side of a picnic table. From talking about her summer travel plans to talking about suicidal thoughts, the only breaks of note were when seasonal allergies caused me to sneeze.

The upside of the counselor talking to Nathalya's parents was that they started checking in with her more. Her mom started calling her when stuck in traffic to make sure that she got home from school. Her dad started asking her how she was doing. Things got better. "Somehow" she passed that year and she realized that her wealthy friends were "fake." She realized, "I don't want to be getting drunk after school on a weekday and getting back home at 7pm to do the [school] work. That's not who I am. I don't think that's who my mom wants me to be."

Nathalya said, "then eighth grade, I remember, that was a changing point for me." After her two-year excursion into rebellion, Nathalya didn't drink again until college. The summer before eighth grade she started reading books and became very engaged in social media. She explained, "I started developing other interests. So, I got really into rock and metal." Though she was not allowed to go to concerts, she would come home from school, rush to get out the school uniform that she hated, do the dishes, then shut the shades to make her room dark, and watch "That's Metal Show" on VH1. Then she would read for her philosophy class or get online to read or write about metal, religion, and politics. Social media allowed her to make friends who shared her interests.

Nathalya's interest in metal and rock was something with which we could relate to each other. The music scene was also a huge part of my high school experience and our continued interest in that genre of music was something we discussed. For those who are not in that scene, it might be surprising that an interest in metal often goes hand-in-hand with political awareness. Metal was started as a statement of rebellion against societal norms and over the years has continued to provide a platform for dissonant expression.

Reading online and reading books became Nathalya's "new type of coolness." Because she enjoyed reading, she would actually read what teachers assigned. She started doing really well in school, and started voicing her opinions in class. Nathalya said to herself, "I have this argument. I want to support it." She enjoyed being informed and using that information to make points.

Nathalya also discovered an interest in philosophy. In ninth grade she had a philosophy class. She got very close to the teacher and loved the material of the class. Then, halfway through ninth grade she moved to America. She told me, "I felt like I was just getting started." Then she had to start again in a new country with a new language.

Moving to the United States

One day Nathalya's mom told her they are moving to be with her mom's new husband who had been in the United States for a while. Nathalya had just begun to get invested in school, just developed a new group of friends, and just started dating someone. Leaving all of that behind was hard because, as she explained it, "I felt like I still had a piece in Colombia." Not only was she leaving things behind, but she was entering a whole new world. They moved from inner city Bogota, Colombia to a

suburban part of Connecticut. Everything was different. She described it as an "other country, other culture, other language, other everything."

Nathalya, her mom, and her step-dad moved on the edge of the wealthier area, near her step-dad's sister who had been in the area for a long time. Her step dad, who came from an educated family, had an agricultural engineering degree from one of the most prestigious universities in Colombia, but regretted not studying law. He worked as an engineer in the states for a long time before starting an unsuccessful construction company, going to law school for a little while, and then becoming a paralegal.

Nathalya did not really speak English when she moved. Her school in Colombia had an English class but they only learned some verbs, not how to communicate complete thoughts. She said, "So I knew words and vocabulary. I knew a lot of that, but I didn't know any grammar, structure, writing, comprehension. Nothing." She did not feel like she could understand or really communicate in English.

When Nathalya first visited the school, she was overwhelmed by how huge it was, nothing at all like schools she had been to or even seen before. Two ladies met with her to decide what classes she would be placed in and what supports she needed as an English Language Learner: one "Puerto Rican lady" and one "American lady." She could not really understand them. Although speaking Spanish, the Puerto Rican lady's strong accent made it difficult for Nathalya to make sense of what she was saying. At first, Nathalya was fearful that she would have to take a test, but relaxed a bit when she found out that she did not. Nathalya completed half a year of ninth grade in Colombia, but since their school year does not align with the American school year, it was determined that she would start her freshman year again. The ladies seemed to argue a bit

but when they finally made a decision, Nathalya had blind faith that it would be the best decision. She was placed in intermediate level ESL (English as a Second Language) with other student immigrants who spoke a variety of languages, mostly Spanish.

Nathalya's school had a fairly large Latino population including five Colombians. There were about 100 students in the ESL program. She said, "I was meeting people from every place like Mexico, Guatemala, Peru, even from Colombia." There was also a large Haitian population. The other students in the ESL program called her "Rola," a nickname for people from Bogota. Although, the internet informed me that the term has historically had a derogatory connotation, Nathalya did not seen to take offense to the nickname. Only one other student in the program came to the states within the past six months; most of the students were in the ESL program for two or three years but still were unable to converse in English. She said, "I started noticing those education gaps, like those achievement gaps. And I was like 'wow. There's something off'."

In addition to still working toward English proficiency, many of the students in the ESL program did not have much education before coming to the United States, so Nathalya felt like she was "at a higher level of education" than most of them. But, without knowing English, her education did not get her very far at first. All of the ESL students were put into the same subject classes, the easiest classes the school offered. With a resentful tone, she explained to me, "I was just taking algebra one and earth science." Nathalya found the classes easy even with the language barrier. She said she could finish the work assigned in a few minutes.

Nathalya was also accidently placed into an introduction to business class. It was not a class she was particularly interested in and it was not a class that ESL students were

typically placed in. The ESL students were all typically placed in the same remedial core content classes with a translator. The business class was the only class she took that did not have a translator and did not have any other Spanish speaking students. She felt like all of her classmates and her teacher spoke really fast, which I have to laugh about while transcribing Nathalya's incredibly fast paced accounting of the experience. In order to not be put on the spot, she would pretend to know even less English than she did. She said, "whenever people were speaking something to me or saying 'hey did you did do the homework?' or 'how are you today?' I would be like, 'no English' because I was so shy." She felt like people looked at her like she was "an alien or something." It was difficult for me to picture Nathalya during this time of her life, as "shy" was a word I would never use to describe her.

At first, following anything that was happening in the class was impossibly difficult but over time it became easier. She said, "by the end of the year, I was able to pick up a few things that he [the teacher] was saying." She attributed the improvement to not having a translator. When I told her that the district I taught in used an immersion strategy with English language learners, Nathalya seemed torn when articulating her opinion on bilingual education. Starting and stopping with several different sentences, she eventually said, "for me, at first it was frustrating not having the translator in the classroom, but it also forced me to seek out for myself." She said the most helpful thing the translator would do in her other classes was explain specific words, but she also wondered if using a dictionary would have been just as helpful. She questioned who would bother learning a language with access to a translator all of time. Without

explicitly saying so, she seemed to attribute her fellow ESL classmates' lack of progress to their constant access to a translator.

At the time that we were talking, Nathalya had taken several education courses, so inevitably she also reflected on bilingual education from the perspective of a teacher. She said, "for the teachers' perspective, they're lost. They don't know if their students are learning. They don't know when to stop talking so that the translator can interfere. They don't know. They can't have that one-to-one relationship."

Despite struggling with understanding the fast-talking English-speaking teachers and students during her first year in the states, Nathalya always completed her homework and she completed it quickly. In the classes she had with other ESL students they would say, "Rola, come here. Help me out with this." She would explain concepts that she already knew or picked up quickly to her classmates who seemed to have no prior understanding. The teachers would also ask her to help her classmates when the translator was busy. At first, helping seemed to provide a way for her fit in with the close-knit ESL community, but eventually she felt taken advantage of. The students started asking her to do their homework during lunch in addition to helping them out during class. Rather than making her feel more a part of them it made her want to distance herself from them.

Pushing Back Against Counselor Advise

Throughout her first year in the states Nathalya gained more confidence in her academic abilities and more frustrated with the opportunities she was given. She said to herself, "I feel like I want more out of this and I'm not getting it." She also wanted to separate herself somewhat from the identity of being an ESL student in order to become more a part of the school at large. She explained to me, "I feel like we were an isolated

group. That we were looked upon lower than everyone else." Since all of the ESL students took remedial classes together all day, they really operated as one, insulated unit. Though there were other students in their classes, they rarely interacted with the other students, particularly given the language barriers.

The school served a very wealthy community and a highly impoverished community. Nathalya explained, "there were people who owned yachts and Ferraris and things like that. And then there were people who lived in public housing." She noticed that the students in the advanced classes seemed very privileged and seemed to look down on other students, including, she felt, students with accents. The lower opinions were reinforced by the fact that many of her ESL classmates were not interested in school. She reflected on their perspective regarding education saying, "maybe because they didn't have the resources or maybe because they come from a family that only worked and they didn't know what school was." She explicitly and reiteratively told me that she did not think less of her classmates who aspired to start working right out of high school, but it was not who she was and didn't appreciate the perceived assumption that her classmates had that she did not value education.

After about one year in ESL, Nathalya went to her guidance counselor and said "I wonder if I can take this class that I saw that you guys offer. I think that it would be interesting." The counselor responded, "You're an ESL student. Why do you want to take it?" So, in order to show her ability, she requested to take a standardized reading, writing, and math test that all of her classmates took at the end of middle school. After less than a year in the states, she was hoping that the test would show she was capable enough to exit the ESL program and enter the main stream education program. She must

have done well enough to prove herself because in 10th grade she was "fully immersed with everyone." By 11th grade she was in mostly honors classes and by 12th grade she was taking advanced placement (AP) classes.

About a year after Nathalya requested to be tested her step-father told her that the local community college allowed high school students to take classes. She thought to herself, "This is awesome. I want to take an anatomy course, I want to take a biology course, I want to take a philosophy course, I want to take a math course." She again went to her counselor to discuss the option, to which the response was, "You could do it but it's going to be really hard, you know that? You've only been in the country for two years." At that point Nathalya decided to give up on going to counseling for advice and saw their position as something she had to learn to work around. She asked her counselor to just sign the needed paper work, which she did.

Her senior year, while working on college applications with her guidance counselor, Nathalya indicated that she wanted to apply to George Washington University (GW). Although she had never visited GW, she wanted to go to school in the city because they, "have more people from all over the place." Despite Nathalya having a 4.0 grade point average, the counselor replied, "you know GW is a big school. It's ranked up high…. Since you've only been in the US for three years and half, why don't you just stay local?" The counselor advised her to think about starting at a community college, the same one that Nathalya already took classes at for two years, doing very well in those classes. She also advised her to apply to several back up colleges. Perhaps applying to backup colleges was good advice for any student, but to Nathalya, it felt like another assumption of ineptitude based solely on her identity as an English language learner.

I asked Nathalya how she learned to advocate for herself. She replied, “I started seeing those patterns of being so strictly segregated, and me being like, ‘Ok. But don't forget I actually care about my education’.” She continued by explaining that her mom’s emphasis on getting educated always stayed with her and motivated her. Also, her mom was a role model, practicing what she preached despite not having the opportunity to get a higher degree herself. When they came to the states, at age 40 or 45, her mom enrolled in English classes at the community college. She then completed a two-year program to get a cosmetology certification. She had the option of completing the program in Spanish but chose to complete it in English, saying, “I have to speak English” and “if I want to be a hair stylist, I need to have a license.” Nathalya thought to herself, “If my mom was doing it, why not me."

Seeing Her Sit in Front of a Desk

The third time that Nathalya and I met, again outside, Nathalya was wearing a dress and makeup, which was not typical for her, and her long hair was up in a bun, which was typical for her. When I told her that she looked nice, she explained that the dress was both professional – for her summer internship – and cool – since she knew that we would be outside. After talking for a little while about her work, I asked her about her history with science. I said, “It's interesting to me that you told me your whole life story but science didn’t come up at all because you now are studying science.” This was met with an uncharacteristic moment of silence and was a turning point in the cadence of our conversation. The previous quick-paced story now held more utterances (like, um), false starts to sentences, and pauses. The back-and-forth became more typical to conservations that emerge rather than previously orated and recorded recollections.

In response to my expressed surprise regarding the lack of science in her history, Nathalya explained that, starting in elementary school, math was always something she loved and was good at. But it seemed to her like a school subject, not something with application. In fact, she never really recognized much of an application to math until high school physics during her senior year. For a short period in middle school, she wondered if, since she was good with numbers, she should become an accountant. Because of this thought she paid more attention to her aunt, since she was an accountant. She watched her aunt at work and listened to her when she talked about her day. Nathalya quickly realized, "no, I don't want to do that anymore." She explained to me, "it's just sitting around and it's always in front of a desk." She said to herself, "I want to move around, be more social."

After Nathalya moved to the states she had even more of an opportunity to see what accounting was really like because she would help out her step-father's sister sometimes, particularly during the summers. Papers would get filed and numbers would be input into QuickBooks. She realized she liked it even less than she thought she would. She explained, "I thought it would be more of analysis or like with economics you actually have to know more math and apply stuff." She continued by explaining that she felt accounting was just keeping track of people's "cash." So, accounting, and seemingly a career in math was out of contention for future careers.

Buying a Book by Its Cover

After describing her interest in, but lack of career options with mathematics, Nathalya explained to me her history with science. She transitioned with, "science came actually pretty late." In middle school, philosophy was the only thing that held her passion. When she asked her teacher about jobs related to philosophy, he said, "if you

want to be a teacher you can be." She ironically – given her future studies in education – responded, "I don't think so!" She explained this initial lack of interest in teaching by saying, "it's also part of the culture that if you don't study economics or medicine or engineering or law then you're not as worthy." Cultural ideals made teaching out of the question.

Early on, Nathalya's mom tried to persuade her to pursue medicine saying, "one of my three kids has to be a doctor." At this point her brother and sister were already studying at University so it was too late for them to choose a path in medicine. The suggestion didn't seem to pressure Nathalya. She would say, "Well, that's not going to be me, mom. Unless you have a fourth child and then they want that." From her own experience, she pictured a doctor as someone who sat at a desk, looking at a screen, asking, "how's your eating habits? Do you sleep enough?" She didn't see that they had any real impact. A few short years later, an unexpected occurrence changed her perspective on studying medicine.

Near the end of middle school, Nathalya's passion for philosophy motivated her to read anything and everything. Old downtown Bogotá was known for housing stores with cheap used books and illegally photocopied books. One day Nathalya and her mom went to the area to see what they might find. Her mom said, "let's just choose a few books that you want." Walking through the streets, tiny stores beckoned patrons with their wares while the stores' proprietors loudly shouted to draw attention. "What do you need? What do you need? We have it!"

Finally, for no particular reason, a store got chosen by Nathalya and her mom. Nathalya said, "all the books seemed really old and abandoned." I can picture the dim

lighting inside contrasting with the bright sun outside and piles of dusty tomes laying around in no discernable order.

Nathalya's lack of having any particular text in mind led her to asked the "guy" working there for a recommendation of a book about crime. She told me, "he was just there working but he didn't seem like he knew much." I imagine him more interested in getting clients in the door and making a sale then helping a girl to find what she was looking for. Maybe the book caught his attention before or maybe it was just close at hand. She said to me, "the guy just judged the book by its cover because he had no idea." For whatever reason, he gave Nathalya a thick book with a red cover with a cross on it titled "None Should Die."

As soon as Nathalya got home, the allure of a new book enticed her to open the pages and begin reading. She quickly realized that the book was not what she thought; it was not a crime book. She also realized that she loved it. The gripping novel where the main character was a student going through his medical residency, drove her to turn the pages more and more quickly. She was thrilled by "how much he had to do" and his busy days "running around."

As Nathalya continued reading she realized how much knowledge doctors have to have. The book would be temporarily set aside in order for her to google diseases that were discussed, learning more as she went while also realizing how much there was to know. She thought about how exciting being a doctor could be, forming a mental image of doctors running through halls, hurrying to save someone's life. She also realized that doctors make a difference. Describing the main character, she said, "[he's] dealing with patients but also saving lives. So, I saw some impact." Nathalya explained, "that's what

started drawing me to science." She started watching Grey's Anatomy. She said that it wasn't until she came to the states that she really had a science class.

Debating Medicare

During Nathalya's sophomore year of high school, she took biology. Other than saying that her interest in medicine drove her to pay more attention in biology despite still struggling with the language barrier, she didn't say much about the class. She also mentioned that the teacher spent time in Spain when he was young, so he spoke Spanish. In one-on-one conversations, he talked to her in Spanish and she would insist on replying in English so that she could become more proficient. They built a relationship around talking to each other in the other's primary language.

Between sophomore and junior year, she attended a two-week summer camp in Boston about medicine. She said, "we had speeches and talks and colloquiums from residents, from different types of surgeons." This experience got Nathalya excited about neuroscience which she thought about as a major until she got accepted to GW which did not have a neuroscience degree at the time.

This summer camp was only one of many experiences that Nathalya briefly mentioned that seemed exceptional to me, but she quickly passed over. Haiti, China, Peru, The Dominican Republic; she traveled her junior year of high school with a community service organization, her senior year of high school with her foreign language department, her spring breaks in college with a different community service organization. Boulder, Salt Lake City, Austin; she attended a plethora of conferences. Although Nathalya passed over many of these experiences without going into great detail or dwelling on what an amazing opportunity they were, I don't believe they just fell into her lap. She would also often mention seeking out financial support and fundraising for these

opportunities. At a different moment, when she was talking about the pressure that she puts on herself to do well academically, she told me that she always wanted to take advantage of any and all opportunities. That statement seemed to explain the many and varied experiences that she mentioned throughout our conversations.

One of the last times that we met, I asked Nathalya to tell me more about the summer camp in Boston. She said that she got a letter in the mail inviting her to apply. Someone from her school had nominated her though she never knew who, possibly her biology teacher. She did some research and realized that the students from her school who previously attended the program all went to prestigious universities. She applied, was accepted, and was awarded funding.

She loved the call of the city waiting to be explored during her free time, she loved the dorms which made her feel like she was getting a taste of college life, she loved the talks about medicine that captured her attention, but most of all she loved the structured debates that were part of the program. She described the debates as a model UN, but for science. The man in charge of the program would work with the students to prepare small debates on topics such as Medicare, climate change and other science policies. The most successful debaters would go on to a larger debate and the other students would be audience members. Nathalya thought to herself, "wow. People actually really care about [these topics]."

Getting Rides Home from Anatomy Class

After attending the summer camp, during her junior year of high school, Nathalya took chemistry. She said, "I liked it?" with her voice raising at the end as if she was incredulous about what she was saying. She then explained, "It always felt like I always had to just read for instructions and do it rather than me just wondering about

something." Then, her senior year she took AP chemistry and AP physics at her high school and anatomy and physiology at the community college. She said that most students only took one AP science class or, at least, only took one a year. She managed to take two and the college course, and although challenging, she did well in all of them.

Many of the individuals that she was taking classes with at the community college were nontraditional students who had families and were coming back to school. She quickly made "so many friends" with her classmates who treated her like she was "their kid" by giving her rides home and making sure she was doing ok. But while it was an enjoyable social experience, anatomy and physiology was a really hard class. She said, "that class just consumed my entire semester." The course was required for nursing majors and was known to be a hurdle for students. Many of her classmates were taking the class for the second or third time. It was hard for Nathalya. Despite only taking the class to satisfy her own interest in learning more about the human body, she worked hard and she did well.

Nathalya did not feel as warmly welcomed into her AP classes as she was in anatomy and physiology, particularly AP chemistry. There were only seven or eight students in the class and they were "literally the top kids in the entire school" and "knew each other from the wombs." She was the outsider. She said, "even though I was one of them I was never looked as one of them: because of where I had come from, because I had just learned English. I was still learning, because I had an accent, because all these things." She also said, "I started getting a little frustrated with my accent because people would look at me weird because I started taking AP classes." She did not feel

comfortable in the classes but felt like it was important that she be there in order to "make it somewhere."

The feeling of being treated as an outsider changed after her classmates found out that she was accepted into GW. Explaining how things were, Nathalya said, "They started talking to me more, just because they knew I was going to college, that I wasn't just going to stay doing other labor jobs." Although she no longer felt like she was treated like an outsider, the encounters that she had regarding her accent left her insecure. She has actively tried to get rid of her accent and spent periods of time speaking only English in order to "immerse in the culture and learn it well."

Although the students in AP chemistry were friends with each other, they were really competitive. Nathalya felt like the students competed for fun, discussing who got the higher percentage on each test. Nathalya just wanted to do well without having to compete. She said, "I like to work with people. I don't want to have you against me if I know that we can work together." She also felt like the competitive nature of her peers made them hesitant to ask questions in class. They all wanted to give the appearance of understanding even if they were lost. Nathalya asked a lot of questions and felt that the other students looked down on her for that. However, she would see some of those same students after school getting help from the teacher.

Despite not feeling comfortable in the AP chemistry, she did well in the class. AP chemistry class was fairly easy for Nathalya. She said, "I can study this, this is how it works, makes sense, I can see it in the lab. You mix the two things together, this happens, and this is why it happens." AP physics class, on the other hand, was more challenging. She would often think to herself, "I don't get it. I'm getting things right but

do I understand them well enough?" She felt like even though the teacher was "amazing" and she was able to get correct answers she was not really understanding what was happening the way that she was in chemistry.

AP physics was a larger class of mostly juniors, though Nathalya was a senior. At one point I asked Nathalya if she made friends in her physics class that semester. She explained that most of her friends in high school were from the community service organization that she was part of. She then said there was one girl that she remembered who was "super smart and also such a hard worker." This girl was not popular with the other students who would say, "She's a weirdo. We don't like her. She doesn't have money." She and Nathalya would help each other out with assignments but did not keep in contact after graduation.

All of Nathalya's high school classes had "tons of worksheets," but physics was one of her only classes where she also had a lab notebook. She recalled a lab with pulleys and boxes where she had to find the coefficient of kinetic friction. The visual provided for one of many opportunities to really see the application of math, a subject she always loved. She said, "That was just literally seeing how math was applied to find something that we see every day in life . . . . That was so mind blowing."

On days that students were not doing labs the teacher would "talk a lot" and then gave students time to work on problems together or individually. Because the students were all interested in science, she could "teach even more stuff." She was strict and communicated high expectations to the students. She would also share about research she had done when she worked as a physicist before becoming a teacher. Nathalya said, "she settled because she had babies and so she was like, 'I'm just gunna be a teacher for

now and see.' But she wanted, I think, to go work for industry because she liked that better." She went on to say that despite knowing that teaching was not what she wanted to do, she was good at it.

Nathalya really enjoyed physics, particularly, when doing labs that made it clear to her how the math related to the real world. It was a challenging class for her though. She would say to herself, "I need to be doing work all the time because if not, I'm not understanding. I'm behind." But she did work hard and she did do well in the class, although not earning a high enough grade on the AP test to receive college credit.

When deciding on a major to pursue after college, Nathalya knew that she wanted to study a science but did not know which one, although from her comments, biology never seemed like a contender. She thought of her undergraduate studies as primarily helping to prepare her for medical school, but she also wanted to study something meaningful. She said, "My end goal would be medicine, but I want to do something significant in my, during my undergrad. I want to make it count."

What was meaningful to Nathalya was challenging herself, so Nathalya's struggles with understanding physics did not deter her, they spurred her on. She explained, "That is why I leaned towards physics because I wanted to find that thing that I was lacking that was really pissing me off." She wanted to really understand what was happening behind the math in physics.

Walking Through the Physics Building

Despite having a draw toward physics, Nathalya hoped to start college undecided, take both physics and chemistry freshman year, then decide on a major. One advising meeting squashed that hope. The lady she met with recommended that she not take both

physics and chemistry together as a freshman. So, she ended up taking physics her first semester of freshman year.

The first day of physics class Nathalya was surprised to see a woman at the front of the room, Professor Curie. Her high school physics teacher was also a woman, but she had not expected that her professor would be. She thought to herself, “wow! There's opportunity for women! Who would have thought?”

After class Nathalya approached Curie (the physics students usually referred to their professors by just their last names) and introduced herself. She said, “I'm a sort of perspective physics major but I'm scared. How hard is it? I don't even know if I'm doing the right things, if I'm taking the right classes.” Curie led her to the physics building and showed her around. The building was due for a remodel and from everything I have heard was notoriously dark, gloomy, grimy, and musty smelling. None of those descriptions were used by Nathalya who felt a warm collegial environment in the building. She was introduced to some upperclassmen who said, “physics is hard but we love it.” The students seemed like “nerds” who were sitting together in silence studying and were mostly males. Curie reassured Nathalya, telling her about all the wonderful things the department did and telling her some initiatives they had recently begun to interest more women.

Amazingly, within a few years, Nathalya estimated that the physics students were 60% female. She attributed the diversity primarily to two professors, saying, “the newer generations of professors, they've been really invested in diversity.” One of these professors was Curie. Curie had experienced a very male dominant field while she moved through her studies and through her early career. She found it difficult to get

grants to support her work. Once she did get awarded a large grant and a good university position, she wanted to actively work toward making sure the next generation of women did not experience the same barriers that she did. Nathalya described the other professor, a male faculty member, as someone who "works tirelessly towards diversity" although not describing his backstory that endowed him with such fervor.

Nathalya explained that both professors implemented equitable practices in their classes, educated themselves on inequalities, and "took action." An example of an action was that Curie hosted a physics conference for women and individuals who are gender non-conforming. She started a group for the female physics students to get together on campus. Also, she would point out to boards of organizations that they should invite more women to be on panels and should provide more money for girls to go to conferences.

Second semester Nathalya was signed up for another semester of physics but heard from friends in her other classes that she might be in the wrong class if she wanted to be a physics major. Her friend suggested that she come to class with him and talk to the professor, so she did just that. She went to the second day of class, walked up to the professor, Professor Marsh, and asked if she was signed up for the right class. He set up a meeting with her and said, "You need to sign up for this class right now . . . . this is where you should be . . . . Just listen to me from now on." Because of poor initial advising she took three versions of the same class, AP physics, the basic college introduction to physics class, and the introduction to physics class for majors. After the advice of Marsh, she took the correct class and was on track to be a physics major.

Nathalya ended up loving the physics department. She felt grateful that she did not get into some of the larger science institutes that she applied to because she would have had larger classes and a less one-on-one experience. She also loved that there were a lot of girls in the department. She would say to herself, "This is great because you can empower one another." Becoming more and more involved in the department as time went on, she participated in the physics student organization and eventually served as co-president. She also attended several physics conferences, being awarded full funding for many of them.

While Nathalya was becoming more involved in the physics department, she was also becoming more involved in GWTeach, the education program. During her freshman year two professors came into her science classes and talked about the program. They said, "this one credit class gives you exposure to creating a lesson plan, but most importantly gives you access to DC in a way that you can make an impact." Nathalya loved doing community service in high school and wanted to get to know the city better so was looking for opportunities to volunteer in DC. She went to the University's fair to learn about different organizations, but was not a fan of how most programs were run. She started participating in one program where she felt like she was just babysitting kids and wanted to do more.

She signed up for the first education class. She liked how small and interactive the classes were and how personable the people were. She also liked being able to teach students in DC. She thought to herself, "This is a classroom where it's comfortable and I still learn . . . . That just felt good being able to go and do something good for others and teach them something." So, she signed up for the next class in the sequence. One-by-one

she kept taking classes just because she enjoyed them. Since she planned to continue to medical school after graduation, she didn't see the point in getting a minor in teaching, but even when she had limited space in her schedule, she kept signing up for classes. She explained, "I just kept feeling so comfortable and learning in that environment, and still seeing the impact, that's what kept dragging me to continuing."

Studying with a Political Science Major

By the time Nathalya took her first college chemistry class, her sophomore year, she had already decided on a physics major. Periodically, frustrated with a lower GPA than she would have liked, she would consider changing majors. She thought that she would have done better with a biology or chemistry major, or even a non-science major. She felt a pull between wanting to have good grades and realizing that grades were not everything. She said, "I know that my GPA doesn't really describe how much I know or who I am as a person. But, as a person who has been working towards a higher and a better place than she's been or where she's come from, I've always had that sort of pressure on myself, to do good at everything and to be good at everything." In high school she was able to be involved in many things such as a community service organization and tennis while maintaining a 4.0, but college was different. Wanting the whole college experience, she was not willing to waver on prioritizing involvement in multiple organizations. She also had to work, so found her GPA dropping.

Doing poorly in a class brought Nathalya back to earlier times. She explained, "I've never failed a class. I did when I was in middle school. And I feel like when I'm about to fail or when I remember those time, I just don't like it because that's just not who I am." Who she saw herself as, was someone who did well in school, so much so that she

did not celebrate when she did well. She saw it as expected and would say to herself, "this is what I should get. This is what you need to have."

The pressure that Nathalya felt was self-imposed. When I asked her if her mom put pressure on her to have good grades, she explained that they really didn't talk about grades. She didn't want to worry her mom. Her mom knew that she worked hard. When she would call, her first words would often be, "are you studying?" To which Nathalya would reply, "yup. What's new?" The few times that Nathalya told her mom that she was concerned she would not pass a class her mom would ask, "Can you talk to the professor?" and would be nothing but supportive.

Nathalya's friends were also supportive. Her close friends were not science majors. When she would get down on herself, thinking, "I don't know anything," her friends would respond, "We don't understand why you keep telling yourself that you're dumb because you are clearly not. You are studying bio-physics and you've been able to pass those class."

Eventually, Nathalya only studied with these supportive, non-science friends. For a while she studied with the four physics students who took most of her classes with her, but they made her feel intimidated. She would say to herself, "All these guys, they know so much. They've had so much more experience than I've had." She described the other students as competitive without meaning to be. They'd get so "passionate" about solving a problem that their energetic string of ideas left little room for someone to say, "I really don't get this." She realized that the physics students never really asked a direct question. They would make a guess and ask if they were correct. For example, someone

might say, “in that circuit, these are in series because of this, correct?” instead of asking if they should be in series or parallel. She felt pressure to never show uncertainty.

Nathalya had one class with the physics majors who were a year behind her and found them to be even more competitive. They would compare test grades and act like they knew the “right” way to do labs, leaving no room for trial and error. They would always study together and spend time together but there was “so much pressure” to be the best. None of them seemed willing to admit when they didn’t understand something.

Eventually Nathalya realized that it was not healthy to constantly be comparing herself to others. She realized, “maybe that's [self-doubt] also inhibited me from doing better in school.” She would say to herself, “I'm not trying to compete. I'm just trying to learn.” So, she stopped studying with the other physics majors. She started studying with her friends who were non-science majors, like one friend with a major in political science. She would talk through problems with them, appreciating the opportunity to process her thinking orally even though they did not understand what she was talking about. She said, “I would feel safer . . . . But I could be so wrong and they wouldn't know. And I couldn't feel ashamed.” Her friends told her that the competition she felt was not something they experienced in their programs of study.

In spite of all the conflicting emotions regarding grades, and competition, and self-worth, when Nathalya considered changing majors, the thought was fleeting. She would say to herself, “Maybe it's the classes, maybe it's the major that's really challenging. But I'm passionate about it!” She would stick with physics because it was what she loved and what challenged her.

Solving a Puzzle

Since Nathalya didn't study with other physics majors, I asked her what she did when she really didn't understand something. Her first response was, "Sometimes I just end up giving up." Next, rather tentatively, she said, "Sometimes I go to the professor." She explained that, perhaps since things always came easily to her when younger, she had the mentality of, "I'm gunna study until I get it." If, with studying, she was not understanding the concept she would try to memorize how to do problems and "hope for the best." Because of this mentality she found it difficult to admit to others, like her peers and professors, that she did not understand.

I was perplexed that Nathalya would not go to professors for help when she so fearlessly went to them to ask for advise on how to become a physics major and what classes to take. She said that there was a difference when it involved admitting to not understanding the concepts. She then said that there were some professors she was less likely to ask for help and some professors she was more likely to ask for help. Some professors made her feel intimidated and, though she respected them, she did not feel comfortable going to them.

The professor that Nathalya went to the most for help was her organic chemistry (orgo) professor. Nathalya loved that class. She saw mechanisms as puzzles with a starting point and an end point and all these different things that you could do in between. She loved that there was no one right way to solve the problem. She said, "if I wanted to do 10 steps or two steps to get me there, it's up to me." Because she loved the class, she studied really hard. She made it her goal to get her first A in a college science class.

Nathalya wanted to really understand how and why every mechanism worked. She would go to the professor's office hours and say, "Let's say you have this

here. Could you do this? Why couldn't I?" Her fascination with the subject and her desire to develop a deeper understanding drew her to seek extra help, not a lack of understanding. Seeming to come to this realization for the first time while talking to me, she said, "because I thought that I had grasped the concept, I was more confident to go to her."

The class that Nathalya had after orgo was biochemistry. Due to her success in orgo, she entered the class with confidence. The first few days of class she would look at the mechanisms that the professor showed and think about them based on what she learned in orgo. She would raise her hand and ask, "I learned this mechanism in orgo, so why wouldn't this hydrogen detach from this if it's carboxylic acid." The professor would respond, "just don't over think it." After a few similar encounters, she stopped asking questions and stopped trying to understand why things happened the way they did. She said, "I ended up with a C+ in the class or something because I was just memorizing every mechanism, not understanding where they came from."

Though Nathalya shared that the biochemistry professor shut down her questions, she also reflected on some of the things that other professors tried to do to get student to open up. She told me about her professor who had weekly brown bag lunch gatherings. Though the gatherings were a "safer space" to open up, the students still didn't. Even when most of them were confused they would sit there in silence.

Waiting for an Order of Biochar

The summer before Nathalya and I met she spent the entire summer in DC without going to Colombia to visit or dad or siblings, which she typically did at least once each summer, and without going home to her mom's house in Florida. She stayed

in DC to take the two semesters of organic chemistry and to participate in a National Science Foundation (NSF) funded nanotechnology fellowship program.

The fellowship was an eight-week paid program that left Nathalya feeling like she had a sense of what research was really like. She said, "it made me feel both the good things and bad things about research." It was structured so that the students attended lectures by professors from a variety of programs within the School of Engineering and Applied Sciences, did mini projects to get acquainted with types of nanotechnology research, and worked with PhD students to complete research.

During the first two weeks of the program Nathalya and the other eight students in the program received instruction from the head of the program. She was a mechanical engineering professor who had an intimidating presence, an impressive background, and they all looked up to as a role model. When Nathalya first mentioned her, she said, "She's just like our role model. Again, a woman, of course. She is just like so amazing. She's so intimidating. I've never met someone who makes me feel so intimidated from the first minute, from when I've seen her." Nathalya spoke of her with reverence, telling me how she taught physics through Teach for America before pursuing an advanced degree, and how she wanted to work in the industry but ended up in academia.

Nathalya seemed to respect the professor's rich and varied academic history but she also respected her as a teacher. She said, "she doesn't give you the answers." She would pose a problem then work with the students step by step until they discovered the solution. From this experience Nathalya was able to derive many equations that she had previously memorized, really understanding them for the first time.

Seeing a woman whom she respected, who had been a high school teacher and was now a college professor changed Nathalya's thinking about teaching. Until this point she was taking education classes because she liked them and as a way to give back to the DC community. Seeing this woman, Nathalya thought to herself, "I can still be successful. It doesn't mean the teacher's not worth it." She explained to me again that in her culture teachers are not valued. She also felt like all of society did not value teachers. They are underpaid and when you tell someone you have a degree in physics, they expect you to be doing something like working for NASA. Nathalya started to think about teaching as something she might want to do for a few years after college.

The PhD student that Nathalya was assigned was the head of the program's "right hand." He shared a work space with Nathalya, met with her once a week, and coordinated her use of shared pieces of technology such as the sonicator and the scanning electron microscope. Over time he and Nathalya realized they both liked biking, the outdoors, and cats. They ended up forming a close friendship staying in contact with each other. On the day Nathalya was recollecting her experiences of the fellowship with me, she had spoken to the PhD student only a few days earlier.

Although Nathalya learned a lot and met a mentor and a friend during her fellowship, the research did not go as well as she would have hoped. She was working with biochar for an ink jet printing application, an environmentally sustainable alternative to standard ink. She had done a first round of tests with no discernable findings. Then they had to order more biochar. A week passed, then another; soon there was just over a week left in the program. Nathalya was stressed but her PhD student said, "Welcome to research. Sometimes you just have to wait around for materials . . . . This is research in

academia." The Friday before the last week the biochar finally arrived. They ran some last-minute experiments, adjusting the plan as they went so there would be findings for Nathalya to present.

Despite the challenges, Nathalya discovered that she really loved research, and decided that she didn't want to go to medical school, which was her intent up to this point. She said to herself, "I feel like I can still do it, but from another perspective . . . . I feel like I can still have an impact with the medicine if that's still what I want to do." She found that she was interested in so many things that she wanted to study all of them. Therefore, she became a bio-physics major. She said, "it's a compilation of math, physics, and chemistry and biology." It combined many of things that she was interested in.

Ripping Apart His Power Points

The summer that we met to talk, Nathalya remained in DC to work with Marsh, the same professor who helped her get scheduled for the correct class, his class, her second semester of college. She had been a Learning Assistant (LA) in his class, and got hired to stay over the summer to rework some of the class with him. She said, "we've been collaborating and going over all his lectures, his materials." More specifically they were focusing on a topic about diffusion that was one of the last topics covered in the semester, was very different and unrelated to other topics, and seemed to "go over their [the students'] heads." Nathalya said that the topic went over her head when she took the class and when she was an LA she noticed many other students struggled with that concept.

Marsh was exceedingly open to Nathalya's feedback and help. She would be blunt, saying "you need to change this" and he would be responsive her critiques saying

“ok, let's tackle this.” She said, “It’s weird because he treats me, not like his student. He teaches me a lot of course, but he also wants my input.” He treated her like a collaborator and like someone that he respected. Not only did Marsh respect Nathalya’s opinion but he was extremely willing to critique his own instruction and instructional materials. She said, “He's unbelievable. We literally take his Power Points and rip them apart.” They worked together to make the class material much more student-focused, with more opportunities for students to work through problems and less lecture. They also redesigned the main lab for one topic.

Throughout her time working with Marsh as a student, a LA, and in his lab, one of the biggest things that Nathalya learned from him was something that seemed to gradually sink in: that there are multiple ways to approach physics problems. He was very “into modeling” and then using those models to figure out how to solve a problem. There were often many different, equally effective ways to model a problem. This gradual realization made Nathalya feel more confident as a physicist. She said, “It's up to your interpretation how you want to model it and how you want to describe it mathematically . . . which makes me more comfortable because I don't have to stick to one idea or one theory.”

In line with his interest in modeling, one of the things that Marsh and Nathalya worked on was making illustrations to share in an online database and use as a teaching tool as one way to model physics. While working on some drawings depicting physics concepts, Nathalya reflected on how illustrations impacted her interest in science at points in her life. She said that even though she did not have exposure to science at a young age, she did remember loving pictures in books. She would say to herself, “I've

never been to the ocean, and that's a thing that divers do, but I'm not a diver, but I'm able to see what they're doing and learning what they're doing out there through videos, through images." She also recalled her first few science classes in the states saying that she was assigned to transcribe the book which was terrible, "but then seeing the graphs, the pictures, the illustrations was what helped me go through those processes." Like the models in college, the science-related images earlier in life helped her to understand science and see it through multiple perspectives.

A blog that Nathalya followed reaffirmed her belief that physics was all about looking at problems in different ways. The blog provided a platform for physicists with advanced degrees to debate with each other on advanced topics. It stood out to Nathalya that each of their arguments was based on looking at the topic in slightly different ways rather than completely questioning the accuracy of each other's thinking.

Nathalya seemed to respect Marsh's humility, appreciate his openness to her ideas, value his teaching approach, and like him a person. She described how they would talk while waiting for jells to melt when redesigning a lab, "We talked about politics, my family, his family, drama family. We talked about soccer. We talked about his high school. And I asked him why he choose physics. And he always talks about his family." She went on to tell me about his teenage sons and how close they were to their father.

Nathalya's work with Marsh ended up being the foundation for her senior thesis. She was one of two students who I knew in the physics department who were basing their senior thesis on education-related studies rather than traditional physics research and I did not know any students in other STEM majors doing likewise. The department was seemingly very open to allowing their students to tailor the requirements of the senior

thesis to meet their unique interests and open to students studying the teaching of physics. We also discussed how it seemed to us that there are many physics organizations and publications dedicated to the University level college physics pedagogy and many physics professors interested in the art of teaching. Again, this seems contradictory to other STEM disciplines. Perhaps this was our perception based on having a physics department at GW that was more engaged in teaching research or perhaps it was a more generalizable trend. Nathalya theorized that physics professors might be interested in researching teaching and learning because it was such a "scary subject" and that college professors often have to teach against inaccurate preconceptions that are formed through student observations in the world and through high school classes.

It was obvious from my conversations with Nathalya that she was engaged in this work and highly motivated by being allowed to have a say in this type of pedagogical work. In regards to using educational research for her senior thesis, she said, "I'm excited because I didn't know that could be a thing. But we just sort of talked about it and he's like, 'Yeah. I really want to change this.' And he's so open about it."

Missing Colombia

When I spoke with Nathalya she was unclear what she wanted to do after finishing college. The fourth time that we met, heavy rain forced us indoors to a café. Her long hair was down for once, reaching most of the way down her back. The conversation was so engrossing that I left with the idea that it had been quiet in the café. When transcribing the conversation, on the other hand, a loud, continuous bark of laugh in the background caused me to be distracted frequently. During this meeting Nathalya talked a lot about her insecurities in science, some of which were previously described. She also talked about how these insecurities led her to decide against going to graduate

school in physics. She said, “a huge reason why I wasn't eager to just go into grad school for physics right away or go into a PhD physics program is because I was looking at people around me.” She felt like others had a better understanding of more of the concepts. She insinuated that she might consider graduate school at a later day, feeling that time would help her to develop greater understanding. As she explained, “my hope, I guess, is that with time and through teaching I would be able to get better at it [physics].”

Periodically Nathalya referenced teaching after graduation, but she also talked about other hopes mostly involving travel. She said, “One thing I was thinking, because I do miss Colombia so much, I think what I'll do is once I graduate next May hopefully then I just want to spend summer there until work starts. I was also thinking maybe I'd go home for like a year and half. But I can stay a few weeks and go and travel some . . . . But I do want to do Peace Corp or some volunteer abroad.” Nathalya had been involved in community service since high school and loved it. She said that community service is, “something that’s more me than anything.”

Nathalya had long-term thoughts about how to combine her interests in community service, education, and science. She saw first-hand how poverty in Columbia affected access to science education and wanted to do something to provide better science resources to impoverished communities.

Two years after the summer that Nathalya and I initially met to talk, I had the opportunity to catch up with her. After graduating she taught for a year and was preparing to teach the next year. Saying, “two more years of teaching, three, maybe one,” Nathalya explained that she did want to go back grad school at some point. Maybe she would study nuclear engineering or maybe medical physics. One of the last things

she said to me before we said our goodbyes was, “I think that at some capacity, I'll always be teaching.”

Chapter 7: A Diffractive Reading of the Narratives

As described in the Chapter 3: Existing in the Borderlands to Rethink Method, reading narrative inquiry should evoke a story within you and awaken new understandings of complex issues (Clandinin & Connelly, 2000; Rosiek & Snyder, 2018). In this chapter, I will elucidate how Visha's, Mae's, and Nathalya's stories worked in combination with my life experiences and the literature that I have read to facilitate the emergence of new insights and meanings. I highlight aspects of the narratives in order to open the reader to new sites of wisdom, not to point out definitive "knowledge" (Hendry, et al., 2018, p. 10). In many ways, my experiences with the texts differ from those of other readers. Readers intra-act with the words on paper or on a screen. I intra-acted with the women themselves. I knew all of the women for several years before asking them to tell me about their experiences in science. I sat with them while they reminisced, was able to ask them questions, heard their inflections, and laughed at their jokes. I listened to their voices over and over while transcribing and writing. Because of these unique intra-actions, the stories may have made meaning for me in ways that did not emerge for others who read the narratives. Every unique intra-action will form a unique diffraction pattern and each pattern can provide a new and different perspective on the underrepresentation of women in science. I invite you to make meaning from the narratives through your intra-actions with them, which is no doubt different from the meaning I have made. Your own life experiences, continued dialogue with other individuals, and engagement with literature and research can be read together with the narratives to build diffraction patterns that are new and meaningful to you.

The research questions guiding this work were: What are the stories of female undergraduate science students' experiences in science, and What are the diffraction patterns between the students' epistemologies and the culture of science that they have experienced? Visha's, Nathalya's, and Mae's narratives included times when their epistemologies aligned and did not align with the culture of science that they experienced. Although, as will be shown, much of what the women expressed as important to them has previously been identified as important aspects of science, the environments in which the women engaged in science learning did not reaffirm these aspects as important. In fact, there were often practices that were antithetical to these aspects. In other words, although there are heavily researched ideas about epistemologies of science that are generally accepted in the science education scholarly community, these ideas have not permeated science education contexts.

The first section of this chapter will explore several ideas that were prevalent in the women's stories and have previously been taken up by epistemologies of science researchers. For example, the women shared about learning science in competitive and collaborative environments, speaking to the socially constructed nature of scientific knowledge (Burgin & Sadler, 2013; Elby, et al., 2016; Sandoval, 2005; Wickman, 2004). As another example, the women talked about their peers' and professors' emphasis on knowing correct science instead of thinking about science as a process of evolving ideas. In other words, scientific knowledge is a body of theories based on evidence that is changed or dismissed with new findings, not stagnant facts (Burgin & Sadler, 2013; Elby, et al., 2016; Sandoval, 2005; Wickman, 2004).

Traditional explorations of epistemologies of science examine features and processes for generating scientific knowledge, with a somewhat singular notion of epistemology of science, primarily shaped by science in the post-Enlightenment European tradition (Belenky, et al., 1997; Schommer, 1990). Some researchers are calling for a more inclusive science education that includes multiple epistemologies (Bang & Medin, 2010; Russ, 2014). In my diffractive reading, I explore two topics that are particularly relevant to feminist epistemologies of science: material ways of knowing and relational ways of knowing. For each, I mapped the diffraction patterns that emerged within and between the narratives, showing, not just areas of resonance and dissonance, but the effects of these (Barad, 2007, p. 72). Since many of these ideas are seen elsewhere in literature regarding the underrepresentation of women in science, I read the narratives through the apparatus of this literature, paying attention to how the narratives do and do not resonate with this literature. Following the two sections focused on epistemologies I reflect on the method used in this study, narrative inquiry, and the relationship between the method and the theory.

Fleeting Moments of Intelligibility and Questions Regarding Epistemologies in Science

In the narratives, there are many examples of epistemologies promoted in the epistemology of science and nature of science research, but were often not what the women experienced in their formal science learning experiences. As a science education practitioner invested in the puzzle of the underrepresentation of women in science, these apparent tensions are a launching point for further questions and "fleeting moments of intelligibility" (Hendry & Mitchell, 2018, p. 29).

Competition

One aspect that was part of the stories of all three women was competition. Many of their experiences highlighted competition and very few of their experiences highlighted collaboration. In terms of epistemologies of science, competition appears in the studies of science and science education literature in two ways. First, more commonly, competition is characterized as a process occurring among ideas, explanations, or models. History of science literature includes many stories of competing explanations for phenomena being tested; those which "best" align with the evidence are retained, while those that do not hold up are discarded. Unitary views of science, which hold that all phenomena should be explained by one consensus theory, view the existence of competing theories as a problem to be resolved. Pluralistic approaches, on the other hand, allow for the existence of competing explanations or models which might serve different purposes (Longino, 2019).

Secondly, competition can occur among scientists themselves. As pointed out by Prowell (2018), as scientist and scientific agencies race for new discoveries, they inevitably compete for funding and recognition, leading to more and more comparative metrics. As early as the 1960s, sociologists began to recognize that scientific knowledge is impacted by social factures (Goldman, 2010). Thomas Khun's (1970) work was highly influential in these initial claims thus beginning the field of social epistemology of science, although he did not use that term. It is now widely recognized that modern science research involves substantial collaboration and competition (Andersen, 2016; Fallis, 2009; Powell, 2018; Wray, 2002). As stated by Prowell (2018), "how we collaborate and compete to find solutions to the problems and challenges of our age

vastly impacts our individual and group success and well-being" (p. 1). The two seemingly opposite characterizations are not necessarily mutually exclusive, and it is also problematic to assume that there is one "most sophisticated" way of doing science (Sikorski, 2019) in all contexts.

Modern science education literature often advocates a collaborative inquiry approach to learning (Jarvenoja, et al., 2020). The rationale for collaborative instructional practices varies but the practice is generally considered advantageous. For example, the Next Generation Science Standards advocates for collaboration between students because it replicates the practices of scientists (National Research Council, 2012). The Programme for International Student Assessment (PISA), on the other hand, highlights the advantages of collaboration in problem solving (OECD, 2017). Additionally, recommendations for creating classroom environments that are welcoming to women discourage a competitive environment (Sinnes & Loken, 2014) as some studies have shown that competitive environments are demotivating for women. For example, Aelenei et al. (2020) conducted three different studies with a total of 439 students. The students were survey after completion of a course and a description of success in the course based on self-enhancement values such as competitiveness or self-transcendence values such as cooperation. They summarized their findings by saying, "three studies showed that when success was depicted in terms of self enhancement values, women – but not men – expressed a lower sense of belonging, had lower self-efficacy and were less likely to pursue a given academic opportunity both in STEM and non-STEM fields of study" (p. 343).

Historically, women, as a group, are enculturated to see competition as adversarial (Fisher, 2017). On the other hand, men, through activities such as sports and debate, are enculturated to see competition as a means of growth and socialization. This is not to say that women are never competitive. As described by Merten (1997) female competition does exist but often looks different and has different purposes. Also, Fisher (2017) cited research showing that as societies become less patriarchal there is less of a gendered response to competitive situations. Despite this gradual shift, currently competitive schooling environments typically disservice and detract females much more than males (Nielsen, et al., 2017).

Although there are efforts to support collaboration in science education (Sinnes & Loken, 2014), what Mae, Visha, and Nathalya experienced was often an environment of competition, rather than one of collaboration. For Visha, competition was something she recalled from as early as elementary school. However, both Mae and Visha did not always feel that the competition they were exposed to was a bad thing. Visha shared about a friend of hers in elementary school with whom she felt competitive. The rivalry pushed them both to do better. She also described a contest that her biology teacher introduced during the pig dissection to see who could get the longest segment of intestine, which she found to be fun. Additionally, Visha described a college project that involved collecting bugs in competitive terms. In this case it seemed like she was competing against herself to see if she could enlarge her collection. She collaborated with her classmates by trading specimens. Mae also found some value in competition. She said that she and her friend Gary would compare test grades but they did not take the comparison overly seriously. They seemed to do it in order to motivate each other to

work harder for the next test. She felt that her high school was a very competitive environment that she perceived as both good and bad. It was a culture of valuing learning that she appreciated and had not found in public school, but it was also a lot of pressure.

Contrary to Visha and Mae, Nathalya never spoke about competition in a positive light. She felt that it created a very stressful environment. She did talk about comparing test grades with friends or experiencing a competitive class assignment as if it were a game. She seemed to put pressure on herself to do well and to learn and experience as much as she could rather than feeling pressure based on others. Nathalya also discussed how the competitive culture in her college major negatively impacted her and her classmates. There was a feeling of never wanting others to see when they didn't understand, of protecting their identity as knowers of science. This made students not want to ask questions in class and not want to admit to confusion when studying with peers. Because of feeling overwhelmed by the competitive environment, Nathalya stopped studying with her fellow classmates.

Mae described an almost identical situation with her fellow chemistry students. Because the other students didn't admit to confusion in classes she always assumed that they understood the content better that she did. This assumption made her feel intimidated about asking her classmates questions or studying with them. Therefore, Gary was the only chemistry student with whom Mae studied, isolating her from much of the competition that she was sure occurred between the other chemistry students.

In addition to not wanting to show any lack of understanding to her classmates, Nathalya avoided showing professors when she didn't understand, so she didn't like to

get professors' help when she was confused. Visha also didn't want to go to professors for help because she didn't want to "look stupid." As described by Scantlebury, Danielsson, Hussenius, Gullberg, and Andersson (2019) when discussing a similar finding, "fear of not 'wanting to feel stupid' rendered the students silent" (p. 237). Both Visha and Nathalya described being more willing to ask questions in class and go to professors' office hours when they did understand what was going on in class. Although Visha did not want to show lack of understanding to professors, this is not how she described her classmates. She said that their competitive nature led them to be "cut throat" and constantly ask questions and ask for clarification in class. They dominated the classes while also showing the teacher and their classmates how much they knew. All three of the women seemed to perceive "ideal" science students as those who quickly obtain and demonstrate understanding rather than those who work toward understanding through questioning and conversation. However, they usually did not see themselves in that manner and prided themselves on the hard work they put into being successful science students.

As discussed, all three of the women felt pressure to not look stupid in front of peers and/or professors. Nathalya expressly talked about how fellow physics majors approached every problem with an immediate answer, then would think through that answer to determine its accuracy. Nathalya wanted to approach the problems with thinking the problems through in order to get to an answer. She also talked about how the friends with whom she studied did not think that the people in their majors were as competitive as those in physics. They were studying disciplines like political science in

which classes were more discussion-based and assessments were typically papers or projects, both practices that demonstrate a valuing of multiple perspectives.

There is a growing consensus among epistemology of science researchers that there are multiple ways to approach science rather than one correct way and that scientific knowledge claims are not indisputable facts but are tentative claims based on evidence that vary in certainty (Burgin & Sadler, 2013; Elby, et al., 2016; Sandoval, 2005; Wickman, 2004). Despite the growing acceptance of these ideas within the research community, Nathalya, Visha, and Mae experienced educational settings that reinforced the antithesis of these epistemologies.

There is also an abundance of research dedicated toward addressing the question of how science instruction and assessment might change to acknowledge multiple approaches to science. Inquiry, argument-based instructional practices, and alternative assessments have been researched and advocated for in science education for almost 50 years (Anderson, 2002; Sandoval, 2005). Yet, the mentality of viewing science as an exploration instead of a culmination of facts, by in large, was not what the women experienced.

"Right" Answers

All three of the women talked about the idea of getting the "right" answer in science classes. Visha frequently discussed memorizing facts. At times she realized there was more to science than memorization, but at other times she found the ability to memorize easily to be a valuable attribute in science. She memorized names of birds and the parts of photosynthesis and loved it. She also memorized the periodic table and facts about earth science and did not like it, equating it to learning facts without application.

The difference between situations when she did or did not appreciate relying on recall was unclear but seemed related to whether or not she liked the subject and whether or not she liked the teacher. More specifically, with biological information she seemed able to connect the information that she was memorizing to application of that information, something that she struggled with in other disciplines.

Both Visha and Nathalya had teachers who required the students to memorize information. Nathalya shared about a college professor who told her not to worry about why certain things happened when she asked questions. Because of this she became uninterested in the class. Unfortunately, science education that focuses on memorization is not an uncommon experience. In a 2009 article, Alberts said, "Most students gain no sense of the excitement and power of science, because we adults have somehow let science education be reduced to memorization of 'science key terms'"(p. 77). I would augment that statement to add that a focus on memorization perpetuates a misconception of what science really is; it reinforces incorrect epistemologies of science. Cherbow, McKinley, and McNeill (2020) highlight the epistemological misconceptions reinforced through teacher-centered, memorization-focused instruction. They observed science classes in four schools across four months and found three themes that were abundantly evident in all of the schools: content memorization, literacy, and hands-on learning. Although one might imagine that hands-on learning would aid students in recognizing the tentative and emergent nature of science, activities were highly structured and had a goal of definitive findings. Cherbow, McKinley, and McNeill found that instruction was highly motivated by administrative pressures such as having students perform well on standardized tests. Albers reiterated this idea, arguing that an over-emphasis on the use

of textbooks and standardized test are two of the main reasons science education continues to focus on memorization.

Mae and Nathalya memorized things when they struggled with understanding a concept, and falling back on memorization seemed to make them enjoy classes much less. If they could not understand the why, they relied on recall to do well in a class. All three women fell back on plugging numbers into memorized equations on assessments and hoping it worked when they did not fully understand what they were doing. The women's tendencies to rely on memorization when rationalization failed them points to the tension between seeing science as a process and seeing science as a set of "facts." Visha also shared about her organic chemistry lab which emphasized getting the right answers or results. She felt that getting good grades in the lab was dependent on getting correct results, and therefore, learning was deemphasized. Allen (2008) described this tension saying, "within school science the parallel encouragement of positivist and constructivist attitudes means that two conflicting epistemologies coexist in a state of uneasy peace" (p. 320). Even teachers who use an inquiry approach in their classrooms often have discrete factual information as the desired outcome of that inquiry. Allen goes on to say that students recognize that getting desired results and knowing "the right answer" is what leads to good grades. Therefore, students learn to value this over the process of discovery.

Nathalya realized over time that science is not a set of right answers or right processes. She saw that there were different ways to approach problems and work through problems in physics and in chemistry. She valued a summer experience where she was encouraged to derive equations that she had previously memorized, allowing her

to understand them more fully. Mae reflected on a lab class where the students designed their own experiments rather than following one that was written for them. This made her feel confident and that she was acting like a scientist even though she experienced more failure than in other lab classes. Unlike Nathalya and Mae, Visha did not talk about a class or experience when she became aware of a possibility of multiple approaches.

Helping students to see that there are multiple ways to approach a problem may increase the interest of some students in science. It also is more authentic to what scientists need to do in research. If something does not work, scientists need to be able to think about the problem in a new way to find alternative possibilities. This often requires creativity (Elby et al., 2016; Lederman et al. 2002; McComas, 2002). As described by Lederman et al. (2002) when writing about the nature of science, "Science, contrary to common belief, is not a lifeless, entirely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists" (p. 500). Despite the need for creativity in the scientific process, creative endeavors are often viewed as opposite to scientific endeavors.

Humanities and Science

A commonly held belief is that students who are good at or interested in science are not as good at or interested in the humanities and vice versa. Individuals are either "science people" or they are "creative people." In fact, in many cases students perceive "soft" fields like the humanities to have different epistemologies than "hard" fields like science and mathematics. In a review of the literature on domain-general and domain-specific epistemologies, Muis, Bendixen, and Haerle (2006) synthesized 19 studies which

have general agreement that there are both similarities and differences between domains. For example, they highlighted a study by Lonka and Linbdlom-Ylanne (1996) which found that medical students had more dualist thinking while psychology students had more relativist thinking. In general, the studies outlined by Muis, Bendixen, and Haerle (2006) found that students in "hard" disciplines saw knowledge as more structured and authority-driven than their counterparts in "soft" disciplines.

Given the perceived notion that there are "science people" and "humanities people" and the different ways of thinking about knowing and knowledge held by those in "hard" and "soft" disciplines, it might be assumed that science students are uninterested in also engaging in more humanities-oriented endeavors. However, Visha and Nathalya are examples of science students who wanted to study science and who also enjoyed the humanities. Visha loved writing poetry as a child and continued to write for enjoyment. Nathalya also enjoyed writing. She also had a passion for philosophy and enjoyed art. The joy and passion that Visha and Nathalya felt towards creative endeavors was not unique to them. I have had several science students over the years describe to me how rejuvenated they felt by taking an art class or by being involved in artistic extra curriculars such as theater or music. The classes for science majors are notoriously difficult and many students experience burn out. For many of my students, creative endeavors have been a way to combat that burn out.

Both Nathalya and Visha talked about creative writing as something that went by the wayside due to the demands of college studies. They both seemed to miss this outlet. For some students, not having a creative outlet may deter them from studying science. A 2016 study by Valenti et al. studied students' implicit associations of science with

creativity and of science with self. The study found that for women a science-creative implicit association correlated with career interest in science. In other words, if the women viewed science as a creative endeavor, they were more interested in a science-related career. However, Valenti et al. also report that it was uncommon for women to see that there is a creative side to science.

During the time that Nathalya and I were meeting, she was combining her interest in art and her interest in science to make illustrations of physics concepts. She did this as part of a summer research opportunity and found joy in it, showing me some of the artwork that she made with pride. Like Visha and Nathalya, I am interested in humanities and science. In my undergraduate studies I had a double major in chemistry and humanities. I recall feeling a great sense of interrelatedness between my science classes and some of my humanities class. I could see those connections due to my unique combination of majors but those connections were never addressed in my classes. The connections that I made between science and humanities and that Nathalya made between science and art is not something commonly explored in science education. As stated by McComas (2002), "Unfortunately, many common science teaching orientations and methods serve to work against creative elements in science. The majority of laboratory exercises, for instance, are verification activities" (p. 60). Despite common practices in science teaching having a potentially negative effect on the relationship between science and creativity, some teachers are looking for ways to marry art and science through their instruction (Liao, 2016; Sousa & Pilecki, 2013). For example, Adkins et al. (2017) describe students engaging in agar art. They found that those who participated had great confidence as scientists. Though Visha and Mae both discussed engaging in and

enjoying middle school science projects that required art, none of the women shared experiences in which teachers intentionally wove together science and the humanities.

Material Agents

Feminist scholars have proposed feminist epistemologies of science that recognize that knowledge is situated. Every unique intra-action forms new and ever-changing phenomena (Barad, 2007). The narratives of Visha, Mae, and Nathalya were all about the intra-actions that they had throughout their lives that shaped the phenomena that was their relationship with science. As stated by Tal and Dierking (2014) in the introduction to a special issue of the Journal of Research in Science Teaching which was dedicated to informal science education, "Learning in general, and science learning in particular, is cumulative, emerging over time through myriad human experiences, including but not limited to learning opportunities in museum-like settings, schools, while watching television, reading newspapers and books, conversing with friends and family, and increasingly frequently, through interactions with the Internet" (p. 252). The research presented in that issue clearly presented a case for the diversity of experiences that engage students in science learning. One study in the special issue, discussed in detail in Chapter 2, followed one girl over a period of about one and a half years (Bricker & Bell, 2014). Nathalya's, Mae's, and Visha's narratives illustrate, over a much longer period of time, the multiple and constantly emerging intra-actions that shaped the women's interests in science. Two prominent types on intra-actions were those with material agents and those with other people.

Intra-actions with material agents is one type of relationship that emerged as being influential in the women's experiences in science. The narratives show that

material engagement leads to knowledge, in this case, about science. As stated by Barad (2007), "knowing is a direct material engagement, a practice of intro-acting with the world as part of the world in its dynamic material configuring, its on going articulation" (p. 379). Engagement in the world led to knowledge of that world and interest in learning more.

Mae and Visha both had early experiences with the world around them that shaped their life-long love of science. The Committee on Learning Science in Informal Environments (2009) distinguish between two types of informal learning experience: spontaneous experiences and more deliberate experiences. Visha's early engagement in science was made up of mostly spontaneous experiences. Visha spent a great deal of time in nature exploring wildlife, heard exciting insect-related stories, played with an insect set and a doctor's kit, and had many books about animals. Mae mixed beauty products to "make" lotion, made slime, and experimented with cooking ingredients. For Visha, observing and being part of nature was a way of life, so much so that in her concluding remarks to me, she pointed out two things that she felt had influenced her interest in science: one was the nature she grew up being part of. Nature was her playmate and her teacher. Mae's early engagement in science was made up both spontaneous experiences and more deliberate experiences. For her, mixing things to see what would happen was such a common occurrence that it was how she played and how she thought about substances with which she came in contact. She said that she liked working with her hands. She also participated in at least one science camp.

In the free play of childhood matter was the agent shaping their understanding of science. Once in school, the agency seemed reallocated to the teacher. Mae's and

Visha's interests in science, in understanding the natural world, decreased when school took center stage, as opposed to the material world. Scantlebury, Danielsson, Hussenius, Gullbery, and Andersson (2019) describe a similar theme in the recollections of preservice science teachers with whom they spoke. They said, "Some preservice teachers connected spacetime in nature to authentic science learning. Yet a different spacetime, that is, the classroom and secondary school, produced material-discursive practices such that according to students were not engaged with science learning" (p. 45). Mae and Visha did describe some material engagements within school settings and these material intra-actions were always accompanied with increased interest.

Like what is seen in Visha's and Mae's narratives, some research shows a strong correlation between early science experiences and developing a later interest in science (Bricker & Bell, 2014; Committee on Learning Science in Informal Environments, 2009; Dabney, et al., 2012; Maltese, et al., 2014; Maltese & Tai, 2010). However, it is important to note that early experiences in science are not necessary for later interest in the discipline. Nathalya did not mention any specifically scientific experiences until late in middle school. Her first science-related material intra-action will be addressed later in this section. Much of the research exploring how early engagement in science activities affects later science pursuits focuses on quantitative analysis. Some of the research, such as that done by Dabney et al. (2012), uses predetermined categories in surveys that do not include the types of science activities that Mae and Visha engaged in like "mixing things" or observing nature. Other research, such as that done by Maltese et al. (2014), does include categories such as playing outdoors but does not disaggregate the data by gender. Mae's and Visha's narratives show that early interest in science may look different for

different people and may be outside the bounds of typical categories used in the existing literature.

One aspect of Mae's and Visha's narratives that stood out was that their early experiences aligned with their future specific scientific disciplines. Where Visha was interested in animals, Mae was interested in mixing things. This later translated into Visha studying biology and Mae studying chemistry. Visha's interest in animals seemed to carry throughout her life. All of her favorite middle school and high school labs and projects had to do with animals. Mae's interest in science in general waned in middle school but reemerged with high school chemistry. Perhaps later academic studies around a subject reinforced the significance of earlier experiences, or perhaps the early experiences altered the trajectory of their lives in ways that led them to maintain an interest in a specific subject later in life. For example, Visha's in-depth studies of living things may have increased the significance to her of memories regarding her early love of animals or her early love of animals may have shaped her life, eventually leading to a study of living things. There may have also been an innate, inborn interest in animals for Visha and in mixing things for Mae although their experience certainly contributed to any biological predisposition. While, as previously stated, many studies have shown a correlation between early engagement with science and later obtainment of science degrees, the studies do not disaggregate the data by science discipline.

A 2010 article by Maltese and Tai summarized findings from interviews with 116 chemists and physicists. One of the main findings of the study was that 57% of the males interviewed indicated that their early interest in science was intrinsically motivated, often indicating that they were interested in how things like tinker toys worked. On the other

hand, 52% of females indicated that their initial interest was associated with school. Since this study only included participants in the physical sciences, the findings might have been different for biologists who may have been engaged in different types of early play. Many of the types of science-related activities indicated in the interviews by Maltese and Tai were about tinkering and figuring out how things work, activities that are stereotypically of more interest to boys and are related to physical science endeavors. Absent from the responses were descriptions of engaging with plants and animals, things that is stereotypically of more interest to girls and are related to life science endeavors. A study that was not domain specific showed that two of the most important types of experiences that generated STEM interest were tinkering and spending time outdoors (Maltese et al., 2014). This further supports that the absence of as outdoor play in the study by Maltese and Tai (2010) may be due to the domain specificity of the participants. Visha's narrative indicates that female biologists might have shown greater earlier interest in science stemming from intrinsic motivation to play outdoors rather than initially being motivated by school.

Something else that was prominent in both Mae's and Visha's narratives was that their early experiences with science-related materials involved a great deal of autonomy. The narratives show the importance of autonomy with science that is engaged in at home and that this autonomy may be influential for women's interests in science. Scholars who research informal science learning refer to autonomy as free-choice science learning (Phipps, 2010). Most of the research in this area focuses on experiences outside of the home such as those in museums or special programs. Very little of it is based on everyday science that happens in homes and through play (Phipps, 2010). The research

that does explore the science engagement that happens in homes is often structured around specific materials or learning outcomes that were dictated by the researchers (Hall & Schaverien, 2001) or catalogs the types of science activities that occur at home rather than exploring the nature of that engagement (Korpan, et al., 1997). Much of the existing literature that looks at the importance of autonomy in science learning for older children is specific to school-based learning and providing more student-centered learning opportunities (Jalil, et al., 2009; Ramnarain, 2010). Because of the school-based context the experiences are designed with specific learning outcomes in mind, although advocating for more student choice.

In a 2011 report Morre, Bathgate, Chung, and Cannady proposed an instrument designed to measure five dimensions that enable success in science, one of which was perceived autonomy. The authors argue that areas with a large amount of research such as interest, value, and self-efficacy are not enough to predict if students will continue to engage with science. A measure of youth's feelings of autonomy is also needed. The purposed instrument surveys students' perceived autonomy with science at school, in a science museum, at home, and anywhere. No further publications reference the use of this instrument. Visha's and Mae's narratives provide evidence that the instrument in combination with other information may yield some valuable findings.

Based on Mae's and Visha's experiences, autonomy of early, informal learning experience may be more important than existing literature acknowledges. Out of several studies on the importance of informal science experiences (Bricker & Bell, 2014; Committee on Learning Science in Informal Environments, 2009; Dabney et al., 2012; Dou et al., 2019; Maltese et al., 2014; Maltese & Tai, 2010) only two included direct

quotes from participants. In both of these autonomy in early learning experiences was mentioned by participants but was not a point of analysis by the researchers (Bricker & Bell, 2014; Maltese & Tai, 2010). Mae would escape from the noisy crowded space of a family gathering and find peace and quiet while mixing lotions and fragrances. Bricker and Bell (2014) share a quote from the mother of the girl, Brenda, who was followed during their longitudinal study. The mother tells of how Brenda and her cousin would lock themselves in Brenda's grandmother's bathroom and mix cheap perfumes. The mom mentions several times that the children did not want parents to come in. For Mae, part of the intrigue was having a private space, part was making the concoctions, and part was sharing those concoctions when she reemerged from the bathroom. Mae also had full control over her slime making ingredients which were stored where she could get to them and choose when and how to use them.

Visha also had autonomous interactions with the science she grew to love. She and her sister would spend most of their early years in free play outside. During this time, she developed a bond with worms, birds, caterpillars, and snakes. The supervision from her grandparents was vigilant but distant. They made sure the girls were safe but also gave them a great deal of space. The supervision at her daycare seemed equally present but from a distance. It was through independent play that Visha developed a love of living things. Visha and Mae often intra-acted with materials without the mitigating influence of adults. They built relationships with the materials that altered their understanding of and passion for science. Seeing science through the apparatus of adult facilitation would have created different, less personal relationships with the animals and substances.

Although relationships with people will be explored in more detail in the next section, I would like to point out now that Visha's and Mae's investigations of the world were not without human interaction. For both women, then children, sharing their creations or findings was important. Mae would have her entire family try the lotions that she made and Visha would show her grandparents the bugs that she found. Their material and relational worlds were brought together in those moments. The material and social worlds are inseparably entwined.

Early unmitigated intra-actions with the materials of their disciplines likely shaped the relationship that Visha and Mae had with the subjects of investigation in those disciplines. I also wonder how independent experiences impacted the women's later confidence with experimentation. In their article, which described longitudinal in-depth observation of a girl named Brenda, Bricker and Bell (2014) list several scientific practices that they noticed Brenda using while playing with a perfume making kit. Brenda then utilized some of these same skills, such as labeling and organizing materials, in a school science experiment. Although Visha and Mae did not discuss skills they may have developed through their early experiences, it is likely that the ongoing intra-actions with observing nature for Visha and mixing substances for Mae developed a relationship with the materials of study that made them more competent and more confident in later investigations.

Research shows that young women can be hesitant when completing formal science experiments (Holmes, et al., 2014; Jovanovic & Steinbach King, 1998; Wieselmann, et al., 2019). Other research shows that informal learning experiences, such as those that Mae and Visha engaged in at young ages, can help to increase confidence by

allowing learners to develop scientific theorizes that integrate learning from multiple contexts and help learners acquire skills such as perceiving, noticing, making connections, and making inferences (Committee on Learning Science in Informal Environments, 2009). Perhaps developing skills in an unmonitored and therefore, nonthreatening environment allowed Visha and Mae to be successful in later, more formal environments. The informal experiences may have helped them to develop confidence and skills that allowed them to engage in science classes in school without the hesitancy that is typical for many female students.

For both Visha and Mae, autonomy played a prominent role in their early experiences. However, none of the women described experiences of complete autonomy later in their scientific lives. Although studies show that classes that allow students to have autonomy in experimentation increase students' interest in science and can also increase their science comprehension (Jalil, et al., 2009), studies also show that most classrooms have more structure in science learning than autonomy (Ramnarain, 2010). Nathalya, Visha, and Mae did not discuss any classes in grade school that involved them having freedom to experiment and develop their own understandings of science. Mae did describe one college lab section where the students designed their own procedures. Although she found this difficult, she liked it and felt like she was acting like a real scientist. Visha's experience collecting bugs for insect biology was also a fairly independent project. She loved this project and the experience changed how she experienced nature. She liked getting her hands dirty. I wonder to what degree schooling influenced their decreasing independence and self-reliance with science. Perhaps if the

women had more opportunities to independently engage in science, it would have increased their interest in becoming research scientists.

As mentioned, Nathalya did not talk about having early experiences with science. The first intra-action that she had that made her contemplate a future in a science field was with a book. The book helped her to reimagine what it might be like to be a doctor. It shifted her perception of a doctor from someone sitting behind a desk to someone running through the halls of hospitals. Several times she alluded to or directly said that she wanted to be moving around in her future career. This reimagining of the role of a doctor caused a dramatic shift for Nathalya that was continued through watching Gray's Anatomy. She started to research diseases and pay more attention in her science classes. The Committee on Learning Science in Informal Environments (2009) pointed out that interests that children show in science through play is often expressed by adults through research and engagement with the internet. Several times Nathalya indicated that she would "google" things that she heard about or learned about, indicating great interest in that topic.

Like Nathalya, Visha also had a transformative engagement with a book. She read a book about dolphin training that made her see animals used for entertainment as animals imprisoned. Her earlier engagement with movies like Free Willy and Flipper made her interested in becoming an animal trainer, something she completely rejected after reading the book. She had several other books about animals that were well-loved throughout her life. Mae didn't talk about books, but did feel that science shows on TV contributed to her interest in science. Although media is not always a tangible "material," the books and shows they engaged with had agency that shaped their

relationship with science. The narratives support the findings of some literature which claims that exposure to science-related media can increase women's interest in science (Blickenstaff, 2005; Brotman & Moore, 2008; Dou, et al., 2019; United Nations Educational, Scientific and Cultural Organization, 2017; Wang & Degol, 2016).

Although many reports and summaries say that the lack of female representation in the role of scientist in media has a direct impact on the underrepresentation of women in science, their argument is based on studies that show two things. First, it can be psychologically harmful to see derogatory representation individuals that look likes one's self or to not see any representation. Second, women are underrepresented and poorly represented in media (Long et al., 2010; Steinke & Tavarez, 2018). Studies that have done female-rich science-media interventions have found no impact from the intervention (Steinke et al., 2006; Steinke et al., 2007). The authors of these studies point out that the interventions were limited in their time scale and it is likely that prolonged exposure to media with a greater and more positive representation of women in science would have an effect on children's perceptions. Interestingly, although Mae, Visha, and Nathalya all talked about how intra-actions with media shaped their relationships with science, none of them mentioned women being prominent in the books they read or shows or movies they watched. Perhaps this is due to the limited media availability that casts women in meaningful roles as scientists.

One specific way in which the narratives might show how media has affected the women differently is by looking through a cultural lens. A 2017 review by the United Nations Educational, Scientific and Cultural Organizations pointed out that Latin American media has a prevalence towards gender stereotypes and negative messaging

about women in STEM. Perhaps this is why Nathalya had more prominent moments of coming to see that women can be scientists. Nathalya several times mentioned how women were viewed and treated differently in Columbia than in the United States. She also talked about how specific careers such as teaching and medicine were talked about differently in the two places. She did not explicitly talk about the perception of women in science, but it may have impacted her without her conscious awareness.

One reason that books may have been so transformative for Nathalya and Visha is their ability to transport people to new places and put them in new shoes. For Visha, books were not the only thing that had the ability to transport her. Visha had several experiences that she described as being immersive experiences that transported her to new worlds. One of these was a mobile planetarium that was temporarily installed in her elementary school each year. It was a full-sensory experience of sound and light. In college she described her insect biology and marine ecology classes as entering new worlds. For both classes she had field experiences that involved looking closely at parts of the world she had previously not noticed. The field experiences, like the planetarium, provided new experiences that acted on her to shift how she saw the world, opening new understandings.

Throughout the narratives, the women intra-acted with material agents which provided new ways for them to understand science and altered their interests in science. Many of the material engagements increased their interest in science although some decreased their interest or just shifted their interest. The phenomenon of their interest in science continually changed with each new intra-action. The three narratives presented demonstrate that material ways of knowing science are important for these women and

provide examples for why it is important to consider material ways of knowing when researching epistemologies of science.

Relational Agents

One thread that ran through Visha's, Mae's, and Nathalya's narratives at all ages was relationships. Their relationships with people and with the subject matter impacted their understanding of and interest in science. Relationships have long been expressed as an important aspect of feminist epistemologies of science (Barad, 2007; Keller, 1985; Longino, 1990; Rose, 2004). Researchers looked at the importance of relationships with female mentors (Blickenstaff, 2005; Brotman & Moore, 2008; United Nations Educational, Scientific and Cultural Organization, 2017; Stout, et al., 2010; Wang & Degol, 2016), with peer groups who value academics (Hilts, et al., 2018), and with parents (Bricker & Bell, 2014). The narratives show that it is not one relationship, but a lifetime of relationships that shapes who students become as learners. Although one teacher, parent, or peer can have a huge influence on a student, the student is never without other influences. Each new intra-action shapes the phenomenon of a woman's interest in science. In the following section I describe how some of the relationships that impacted the women were formed and some of the impacts of those relationships.

When Nathalya, Visha, and Mae were young, as might be expected, their primary influences were family members. Although Nathalya did not recall any specific science-related experience prior to her last year of middle school, she described the role that her family had in her later identity as a scientist. When she wrote about herself as a scientist of color and when she told me about herself as a female scientist, she started her story with when she was born, then went back even further in time to her parents and their

parents. Nathalya's mom worked very hard to be able to provide her with private schooling instilling in Nathalya a value for education and for hard work. She read to Nathalya, kept the house full of books, and served as a role model of someone Nathalya wanted to emulate in many ways. Mae's parents impacted her early interest in science by getting her things like her science kit and signing her up for science summer camp. Mae was also greatly influenced by her relationship with her sister. Her love for her sister was evident in how she talked about her and even how happy she looked while talking about her. She would find herself following in her sister's steps. Although her sister was not as interested in science as Mae was at an early age, she was invested in academics and eventually became a doctor.

The most influential figures in Visha's early academic life were her grandparents. Her grandmother would do her homework with her and her grandfather would continue her schooling throughout the summer. They also encouraged her curiosity by looking at bugs she wanted to show them and getting her books about things that interested her. Visha's parents and extended family encouraged her to be a doctor. At the end of our conversations when she reflected on the two most important factors impacting her interest in science, she said that people, primarily family, encouraged her interests in science and medicine. She wondered what her life would have been like if she did not have that encouragement or if she had been directed toward a different area of interest. There was, however, a turning point when this encouragement turned to pressure from her father and then to disappointment when she did not continue to medical school. Visha perceived her father's expectations of her to become a doctor as partially due to a cultural norm of Indian fathers wanting their children to become doctors. Although her mother and

grandmother supported Visha's decision to not continue to medical school, her extended family expressed disappointment in her decision. Her father's displeasure was devastating to her.

The preeminence of the influence of family more that teachers in women's early lives is also demonstrated in quantitative research. For example, Maltese et al. (2014) found that 29% of their participants indicated that their parents were the primary influence of their initial interest in STEM where 26% of their participants said it was teachers. They point out that these statistics have agreement with previous research. Although this data shows agreement with the narrative presented in this document, the narratives also highlight factors that surveys cannot. Visha was highly influenced by her grandparents, an option that is likely not available on most surveys. Also, it is unlikely that Nathalya would indicate that her interest in science was motivated by her mom, but as described, her interest in learning was highly motivated by her mom. Also, although the first influences the women had were family members, their teachers played an important role in their developing interests in science.

It was not until high school that relationships with teachers became influential in Mae's, Visha's, and Nathalya's stories of science. They recalled some labs and projects that were assigned in middles school but did not say much about their interactions with the teachers. The one exception to this was Mae's fifth-grade teacher, Miss A, who had also been her baby sitter and a student teacher in her first-grade classroom. Mae felt that her prior relationship with Miss A made her more engaged in her class, a trend that we saw again for Mae with her high school chemistry teacher, Mr. Cooper, or Coop. She had a relationship with him outside of class due to the fact that he was her tennis coach.

Mae felt comfortable getting extra help from Coop, something that she was not comfortable doing with other teachers, and appreciated that he knew her well enough to notice and talk to her when she was struggling.

It is striking how much of an influence one or two teachers made on the women's interests in science. Maltese and Tai (2010) found that scientists interviewed who mentioned school as an important factor in their interest in science were drawn to the classes due to more than just interest in the content. They stated, "Participants commonly mentioned interest in the class content (24%); demonstrations, lab experiments, and science projects (18%); or other enrichment experiences (22%). A few of the instances were based on teacher characteristics and related to teacher personality, encouragement, or teaching style (24%)" (p. 679). In their concluding remarks, they encouraged a reevaluation of what is prioritized in schools, noting the importance of teachers' interactions with students. Mae's narrative in particular shows how relationships with teachers that extend beyond engagement with science content can have a long-term impact on students' interest in science. Maltese and Tai did not comment on whether there was any difference between males and females in regard to the role of teachers.

Close relationships with teachers was something that Mae missed in college saying that her science professors didn't really know or care about her, which she attributed mostly to class sizes. Feeling connected to the GWTeach instructors was one of the attractions to the program. Forming relationships was also a major attraction to becoming a teacher. She said that she wanted to form the kinds of bonds with students that she had with teachers in high school. For Visha, forming relationships was also a major consideration regarding her future career. She began to think that there was not

room in medicine to connect on a personal level with patients, and thus she lost interest in the profession.

Being uncomfortable seeking out extra help from teachers was not unique to Mae. Visha felt uncertainty going to see professors during their office hours until a physics professor said that he *wanted* students to come see him. The professor saying explicitly that he wanted students to come to him for help made her feel that she could be open with him about not understanding the content. Similarly, Mae did not go to professors during office hours until a professor invited the students to come see her, even if it was in a social context. I recently attended a plenary session of a conference by Dr. David Laude. In this talk, and in many others including a TED talk which has over 8,000 views, he told of when he first told students in his classes that he was on their side and wanted them to be successful. He said that, unlike in previous semesters where he rarely if ever received one-on-one communication from students, he received a plethora of email that very evening. He encourages professors to let students know they care about them and want them to do well. The importance of this simple act was clear in Visha's and Mae's narratives. Teachers saying, in front of large classes, that they wanted students to come to them allowed Visha and Mae to feel more comfortable seeking the help that they needed to be successful with learning science. Nathalya did not talk about any professor encouraging students to come in for help and she did not go to professors for help. She did, however go to professors for guidance on what classes to take and whether or not she should be a physics major. These professors responded favorably to her seeking out their advice and went out of their way to be supportive of her.

Research on teacher-student relationships in science shows that positive interpersonal relationships can have a positive effect on student interest and achievement in science (den Brok, et al, 2005; Smart, 2014; Wubbels, 1993). Wubbels (1993) demonstrated a dramatic effect of interpersonal teacher behaviors in a study of 66 ninth-grade physics classes, showing that it accounted for 70% of the variability in student achievement and 55% for attitude outcomes (p. 6). Analyzing the interviews of 24 sixth grade science students, Smart (2014) identified several categories of how students described cooperative behavior: helpful (which includes approachable/supportive and available) and understanding (which includes empathetic and slow to anger). Nathalya, Mae, and Visha all discussed appreciation for teachers and professors who were approachable, supportive, and made themselves available to students. This may suggest that being helpful is a particularly important characteristic of teacher-student relationships for women in science. It may also be unique to these three women, highlighting the value in finding out what is important to particular students.

Prior to the positive response of some professors, many of the interactions that Nathalya shared with authority figures were adversarial. The most notable of these individuals was her high school guidance counselor who used Nathalya's status as an English language learner to be dismissive of her desire to take more rigorous classes. Nathalya seemed to not be dissuaded by attempts to derail her from her goals but she also seemed to appreciate people who were supportive. Although Nathalya interpreted her counselor's dismissal of her interest in academics to be due to her status and an English language learner, it is likely that her intersectional identity as a female, Spanish speaking, Columbian immigrant impacted the interactions in inexplicit ways. Other scientists have

noted that aggressions that they experience as people of color are more overt than those that they experience as women (The National Academies of Sciences, 2018). However, their identities as women of color invariably impact their experiences in invisible ways. Nathalya's counselor may have reacted differently if a male student in the ESOL program expressed interest in taking more challenging classes.

The dismissal of Nathalya's interest in academic classes is an example of the type of "microaggressions" that are commonly experienced by people of color and women. Microaggressions are particularly common in science and have been shown to be a large contributing factor to women leaving science (Harrison & Tanner, 2018; The National Academies of Sciences, 2018; Yang & Carroll, 2018). Over time, microaggressions can cause a great deal of psychological damage. Although the dismissal of Nathalya's academic interests by her guidance counselor, and other similar events were frustrating to Nathalya, she did not speak of them as causing her psychological damage. As previously mentioned, it seemed to incentivize her even more to prove others wrong. Nathalya's narrative shows that microaggressions may impact some individuals in more subtle ways than those addressed in the research: the psychological impact and the movement away from a particular field or interest such as science.

Although Nathalya did not seem to form relationships with science teachers as a student in class, she did form relationships with professors in other contexts. Dr. Marsh, or simply Marsh, was a professor that she got close to during her last year as a student by working with him on improving his teaching materials. She appreciated having conversations with him about topics other than science and appreciated that he treated her like a colleague. Of the three women, Nathalya was the only one to talk about seeing

someone as a role model. She described her mom as a role model and described the head of her summer fellowship as a role model. While saying how much she looked up to the head of the program she also described her as intimidating. The professor was someone she respected but they did not seem to form a friend-like rapport.

Having same-sex role models in science has been shown to increase women's retention in the field (Young, et al., 2013). However, "role-model" is defined differently in different studies. Some studies aim to expose individuals to women scientists or assign role models to students. Other studies focus on self-identified role models. Nathalya described many individuals who impacted her science interest but only used the term "role model" for one of them. In a 2008 study Buck, Clark, Leslie-Pelecky, Lu, and Cerda-Lizarraga explored how eighth-grade students identified role models. The girls identified that they sought characteristics of good personality, expertise in science, and the ability to make personal connections in perspective science role models. The one woman that Nathalya identified as a role model was someone who she described as nice, intelligent, and accomplished but was not someone that with whom she formed a particularly close relationship. In comparison, she described a much closer relationship with Dr. Marsh, who was a man. Perhaps gender was an important factor in who Nathalya did and did not describe as a role model.

Shin, Levy, and London (2016) conducted a study in which they were looking at the effects of role models on undergraduate college students. The role models were not European American males and expressed struggles that they had in STEM. Students indicated that the role models had characteristics that the researchers pre-identified as important characteristics in effective role models: competent, likable, and inspiring. The

role models were rated lower in natural ability and luck. This study seems particularly relevant to Nathalya's conception of a role model, particularly when comparing the woman that she described as a role model and another professor that she described, Professor Curie. Curie was also a female scientist who was friendly, intelligent, and accomplished. She seemed to have more of a personal connection with Nathalya and she also shared her struggles in science, as did the role models in the work of Shin et al.. I wonder if the vulnerable act of her sharing struggles decreased Nathalya's perception of her as a role model since Nathalya used the term intimidating and role model side-by-side in her description of the other women. Shin et al. did not have participants indicate, using their own criteria, if they felt the individuals they were exposed to were role models. If they had, the results might have shown that the vulnerability of sharing struggles may have decreased the likelihood of the individuals being perceived as viable role models.

Teachers and family were not the only people who shaped the women's educational trajectory. Peers were also influential. For Nathalya, like with the guidance counselor, she often felt as if she was working to overcome her peers' preconceived notions of who she was and what her capabilities were. It seemed as if her desire to prove people wrong and surpass people's expectations drove her to do more. She did not talk about specific peer relationships in college but was part of many organizations including physics organizations. For Visha, peers were a vitally important part of her support system, to the point that she prayed to have a good study partner in each class. These study partners did not serve only that one role; they also became friends and people she talked to about the Christian faith. She relied on her peers to answer questions

and to give her someone with whom to talk through her thinking. Visha's valuing of peer relationships within science mirrors what some studies have shown. Hilts, Part, and Bernacki (2018) showed that women had a greater intention to stay in science when they had greater contact with classmates and felt a greater seance of relatedness with classmates. This finding was unique to women, and no other group for which the data was disaggregated. Nathalya seemed to have a sense of relatedness from her involvement with science organizations even though she did not speak about specific relationships. Visha was self-aware of the importance of her relationship with other science students.

For Mae, being surrounded by peers who valued academics, like the students in her high school, was important. However, in college she did not seek out chemistry study partners; one found her, Gary. Again, we find Mae forming a relationship with someone outside academics, in this case through Greek life, that then impacts her within academics. Gary became her support system and she became his. Unlike Visha, who had several friends in her major with whom she studied over the years, Mae and Gary were an insular unit. Mae attributed her small science circle, in part, to starting the major late and to not being a part of a chemistry organization. She did, however, feel a sense of relief when she got to know other chemistry students better during her senior year, and realized that they often felt as uncertain as she did about the content.

Relationships with others did not only contribute to shaping Visha's, Mae's, and Nathalya's engagements in science; they also wanted to use these relationships to help others. Doing good for others is something that researchers have found to be a common motivator for women (Diekman, et al., 2010; Ecklund, et al., 2012; Hilts, et al., 2018; Sax, 1994; Seymour & Hewitt, 1997; Su & Rounds, 2015; Wegemer & Eccles, 2019).

Altruism is also something that feminist theorists deem an important aspect of epistemologies of science (Rose, 2004).

Visha and Nathalya, who were interested in pursuing medicine when they entered college, were motivated by doing good for others. Both of them saw medicine as a way to help others. Studies have shown that one reason women are more likely to enter fields related to health, and medical sciences rather than mathematics, physical, engineering, and computer sciences is because of the perception of the former being more altruistic than the latter (Su & Rounds, 2015; Wegemer & Eccles, 2019). Despite medicine being more people-oriented than other STEM fields, Visha, eventually determined that medicine did not allow for the close relationships that she wanted to form during her work, which led her to be interested in ministry or teaching.

Despite having classes that directly connected biology research to environmental issues, Visha did not make a connection that she could help others through science research. Some research shows that students typically do not discuss science research as something to help humanity (Sandoval & Redman, 2015). For Visha, the distance between laboratory research and the people who might be helped through that work, made becoming a researcher something that was not even a consideration. This makes me think of a summer research experience I had working on developing a molecule for the in vivo detection of Alzheimer's disease. At first, I was highly motivated by the end goal, but quickly the research became about the day-in and day-out experience in the lab and lost its connection to the bigger picture. Perhaps if Visha had experience working in a lab she might have seen how research can help others, but likely it would have depended greatly on what that experience was like.

Nathalya saw, through a summer research experience working with biochar for the purpose of environmentally sustainable ink jet printing, that science research could be used to help others. Nathalya's narrative demonstrates that it might not be true that certain disciplines are less altruistic by their nature, but it may be a perception. Experiences that counter the perception may allow more women to see the altruistic potential of other STEM disciplines. Although working as a research scientist was not something that Nathalya planned to do in her immediate future, she left that option open. She expressed a variety of interests for what she wanted to do later in life, all of which involved helping others, such as doing charity work and teaching.

Although much of the research referenced above concludes by saying that steps need to be taken to make it more clear how science is used to help others, very little research has been done looking at what these interventions might look like. Fuesting and Diekiman (2017) proposed that mentors may be one way to promoting the communal goals of science to students. They demonstrated that students prefer mentors who are communally oriented. They also pointed out that it is difficult to find mentors who enact communal behaviors. Clark, Fuesting, and Diekman (2016) showed that exposure to exemplars of scientists who enact communal goals increased students' belief that science can target communal goals and increased the students' positive perception of science careers. Both of these studies show that things can be done to increase the perception that science endeavors can be altruistic. Nathalya's experience also shows that, but it is unclear in her experience what factors led her to see her research as being dedicated to helping others.

All three women saw teaching as a way to help others. Mae referred to teaching as a way to do good for others when she was considering participating in Teach for America; however, she spoke more about being able to build relationships with students like the ones that she had with teachers than about wanting to help others. Visha first considered pursuing something other than medicine when she heard a woman tell stories about the hardships that children in DC Public Schools were facing. She realized that she had skills that could be used to help children like the ones in the story and started seriously considering teaching or ministry as a future career. The women's experiences align with a trend found in data. According to statistics, it is much more common for women with science degrees to become teachers and for men to become research scientists (Economics and Statistics Administration, 2011). A review of 44 studies found that the most frequent factor affecting individuals' interests to become teachers was having altruistic and service-oriented goals (Brookhart & Freeman, 1992, p. 46). For Visha, Mae, and Nathalya teaching seemed to allow them to help others and give back to others in a way that science did not.

In the midst of writing Visha's, Mae's, and Nathalya's narratives, I read and relished the books *Braiding Sweetgrass* (Kimmerer, 2013) and *Lab Girl* (Jahren, 2016). When halfway through *Lab Girl* it dawned on me that there was a highly present relationship in both of these autobiographical texts that is not present in all of the stories that were shared with me: a loving, personal relationship with the subject of study. The affection that Kimmerer and Jaren have for plants is palpable. They wrote about plants as beautiful friends whom they admire and want to understand. Mae, Visha, and Nathalya did not talk about their respective disciplines in that same way with the possible

exception being some of Visha's early experiences with bugs and snakes. They would say in passing that they loved their discipline but in comparison to how they portrayed the relationships that they had with people, the comments were almost negligible. The only examples of people describing their subjects of study as souls to be understood, such as in *Braiding Sweetgrass* and *Lab Girl*, that I am familiar with are biologists. From my experience, scientists frown on approaching scientific subjects with the subjectivity that is implicit when approaching any object of study with love, but this is particularly true with any subject that is "non-living." I recall my high school chemistry teacher taking off points on answers if we ever relied upon personification in an explanation; for example, if we said that an atom "wanted" more electrons to fill an octet. Thinking of the discipline through a lens of the agency of the objects of study was discouraged. A relationship beyond researcher and researched was silenced. In listening to what is not said in the narratives (Eaton, 2018, p. 95), a relationship with the science disciplines is glaringly absent, a relationship that might have kept them invested in continued scientific research endeavors.

Methodological Reflections

When I began planning dissertation research, I knew that I wanted to share the stories of women in science and that I wanted to do so in a way that would engage readers and awaken new insights in them, the way a novel does. I was drawn to narrative methods but struggled with understanding and articulating how narrative scholars produce the narratives. Much of what I was reading addressed the goals and values of narrative but not the logistics. Clandinin and Connelly (2000) were recommended to me as narrative researchers who have provided more explicit information about how to compose narratives. As I read their work I appreciated the clarity and specificity

regarding the process of narrative. I also saw alignment between their work and my theory. For these reasons, I relied heavily on their work as a starting point for my methods.

Clandinin and Connelly (2000) outline the use of a relational three-dimensional narrative inquiry space: interaction (personal and social), temporality (past, present, and future), and situation (place). They discuss how these dimensions impact the questions asked and the texts produced. As previously described, the dimensions fit well with Seidman's (2013) three interview approach in which discussions start broad, narrow to the specific topic of the research, and then focus on feelings. The dimensions also fit well with new material feminist perspectives where time is non-unidirectional and non-human agency is elevated.

When starting the process of interviewing and writing I constantly reminded myself of the three dimensions, but as my work continued, conscious thought about the dimensions as procedural tools faded into the background and the purpose behind the dimensions came to the forefront. I originally thought of the dimensions as discrete aspects of what was shared by the women that I needed to code for in order to include them in the narratives. As time went on I realized that they are more a way of thinking, one that for me was informed as much by the method as by the theory.

I began to recognize that the dimensions are dynamic ways in which the theory is made tangible through the research rather than static codes. For example, rather than approaching discussions with a goal of seeking clarity on the past, present, and future implications of an experience, I viewed experiences through the lens of intra-actions. I asked myself: What past or future experiences might have shaped that moment and how

might that moment have shaped past and future experiences? I also considered the dimension of situation or place. Given the new material feminist foundation of this research, narratives that emphasize the more-than-human engagements in the world were paramount. Focusing on the dimension of situation is aligned to this goal but does not fully capture the process of asking about and reflecting on how non-human entities had agency on the women and on their engagement with science. Their experiences were not just about place but were also about the objects in a place like toys or books or their phones. Interaction was the dimension that I least needed to intentionally focus on in the questions that were asked and the narratives that were created. That does not mean that this dimension was not present. Narrative is a human-based endeavor and the women with whom I spoke grounded all of their experiences in the social. Their stories were, without prompting, about others in their lives and about their own feelings.

The movement away from thinking about the three dimensions of narrative inquiry as a methodological process and toward thinking about theoretical purpose behind the dimensions impacted the narratives I produced in subtle ways. The substance is essentially the same but the impetus shifted from purely procedural to theoretical. Inevitably this did alter decisions that I made in ways that are likely imperceptible to the reader. The most noticeable difference that I felt as a researcher was the ability to let go of the idea of asking the "right" questions and writing in the "right" way and to be in the moment. Thinking about three dimensions as in relationship to the theory of agential realism instead of as a set methodological procedure allowed me to intra-act with the women in the moments of conversations and to intra-act with the recordings, transcripts, and narratives in the moments of writing.

Throughout the process of working on this document many people read parts of the narratives including family members, editors, writing group members and committee members. As they read, they often shared with me how the narratives spoke to them and awoke in them a new and different understanding of the puzzle of the underrepresentation of women in science. Science educators reflected, without being explicitly asked to do so, on their own practices and how they might be more thoughtful of their practices in light of the narratives. Most of the people who read the narrative during the creation of this dissertation were not involved in science or science education. These individuals often reflected on their own experiences or those of their children. People would share with me their past experiences with science as students and through engagement with the world, questioning whether different experiences might have impacted their interest in science.

The reflections of those who read the narratives provide evidence that the narratives did intra-act with different people in different and meaningful ways. An area for future research is to study and put into conversation how the narratives intra-acted with various stakeholders. To do this I would ask several individuals to read the narratives in the same manner that I asked all readers to intra-act with the texts. I would ask these readers to "just be with the text" and to allow the narratives to exert their agency by acting on and awakening the readers. I would also ask that they exert their agency by purposely allowing their life experiences and the literature that they have previously engaged with to inform their reading of the narratives. The readers would be asked to annotate the narratives, indicating how the narratives acted upon them given their specific contexts and goals and what the narratives awoke in them.

In order to highlight the importance of the uniqueness of each set of intra-actions, I would invite people from a variety of contexts who are stakeholders in the problem of the underrepresentation of women in science to participate. These individuals could include an elementary science teacher, a secondary science teacher, a college science professor, a professor of science education, someone involved in a science extracurricular program for girls, and a young woman studying science. I anticipate that the stories will act upon each professional in a distinctive way.

Concluding Thoughts

In many ways the women epistemologies of science aligned with what the literature describes as more "advanced" epistemologies of science. However, the culture that the women experienced was often antithetical to those epistemologies. Also, in addition to commonly discussed epistemologies of science, material ways of knowing science and relational ways of knowing science are seen throughout Visha's, Mae's, and Nathalya's narratives. These ways of knowing are typically ignored by studies on the epistemologies of science, but have been highlighted in feminist epistemologies. The abundance of these influences on the ever-changing phenomenon that is these women's interests in science, indicates a need to rethink the focus on narrow definitions of epistemologies of science. I join my voice to other scholars, such as Meghan Bang, to advocate for an embracing of multiple epistemologies of science, one of which being feminist epistemologies.

Beyond a redefinition of epistemologies of science, the narratives highlight the inseparability between epistemology, ontology, and ethics. Barad (2007) originally argued for the mutual implications between practices of knowing, practices of being, and ethics saying:

> We don't know by standing outside the world; we know because we are of the world. We are part of the world in its differential becoming. The separation of epistemology from ontology is a reverberation of metaphysics that assumes an inherent difference between human and nonhuman, subject and object, mind and body, matter and discourse. *Onto-epistem-ology*—the study of practices of knowing in being—is probably a better way to think about the kind of understandings that we need to come to terms with how specific intra-actions matter. Or, for that matter, what we need is something like an *ethico-onto-epistem-ology*—an appreciation of the intertwining of ethics, knowing, and being—since each intra-action matters, since the possibilities for what the world may become call out in the pause that proceeds each breath before a moment comes into being and the world is remade again, because the becoming of the world is a deeply ethical matter. (p. 185)

Nathalya's, Mae's, and Visha's narratives show the inseparability between knowing and being. Their intra-actions with the material world, with human and nonhuman agents, continually recreated their relationship with science and themselves as science knowers and practitioners. Their actions had implications which they took seriously through a desire to do good for others. Likewise, all agents acting with them in the world produced different material configurations with ethical implications.

I, as an agent who acts with my female students studying science, with K-12 teachers, with school administrators, and with my sons, will continue to reflect on the ethical implications of my ongoing intra-actions, particularly in regards to supporting women in the sciences. Mae's, Nathalya's, and Visha's narratives have acted on me and

will continue to do so. Likewise, others who have read the narratives throughout the process of my writing the dissertation have shared with me how the narratives acted upon them and led them to new moments of wisdom.

Many of the questions and moments of wisdom that arose for me while engaging with the narratives are explored in the existing literature, but the narratives piqued my curiosity in new ways, inspiring me to read different literature and shaping how I made sense of and utilized the existing literature in my own practices. By reading the existing literature and the narratives through one another new insights were found. Many of these insights called into question the conclusions of other research, showing that alternative explanations for findings are possible. While critiquing a call for all education research to be "scientific," Tom Barone (2001) advocates for arts-based research, such as narrative. He states that the goal of science-based research is closure. He says, "This movement toward closure involves reducing uncertainty about truthfulness and usefulness of knowledge claims" (p. 24). Barone explains that it is human nature to look for certainty, but that it is also human nature to, "endow features of our experience with more than a single meaning" (p. 24). Arts-based forms of research, like narrative, focus on showcasing a multitude of meanings. Nathalya's, Visha's, and Mae's narratives highlight the different insights that can be found, and in some cases highlight that "conclusions" made in research can be open to alternative interpretations. They have begun to "reduce the commonsensical certainty" (p. 25) about the factors influencing women in science.

Perhaps the narratives have worked on you to see the world in new ways, reflecting on the ethical implication of each intra-action. Perhaps questions and moments

of fleeting wisdom have emerged while reading the narratives, inspiring you to engage with previously unread literature or to reinterpret literature with which you have previously engaged. Perhaps you are a parent deciding what book to read at bed time asking yourself, "will reading this book about women scientists inspire my son to play with his female classmates differently?" Perhaps you are deciding on activities for a summer camp for girls interested in science asking yourself, "will some girls prefer more time to explore nature and others more time to mix substances?" Perhaps you are designing a science curriculum asking yourself, "can students have more autonomy over how the labs are conducted?" Perhaps you are high school science teacher asking yourself, "will female students be more interested in my class if I make an effort to get to know them outside of the classroom setting?" Perhaps you are a college professor asking yourself, "will female students come to my office hours more if I tell them I want them to be successful?" Perhaps you are an individual involved in school policy asking yourself, "at what age should science be a required school subject?" Perhaps you are a female science student asking yourself, "should I try harder to make friends and study partners in my classes?" Perhaps you are writing a science textbook asking yourself, "should I personify the electron that is moving through the wire?" Reading narrative inquiry should evoke a story within you. I invite you to reflect on how you made different meaning from the narratives through your intra-actions and to reflect on the ethical implications of moments of intra-acting in the world, particularly with regard to the phenomenon of the underrepresentation of women in science.

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Appendices

Appendix A

Table 1

Perry's Nine Stages

Position	Title	Description
Position 1	Basic duality	"Assumption of dualistic structure of world taken for granted, unexamined. Right vs. wrong, we vs. other, good vs. bad, what They want vs. what They don't want. All problems soluble by Adherence: obedience conformity to the right and what They want. Will power and work should bring congruence of action and reward. Multiplicity not perceived. Self-defined primarily by membership in the right and traditional" (Perry, 1968).
Position 2	Multiplicity pre-legitimate	"Multiplicity perceived, but only as alien or unreal. As alien it assimilates easily to error and otherness: 'Others are wrong and confused (M).' Assimilated to Authority, it leads to Opposition: 'I am right; They (Authority) are needlessly confused (M).' As unreal, M is a mere appearance, e.g.: 'They want us to work on these things (M) to learn how to find the answer.' Here Opposition sees Authority not as wrong but simply as failing in its meditational role. In either case M is perceived but not as a signal of legitimate, epistemological uncertainty" (Perry, 1968).
Position 3	Multiplicity subordinate	"Multiplicity perceived with some of its implications. Authority may not have the answers yet on some of it, perhaps because the relevant Absolutes are not yet in view. But trust in Authority, at least in the ideal, is not threatened. Exercises in M may be enjoyed (A) or disliked (Ad); Authority is presumed to evaluate them on skill of presentation (not on structural properties). Ad may fear they are judged on glibness, influence, or pull. Opposition here: 'They judge all wrong.' Self-defined over against Authority and in similar structural terms" (Perry, 1968).
Position 4	Multiplicity correlate; or relativism subordinate	"Duality restructured in complex terms: right-wrong vs. M. Absolutes may be doubted in M area or considered so inaccessible as to be impossible to bring to bear on human affairs in any reasonably foreseeable future. In M, therefore, 'anyone has a right to his own opinions.' M is acknowledged as relevant to self, by being confusing, liberating, intriguing etc. or

		Relativism perceived in M and assimilated to Authority: A(R). That is: Authority can make judgments in M on discernible relations of propositions to each other (coherence) or to date (congruence). However this is still 'how they want us to think,' rather than a consequence of the nature of all knowledge" (Perry, 1968).
Position 5	Relativism correlate, competing, or diffuse	"Relativism perceived as way of perceiving, analyzing and evaluating, not because 'They want us to think this way,' but intrinsically. Authority perceived as authority in R. In R Correlate, world divided into those areas where Authority has the answers (e.g. physics or morals) and those in which R must be used (e.g. English papers). In R Competing, R perceived as applying to whole world (with binary answers a sub-class), but this world view alternates with a previous one. In R Diffuse, the most fully developed of these structures, R is accepted generally but without implications for commitment" (Perry, 1968).
Position 6	Commitment foreseen	"R accepted for all secular purposes including binary judgment and action. Commitment may be perceived as a logical necessity for action in an R world and/or 'felt' as needed (with or without explicit statement of a logical necessity). The realization may bring various reactions: eagerness, ambivalence, dismay, sturdiness, turmoil, simple acceptance" (Perry, 1968).
Position 7	Initial commitment	"First commitment(s) or affirmation(s). Acceptance of their origins in self's experience and choices, some intimations of implication" (Perry, 1968).
Position 8	Orientation in implications of commitment	"Some implications of commitment realized: tensions between feelings of tentativeness and finality, expansion and narrowing, freedom and constraint, action and reflection. Prospect of (or even experience of) membership with authority in areas of commitment (value, address to others, occupation, etc.). Identity sensed in both content of commitment and in personal style of address to commitment" (Perry, 1968).
Position 9	Developing commitment(s)	"Commitments expanded or remade in new terms as growth. Balances are developing in the tensions of qualitative polarities of style, especially alternation of reflection and action. Acceptance of changes of mood and outlook within continuity of identity. Sense of being 'in' one's life" (Perry, 1968).

Table 2

Schommer's 1990 Model of Personal Epistemologies

Dimension	Subset Dimensions	Sample Questionnaire Item
Simple knowledge	Seek single answers	"Most words have one clear meaning."
	Avoid integration	"When I study I look for specific "facts."
Omniscient authority	Don't criticize authority	"People who challenge authority are overconfident."
	Depend on authority	"How much a person gets out of school depends on the quality of the teacher."
Certain knowledge	Avoid ambiguity	"I don't like movies that don't have an ending."
	Knowledge is certain	"Scientist can ultimately get to the truth."
Innate ability	Can't learn how to learn	"Self-help books are not much help."
	Success is unrelated to hard work	"The really smart students don't have to work hard to do well in school."
	Ability to learn is innate	"An expert is someone who has a special gift in some area."
Quick learning	Learning is quick	"Successful students learn things quickly."
	Learning first time	"Almost all the information you can learn from a textbook you will get during the first reading."
	Concentrated effort is a waste of time	"If a person tries too hard to understand a problem, they will most likely just end up being confused."

Note. Adapted from: Schommer (2009), p. 500.

Table 3

Sandoval's four epistemological themes

Epistemological theme	Description
Scientific knowledge is constructed	"These social aspects of scientific practice are most important in the way they locate criteria for scientific knowledge claims within social, historical communities" (Sandoval, 2005, p. 639).
Diversity of scientific methods	"The goal is to help students develop standards for evaluating the fit between observations, methods of obtaining them, and the knowledge claims advanced through them" (Sandoval, 2005, p. 640).
Forms of scientific knowledge	"There are different forms of scientific knowledge, varying in their explanatory or predictive power and in their relation to the observable world" (Sandoval, 2005, p. 640).
Scientific knowledge varies in certainty	"An important instructional goal is the recognition that current scientific ideas may change as new observations or new, competing ideas come to light. This changing nature of theories reflects the cultural, historical development of scientific theories" (Sandoval, 2005, p. 641).

Table 4

Women's Ways of Knowing

Way of knowing	Description
Silence	"Women experience a passive, voiceless existence, listening solely to external authority" (Hofer & Pintrich, The Development of Epistemological Theories: Beliefs about Knowledge and Knowing and Their Relation to Leaerning, 1997, p. 95).
Received knowing	"A perspective of either-or thinking in which there is only one right answer and all ideas are perceived as good or bad, true or false" (Hofer & Pintrich, The Development of Epistemological Theories: Beliefs about Knowledge and Knowing and Their Relation to Leaerning, 1997, p. 95).
Subjectivism	"The source of truth is now within the self . . . . Women in this study are more likely to see truth as an intuitive reaction, personally experienced" (Hofer & Pintrich, The Development of Epistemological Theories: Beliefs about Knowledge and Knowing and Their Relation to Leaerning, 1997, p. 95).
Procedural knowing	"Women demonstrate reasoned reflection, applying objective, systematic procedures of analysis" (Hofer & Pintrich, The Development of Epistemological Theories: Beliefs about Knowledge and Knowing and Their Relation to Leaerning, 1997, p. 95).

Constructed knowing	Represents an integration of subjective and objective strategies for knowing . . . . Knowledge and truth are contextual. The individual sees herself as a participant in the construction of knowledge, one who can be constructed and reconstructed by the knower" (Hofer & Pintrich, The Development of Epistemological Theories: Beliefs about Knowledge and Knowing and Their Relation to Leaerning, 1997, p. 96).

Appendix B

Table 5

Research Timeline

Dates	Activity
March 2018	IRB approval
	First round of recruitment
	Consent meeting with Mae
April 2018	First round interviews (3) with Mae
	Second round of recruitment
May 2018	Consent meeting with *participant 2 (p2)*
May 2018 – August 2018	First round of interviews (5) with *p2*
August 2018	Third round of recruitment
	Consent meetings with two women who did not meet the criteria
September 2018	Consent meeting with Visha
September 2018 – October 2018	Follow up interviews (2) with Mae
	First round of interviews (3) with Visha
December 2018	Mae's narrative completed and sent to Mae
December 2018 – August 2019	Follow up interviews (2) with Visha
August 2019	Visha's narrative completed and sent to Visha
August 2020	Nathalya's narrative completes and send to Nathalya

Appendix C

Elements of consideration for narratives:

- From Research Puzzle and Research Questions
    - **Complexity** – Does the narrative convey the complex and ever shifting of factors impacting the participant's experiences in and interest in science?
    - **Epistemologies of science** – Does the narrative include statements about how participants view what science is and how one comes to know science?
    - **Resonance and dissonance** – Does the narrative make clear ways the participant's epistemologies differ from and align with the science that they have experienced?
- From Narrative Inquiry
    - **Temporality** – Does the narrative represent the participant's past, present and future experiences with science?
    - **Internationality –** Does the narrative represent the participant's feelings, hopes, aesthetic reactions, moral dispositions, and social interactions?
    - **Situationally** – Does the narrative represent the participant's physical place throughout her experiences?
    - **Ascetics** – Does the narrative evoke a story in the reader?
- From Agential Realism
    - **Relationship** – Does the narrative make clear my evolving relationship to the participant?
    - **New materialism** – Does the narrative make clear how the intra-actions between material objects have impacted the experiences of the women, the conversations that we had together, and the writing of the narrative?
    - **Becoming** - Does the narrative evoke a sense of constant becoming of the participant and researcher?

Appendix D

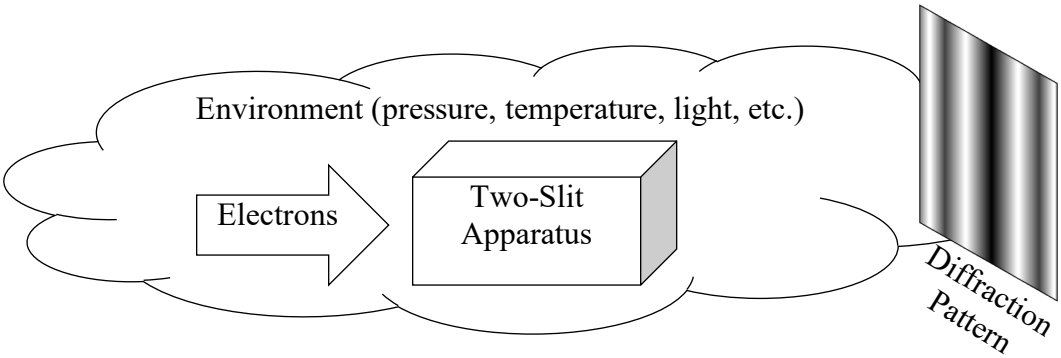

Figure 3. Simplified representation of two slit apparatus. This image shows a simplified representation of the two slit apparatus that will be used throughout to represent various phenomenon present in the study.

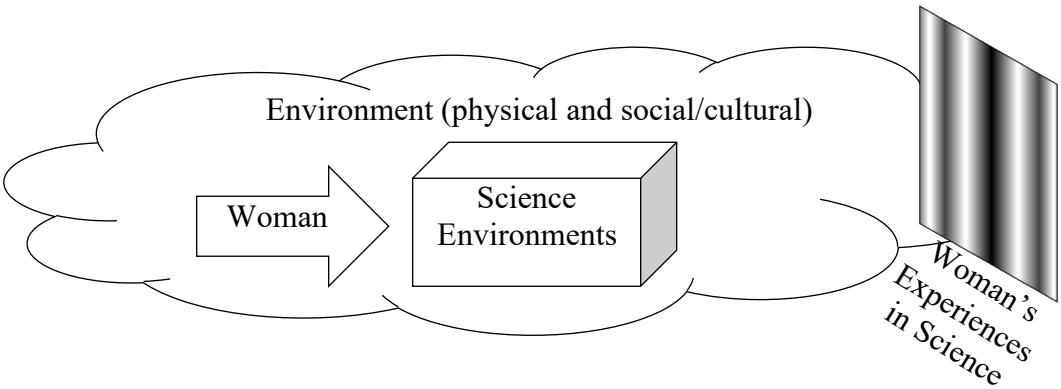

Figure 4. Phenomenon of a woman's experiences in science. This image represents the phenomenon of a woman's experiences in science when the woman intra-acts with science environments and with other aspects of her life.

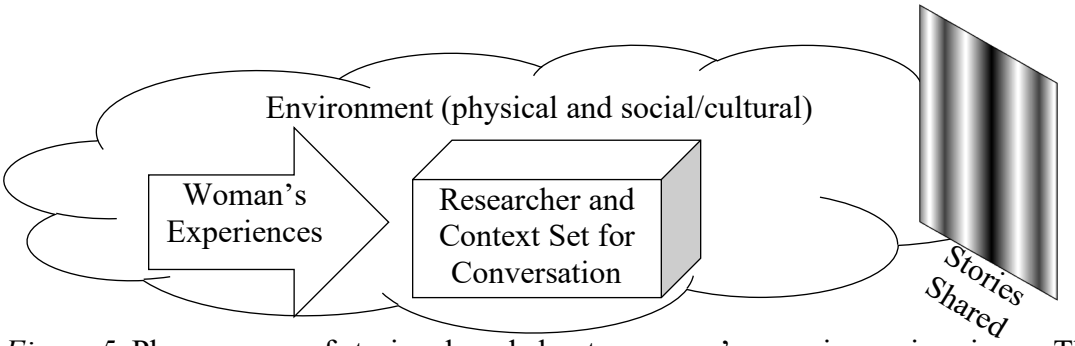

Figure 5. Phenomenon of stories shared about a woman's experiences in science. This image represents the phenomenon of the stories shared about a woman's experiences in science when the woman's memories of experiences in science intra-acts with the researcher, the contexts set for conversations, and with other aspects of the conversations.

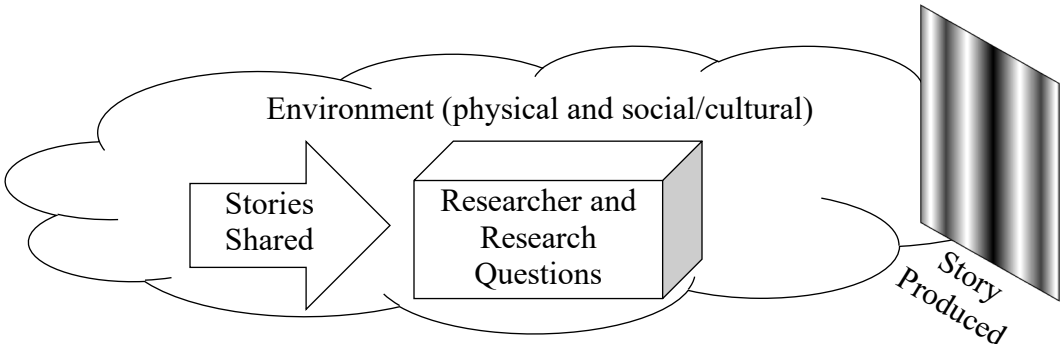

Figure 6. Phenomenon of stories produced about women's experiences in science. This image represents the phenomenon of the stories produced by the researcher about women's experiences in science when the recordings, transcripts, and notes about the women's stories intra-act with the researcher, the research questions, and with other aspects of the research environment.

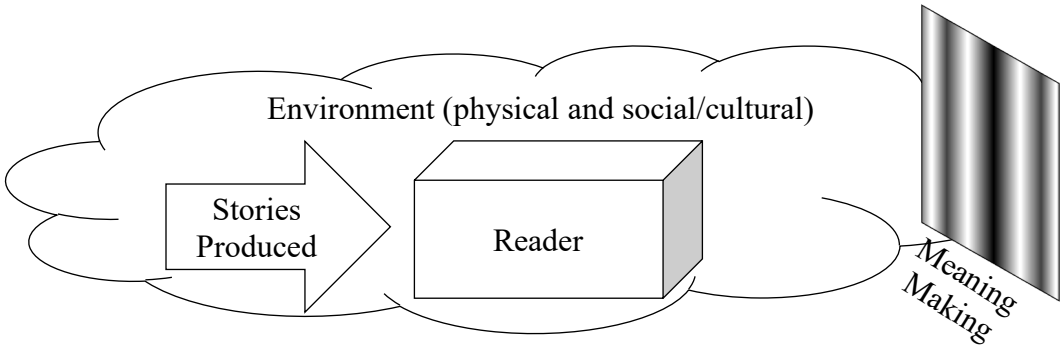

Figure 7. Phenomenon of meaning made by a reader. This image represents the phenomenon of the meaning made by a reader when the stories produced intra-act with the reader and with other aspects of the reader's life.