IN THE FOOT STEPS OF MADAME CURIE: A CROSS-CASE STUDY OF FEMALE UNDERGRADUATE PHYSICS MAJORS

A Dissertation

by

VANI SAVITHRI JALADANKI

BS, University of Mysore, India, 1995
MS, Texas A&M University-Corpus Christi, 2010

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This dissertation meets the standards for scope and quality of
Texas A&M University-Corpus Christi and is hereby approved.

Bryant Griffith, PhD
Chair

Tonya Jeffery, PhD
Co-Chair

Elsa Gonzalez, PhD
Committee Member

Diane Denny, PhD
Graduate Faculty Representative

May 2016

ABSTRACT

Females are disproportionately underrepresented in STEM (science, technology, engineering, and mathematics) majors. Further, the number of females who take physics in college has declined. While female students make up 61% of graduates in biological sciences and 50% in chemistry, the proportion of women completing physics degrees is only 21% (Sawtelle, 2011). In order to improve women's access to science and engineering education, research must focus on personal and environmental factors that motivate them to select these fields (AAUW, 2010). The purpose of this study was to explore how the educational experiences of three female undergraduate physics majors contribute to their current dispositions toward, interest in, and pursuit of physics as a major at a large southern research university.

This qualitative study employs symbolic interactionism (Blumer, 1969) as its methodological framework and social cognitive career theory (Lent, Brown, & Hackett, 2002) as its theoretical framework. Case study methods (Yin, 2006) were implemented to investigate the experiences of three participants. The primary sources of data included critical incident interviews (Flanagan, 1954), photographs, documents, object elicitations, and the researcher's reflections. Narrative and arts-based techniques were employed to analyze and represent data.

Findings are presented as co-constructed narratives of the participants' journeys to becoming undergraduate physics majors. Three major themes emerged from the cross case analysis: carving new spaces, authoring an empowered self, and show me you care and so will I. The direct experiences of engaging with science at a young age and social persuasions of family members, teachers, and peers strongly influenced the participants' interest in and pursuit of physics. Their current dispositions to physics result from vicarious experiences with professors and peers in combination with the social persuasions of the latter.

This study informs science educators in general, and physics educators in particular, about how to motivate and enable female students to engage with physics and possibly pursue it as a career choice. Three major implications for practice were suggested: teach science as a vibrant field, enable students to understand failure as an opportunity to succeed, and shift the focus from competition to collaboration.

DEDICATION

To my Amma and Nanna who always encouraged me to dream big.

To my loving husband, Kalai, and to the most valuable treasures of my life, Sumit and Navya, who constantly inspire me to change my dreams into reality.

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I extend my heart felt gratitude to everyone who believed in me and stood by my side through thick and thin to help complete this dissertation study successfully. Without your continued support, this study would not have been possible.

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I thank the participants of this study who readily agreed to share their experiences. I am positive that your voices will make a difference in the lives of many women.

Thank you, Amma and Nanna. You instilled in me the love for learning and taught me to persevere despite setbacks. You always saw your future in the success of your children. As a result, today I proudly stand before you with a terminal degree in the discipline of education. Thank you for taking care of Navya and Sumit during these years of my study. Your generous support made it possible for me to finish this program. Bobby and Chinna, thank you for cheering me on this often tiring journey. Bobby, your work ethic and your discipline have encouraged me to persevere through this degree and I owe you for setting such high expectations for me.

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Kalai, your support meant the world to me. You are my best friend, philosopher, and guide who believed in me more than I did in myself. Your immense patience, encouragement and unwavering love constantly encouraged me to pursue my dreams. Thank you for always being there for me. I love you Kanna! The joys of my life, Sumit and Navya: you are the reason for my existence and my success. Your wonderful smiles and big bear hugs have kept me triumphing forward even when my tired mind and body wanted to give up. Sumit, thank you for being so understanding when I missed your piano recitals and boy’s scout camps. Your patience and unconditional love are the reasons for the completion of my study. I hope this will inspire

several children like you to pursue their dreams with passion. I love you! Amma is finally done with her study. Now; it is time for Disney Land!

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CHAPTER I

INTRODUCTION

It was the last five minutes of Mrs. Garza's high school physics class. Students were busy finishing up the data analysis and turning in their journals when she noticed Ritha, a senior, walking toward her with a bright smile across her face.

"I just wanted to let you know that I got accepted into the engineering program at MIT. I thought you would like to know," said Ritha.

"Congratulations Ritha! That is great news" screamed Mrs. Garza, embracing Ritha joyfully. "I am so proud of you."

"But, I am not sure if I'm going," Ritha said timidly.

"Why?" asked Mrs. Garza. She was expecting Ritha might be having second thoughts of accepting the offer due to financial issues.

"I want to go because I got a full ride. But I am not sure if I can handle it." Fear sounded in Ritha's voice.

"What do you mean?" asked Mrs. Garza, stupefied.

"I mean, I do not know if I will be able to do well over there. I made only a 670 on my physics subject test. Look at Chris, he made a perfect score. I don't know if I will be able to do well among people like that," explained Ritha.

The conversation came to a stop as the bell rang. Mrs. Garza stood silently outside the classroom gazing at Ritha as she hurried away to her next class.

Ritha is ranked among the top ten students in her grade level. She is enrolled in advanced math and science courses such as calculus and physics. She is a diligent student. Then, why this hesitancy and fear? Numerous questions flashed at once: "Why is she so scared of physics?

What can I do to help these students? Is it all about grades? Why is she giving up such a good opportunity?" Many high school teachers have experienced similar scenarios at some point in their teaching careers. The above vignette highlights the typical low self-esteem of female students compared to their male counterparts in physics and related fields such as engineering (DiBenedetto & Bembenutty, 2013). As a result, women have remained underrepresented in science, technology, engineering, and math (STEM) fields despite representing 51% of the U.S. population (Jackson, 2013).

Background and Setting

Given the current economic challenges, coupled with the loss of scientific and engineering work to other nations, it is now essential for the US to expand the STEM workforce (Bottia, Stearns, Mickelson, Moller, & Valentino, 2015; NSTA, 2011). Despite the presence of high tech companies in Silicon Valley, with dot.com, and biotechnology companies in the United States offering virtually unlimited employment opportunities, the number of students graduating with engineering degrees has declined steadily over the past 20 years (Tom, 2011). According to the statistics released by the Bureau of Labor, the U.S. economy is expected to add at least 1.2 million computer jobs between 2010 and 2020, with universities producing only half the number of graduates required to fill these positions (Bottia et al., 2015; National Science Board, 2015). Sadly, the number of bachelor's degrees in science and engineering has remained relatively stable for the past 15 years at merely 32% (National Science Board, 2014). Bottia et al. (2015) reported that only 27% of the STEM related workforce is made up of females. It is apparent that one of the major untapped sources for increasing manpower in this domain is the population of females who are currently pursuing, or could pursue, STEM majors (Bottia et al., 2015). It is therefore critical to address some of the challenges facing science education in the United States to reduce the high attrition rates of female students in STEM majors (Bottia et al., 2015).

In spite of some major improvements seen in the science performance of U.S. 4th and 8th graders on the 2011 Trends in International Mathematics and Science Study (TIMSS) tests, they were not among the top achieving nations in the world (National Center for Educational Statistics, 2012). TIMSS assesses students' knowledge of mathematics and science based on the curricula of the participating education systems. The National Assessment for Educational Progress (NAEP) is a congressionally mandated study that monitors changes in academic performance of U.S. students in mathematics, science, and other subject areas (NCES, 2012). This study assesses a national sample of 4th, 8th, and 12th graders. Performance on this test is classified as basic, proficient, or advanced. Alarmingly, 68% of U. S. 8th graders performed below the proficient level in science for their grade level on the 2011 NAEP. Male students scored only slightly better, at 154, than their female counterparts, at 149 (NCES, 2012). The Programme for International Student Assessment (PISA) assesses students' ability to apply mathematics and science to solve real-life problems (Organization for Economic Co-operation and Development, 2010). In both 2006 and 2009, the US 15 year olds scored below many other developed countries in science on the PISA (National Science Board, 2014; OCED, 2010).

Besides the low performance of U.S. students at both national and international levels, gender disparities exist among students pursuing science and engineering degrees (National Science Board, 2014). According to the 2014 Science and Engineering Indicators report released by the National Science Board, male students are more likely to take advanced math and science classes such as Advance Placement (AP) calculus, physics B (algebra-based), and physics C (calculus-based), while females are more likely to take AP biology and environmental sciences.

Sixty-five percent of AP physics classes are composed of males meaning females represent merely a third. The difference is much wider for physics C with 75% males and 25% females (National Science Board, 2014).

The low performance of American students can be attributed to traditional approaches to teaching an introductory physics course using passive lectures, recipe labs, and algorithmic problem exams (Gok, 2014; Kazempour, 2014; Lin & Tsai, 2013; Wieman & Perkins, 2005). More than three decades of research show these strategies have been of limited value in enhancing conceptual understanding of the subject (Gok. 2014; Lin & Tsai, 2013; McDermott & Redish, 1999). Conceptual understanding and the ability to transfer knowledge flexibly across different contexts are the two major attributes associated with learning physics. Researchers have observed that with traditional teaching, students at the university level were found to be less expert-like in their thinking, and therefore mastering less than 30% of the concepts they did not already know at the beginning of the courses (Allaire-Duquette, Charland, & Riopel, 2014; Caliskan, Selcuk, & Erol, 2010; Gok, 2014; Wieman & Perkins, 2005). When students fail to see the connection between physics and the real world, the subject becomes less interesting, something simply to be memorized without understanding. The result is a decline in the number of students who choose to take physics during their college studies (Barmby & Defty, 2006; Kost-Smith, Pollock, & Finkelestein, 2010; Riegle-Crumb & Moore, 2014). The drop is seen most prominently in the number of females pursuing physics beyond high school.

Even though tapping into the potential of female students can be a viable option to increase the number of STEM graduates, the alarmingly low participation of women in sciences such as physics needs to be addressed. Females account for 61% of bachelor’s degrees awarded in biological sciences and 50% in chemistry, while the proportion of women completing physics degrees is a mere 21% (Sawtelle, 2011). They do not respond well to physics because of their poor self-perceptions of learning physics and their low self-esteem (Blue, Mills, & Yezierski, 2013). With more females likely to lean towards biology and chemistry at the high school level, physics remains a male dominated domain (Bottia et al., 2015). As a result, science and engineering communities will fall short of possible talent that could help advance the field (Atadero, Rambo-Hernandez, & Balgopal, 2015; Hazari, Sadler, & Tai, 2008). In an attempt to address this situation, President Obama initiated various programs to encourage more females and underrepresented minorities in different areas of STEM (Duncan, 2009). Consequently, the goal of the science community is not just to train a small population to be future scientists but to build a large group of individuals from all racial backgrounds and genders to meet increasing demands of the STEM fields without compromising the position of America as a global leader (Riegle-Crumb & King, 2010).

Statement of the Problem

Science, technology, engineering, and mathematics are essential for our national economic well-being in the 21st century. Since many of the problems to be solved are going to be global in nature, the National Science Teachers Association (NSTA, 2011) identified the need for a more diverse work force that is both technologically trained and adaptively responsive to evolving demands. There is a present need for STEM fields to be more diverse in terms of background, culture, outlook, and approach. Gender disparities among students beginning and attaining postsecondary science and engineering degrees have always been a concern for educators and policy makers because while the number of jobs in these fields is fast growing, the number of women earning these degrees is decreasing tremendously (National Science Board, 2014).

Although women earned 50% of all the science and engineering bachelor's degrees, men earned the majority of degrees in engineering, computer science, and physics. Most degrees awarded to women were in the areas of biological, agricultural, and social sciences, and philosophy (National Science Board, 2014). In 2013, while 36% of STEM undergraduate degrees were awarded to women, a mere 1.3% was in physics (APS, 2014). Figure 1 below indicates the decline in the percentage of STEM undergraduate degrees earned by women, especially in physics, over the past 50 years (American Physical Society, 2014).

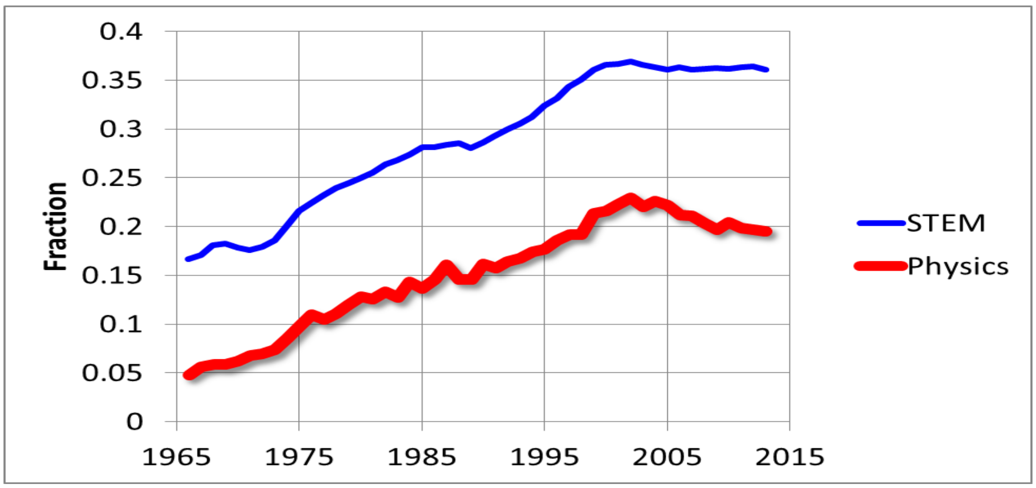

Figure 1. STEM undergraduate degrees awarded to women. (Reprinted from APS/Source: IPEDS Completion Survey, 2014).

The retention rate of female undergraduate students in science and engineering is reported to be the lowest among all disciplines (National Academy for Sciences, 2006). Many female students enter the university with an intention to study physics or engineering but fail to complete a degree in either. As a result, the National Science Foundation (NSF) emphasized the need for research to increase the diversity among the individuals pursuing STEM fields (Yates, 2012).

In order to understand women's access to science and engineering education, it is essential for research to focus on personal and environmental factors that motivate them to enter these fields (DiBenedetto & Bembenutty, 2013). Introductory physics is often a pre-requisite for all pre-medical, nursing, science, and technology majors. In addition, all engineering majors are required to take at least one year of college level physics (Tom, 2011). Although boys and girls perform equally on standardized tests, girls often report low levels of confidence in their ability to perform well in science, enrolling in fewer science courses in high school and college (DiBenedetto & Bembenutty, 2013). Students enter secondary schooling with the same amount of interest in physics and biology. Nevertheless, over a period of time, their interest in physics declined while it remained stable in biology (DiBenedetto & Bembenutty, 2013; Semela, 2010; Whitten et al., 2007). Since research has indicated females face more interpersonal difficulties in science and engineering programs, negative experiences in introductory courses such as physics are often detrimental to their decisions to stay or leave the field (Swan, 2011). It is of utmost importance for research to focus on examining the experiences of female students after they are enrolled into these programs. Many female students who take advanced level science courses in high school fail to pursue this major in college (Teo, 2014). The literature revealed numerous reasons women exit the STEM pipeline. Some include: biological differences in the size of the brains between men and women, lack of academic preparation for girls, lack of female role models, perceived irrelevancy of science, masculine world views about science, and the unwelcoming atmosphere in STEM settings (Allaire-Duquette et al., 2014; Blickenstaff, 2005). Few studies focused on students who switched majors midway through college and their perceptions of college physics classes (Hazari et al., 2008; Whitten et al., 2007), while others examined the connections between factors such as gender, ethnicity, number of math courses taken, and the type of major they chose to study (Maple & Stage, 1991; Mills, 2009; Semela, 2010).

One reason female students leave STEM fields is the lack of positive experiences with science during childhood (Kazempour, 2014; Blickenstaff, 2005). Although several quantitative studies examined different factors that influence students' choice of physics (Dobbin, 2011; Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003), there has been little research on the experiences and dispositions of female undergraduates majoring in physics. Therefore, the proposed qualitative study will potentially add to the literature by exploring how prior educational experiences of female students contributed to their dispositions, interest in, and pursuit of physics as an undergraduate major.

Research Purpose and Questions

The purpose of this study is to explore how the educational experiences of female undergraduate physics majors contributed to their current dispositions toward, interest in, and pursuit of physics at a large southern research university. The specific research questions guiding this study are:

1. What are the critical moments in all of the educational experiences of female undergraduate physics majors that contributed to their interest in, and pursuit of, physics?
2. What college experiences of female undergraduate physics majors contributed to their current disposition to physics?

Operational Definitions

For the purpose of this study, the following definitions apply:

Dispositions – Patterns of frequent and voluntary behaviors of thinking and doing in the absence of coercion (Katz, 1993).

Educational experiences – Experiences between kindergarten and college in and outside of school, with and without family members, school/college personnel, and peers.

Physics – A study of the nature of basic things such as motion, forces, energy, matter, heat, sound, light, and the composition of atoms (Hewitt, 2002).

Methodological Framework

As the purpose of the study is to explore the experiences of female undergraduate physics majors, it will be approached from a qualitative research paradigm. Qualitative studies are grounded in the epistemology of constructionism. Constructionists believe that meaning is not discovered but constructed based on interactions with the world they are interpreting (Crotty, 2004). Several qualitative researchers believe multiple realities arise due to multiple interpretations by individuals based on their own experiences. Since particular people, in particular places, at particular times, interpret and make meaning of various events differently; these events are distinct and therefore cannot be generalized (Mack, 2010; Crotty, 2004; Glesne, 2011). Hence, qualitative researchers seek to understand the experiences of their participants by gathering data personally, taking into account the contexts within which the experiences occur.

This study is situated in the methodological framework of interpretivism, which unlike positivism, assumes there are multiple truths that are constructed based on individuals' understanding of the world (Crotty, 2004). The ontological belief on which interpretivism rests is that reality is socially constructed, complex, and ever changing (Glesne, 2011). This means a possibility exists for multiple interpretations of the same phenomenon. Interpretivists believe there can be useful, liberating, fulfilling, or rewarding interpretations, but no one interpretation can be true or valid for everyone (Crotty, 2004). The specific interpretivist methodological framework for the purpose this study will be symbolic interactionism.

From the interactionist point of view, human beings are active and creative individuals who mutually interact in social contexts during which meaning is constructed based on the experiences within the context (Carlson, 2013). Symbolic interactionism (SI) rests on three simple premises: meaning, interaction, and interpretation of how human beings act toward things (Nilsson, Hofflander, Eriksen, & Borg, 2012). Figure 2 illustrates the interaction of these three constructs.

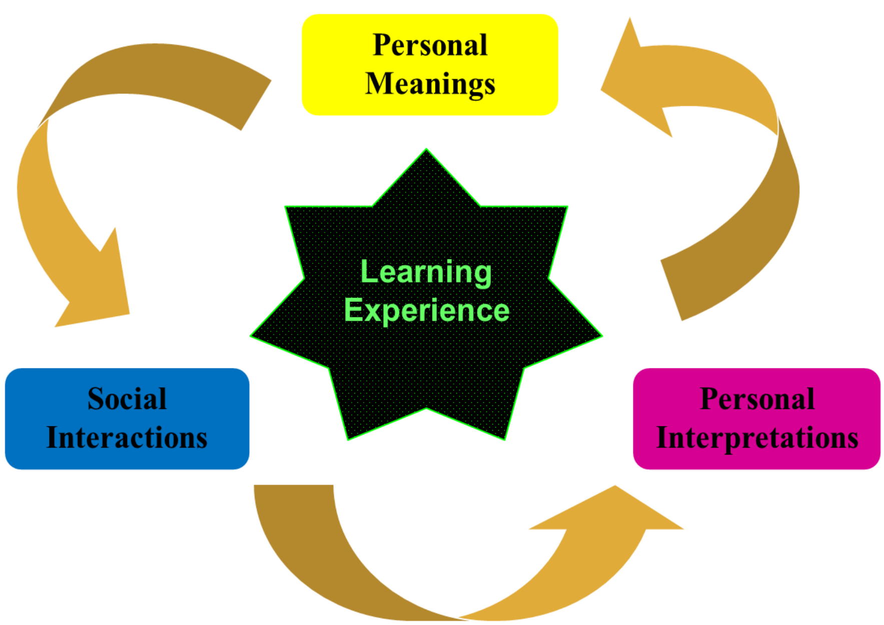

Figure 2. Premise of symbolic interactionism.

Blumer (1969) explains the way an individual acts toward an entity depends on the personal meaning that entity has for him or her. This meaning is derived from social interactions the individual has with other people, which are later modified through the interpretative process of the individual when encountered directly with the entity. Meaning, language, and thought are at the core of SI (Carlson, 2013). According to Charon (1979) symbols involve a class of social objects used to represent whatever people agree upon. In other words, human beings use socially constructed verbal and non-verbal symbols during the interpretive process of meaning making.

Bernard Meltzer (as cited in Charon, 1979) summarized four central concepts of symbolic interactionism: mind, self, society, and the act. The process of thinking and reflecting on previous experiences to construct meaning is referred to as the mind (Milliken &Schreiber, 2012). People attend selectively to some symbols and disregard others based on the experiences of the past and interactions with the present. Another important aspect of SI is the concept of *self*, a symbolic representation that allows an individual to recognize both the subjective *I* and the objectified aspect of *me* (Carlson, 2013). Milliken and Schreiber (2012) emphasized the idea that self is not simply the sum of I and me but it is an ongoing interaction between the two. In other words, people engage in dialogue with themselves as two or more individuals might in a social interaction (Charon, 1979). Self is that part of the mind that engages in an internal conversation to evaluate, motivate, praise, or disapprove of itself (Weigert & Gecas, 2003).

Society and action are the other two major concepts of SI. Society is an organized ongoing process of social interactions among individuals, and acts are social objects (Milliken & Schreiber, 2012). In other words, society provides parameters within which actions occur. Each individual must guide his or her actions based on the intentions of the acts of others (Charon, 1979). The intentions of others can be understood only if the person understands the gestures and the symbols used and respond accordingly (Milliken &Schreiber, 2012). Interactionists believe the individual and society are inseparable. Meltzer, Petras, and Reynolds (1975) explained that while the society is understood in terms of the individuals who comprise it, individuals are understood in terms of the society to which they belong.

Symbolic interactionism is an appropriate framework for this study because participants are viewed as dynamic beings actively engaged in interpreting and guiding social situations as they construct meaning from their educational experiences. Physics as a subject, participants themselves, and other people they interacted with can all be viewed as social objects to which meanings will be ascribed by the participants based on the social interactions they had and their interpretations of these objects as they encountered them in life.

Theoretical Framework

The social cognitive career theory (SCCT) serves as the theoretical framework for this study as it provides a model to explain the process by which students choose and persist in a particular field or major. The SCCT is derived from Bandura's (1986) social cognitive theory that promotes the idea that human behavior is determined by personal, behavioral, and environmental factors. It highlights human agency, while also acknowledging personal and environmental factors that can impact an individual's choice of physics as a major (Ali & Menke, 2014; Atadero et al., 2015; DiBenedetto & Bembenutty, 2013; Inda, Rodriguez, & Pena, 2013; Lee, Flores, Navarro, & Kanagui-Munoz., 2015; Lent et al., 2003; Mills, 2009; Scheuermann, Tokar, & Hall, 2014; Thompson & Dahling, 2012). The SCCT is composed of interest, choice, and performance models that explain how people develop career and educational interests, make choices about careers, and persist and perform in their chosen career or major (Atadero et al., 2015). Both personal and environmental factors lead to learning experiences for an individual which in turn contribute to self-efficacy and outcome expectations that facilitate the development of interest for a major such as physics (Atadero et al., 2015; Lent, Brown, & Hackett, 2002).

The SCCT interest model (Figure 3) explains that self-efficacy and outcome expectations of individuals directly influence their career choices. It was observed that contextual variables such as gender can also play a significant role in informing a person's interest and choice of a major such as physics (Inda et al., 2013; Lent et al., 2002). The kinds of feedback female students receive on their performance in various activities in and out of school can impact their self-efficacy beliefs. Lack of encouragement toward a nontraditional pursuit such as physics can impact the self-efficacy of female students, thereby affecting their choice of majoring in physics. Hence, the SCCT can help to understand different aspects of all the educational experiences of the participants that contributed to their interest in and pursuit of physics.

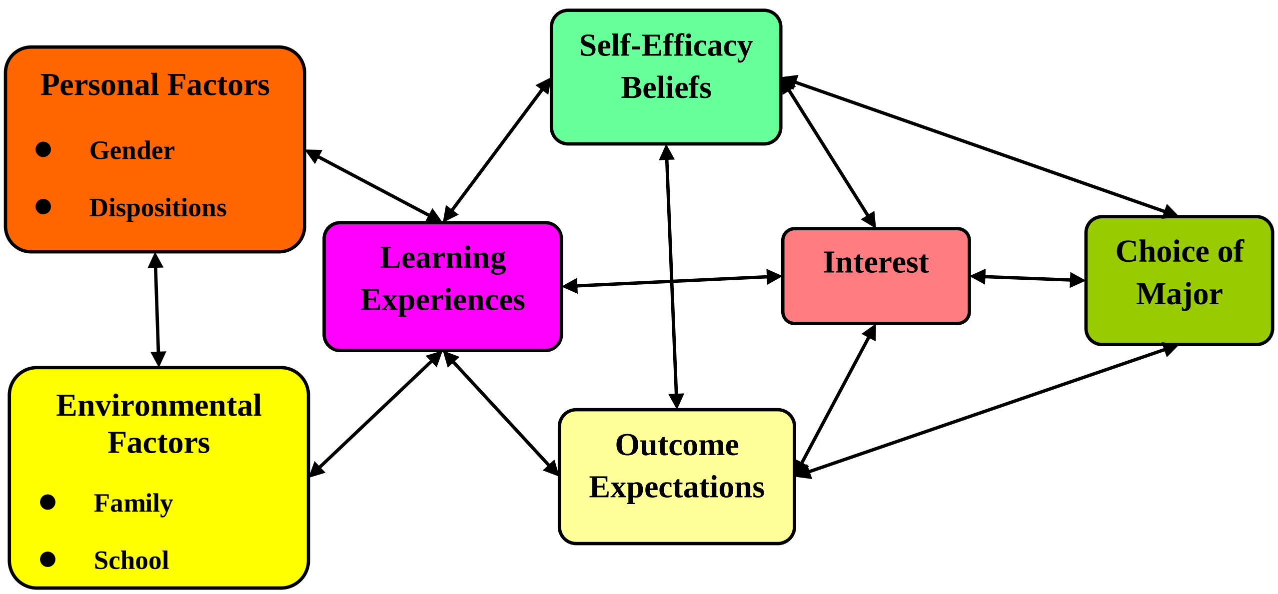

Figure 3. The social cognitive career theory model.

Limitations of the Study

Females are underrepresented in the field of physics and therefore posed a challenge in recruiting participants for this study. Since the participants in the study were students at a university in another city, I could not spend much time with the participants in person to completely immerse myself in their culture. However, I legitimized the study by providing an in-depth and rich description of the experiences of individual participants using data collected from multiple sources such as interviews, object elicitations, photographs, and documents, thus achieving rigor in the study.

Although the findings in this qualitative study are limited to co-constructed understandings of the participants and me; I made all possible attempts to periodically share my interpretations with the participants to ensure I represented their voice clearly. I constantly attended to my subjectivity and revealed it distinctly throughout the process of data analysis and representation in the study. However, that does not completely eliminate the influence of my subjectivity when representing the voice of my participants.

As much as the findings of this qualitative study are limited to the experiences of the participants, the rich, in-depth descriptions provided across the cases allow for transferability to readers. However, a larger sample size with more variability among participants would have definitely contributed to richer data, providing a better understanding of the experiences that contributed to the dispositions toward, interest in, and pursuit of undergraduate physics major by female students.

Significance of the Study

Many points of exit from and re-entry into the pipeline of physics exist for students. But a large number of female students exit the pipeline at every point compared to males (Blickenstaff, 2005; Reigle-Crumb & Moore, 2014; Whitten et al., 2007). One of the critical leakage points is the transition from high school to college (Dobbin, 2011). Therefore, understanding the experiences which led to the current dispositions, interest in, and pursuit of a challenging field for these successful female undergraduates in a male-dominated and ever dwindling STEM major such as physics, points to a need to become aware of the obstacles they face. An improved understanding of these obstacles informs us of the ways in which women can successfully navigate STEM fields. These insights can enable science educators in general and physics educators in particular, to better prepare more individuals, especially females to confidently pursue STEM majors beyond high school, thereby decreasing the dropout rates.

Another major leakage point in the physics pipeline is the appeal of changing majors while in college (Hazari et al., 2008; Riegle-Crumb & Moore, 2014; Semela, 2010). The findings of the study offer advice for designing mentor programs that can support struggling students, focusing mainly on underrepresented populations, to help them complete the program successfully, by encouraging them to remain in the program. The study challenges traditional pedagogical practices of science educators, compelling them to redesign lessons which more effectively engage students in an enjoyable and rewarding process of scientific inquiry, helping students appreciate STEM as a viable career choice. The findings also underscores the role of an educator as a human, who can place the students' hearts at the forefront before caring for their mind, allowing for a more welcoming and nurturing environment in their classrooms.

Summary

The purpose of this chapter is to describe the background in which I situated the study. I also rationalized the purpose of my study by identifying the gaps in the available literature. I grounded the study in the specific interpretive methodological framework of symbolic interactionism that assumes meaning-making as both an interactive as well as interpretive process. The social cognitive career theory formed the theoretical framework that explained the process through which the female undergraduate students made a choice to major in physics. The possible limitations of the study are also highlighted in this chapter. Since the study explores all of the experiences of female undergraduate physics majors that contributed to their current dispositions toward, interest in, and pursuit of physics, the findings of the study can potentially have implications for teacher education programs, stakeholders, university physics educators, K-12 teachers, and students at all levels.

CHAPTER II

REVIEW OF LITERATURE

In order to effectively understand the educational experiences of female undergraduate physics majors, I examined the literature with regard to how individuals make meaning of their experiences and how those experiences contribute to their interest in, and choice of, physics as a major. I also examined STEM education and females in STEM. Therefore, in the first section of this chapter, I present a discussion of social cognitive career theory (SCCT) as the theoretical framework to explain the process by which students choose and persist in a particular field or major. In the second section, I explain STEM Education and the science in STEM. The third section focuses on females in STEM, and the chapter concludes with an elaboration of symbolic interactionism as the methodological framework of the study.

Social Cognitive Career Theory as a Framework for Physics Majors

The social cognitive career theory attempts to explain the processes through which people form interests, make choices, and achieve success in various educational and occupational pursuits (Lent et al. 2002; Szelényi, Denson, & Inkelas, 2013). Although the SCCT interjects several cognitive, motivational, and developmental-contextual career theories, it primarily links Krumboltz's social learning theory of decision making (Krumboltz, 2009) with the applications of the self-efficacy construct described by Hackett and Betz (1981) to women's career development. The SSCT closely aligns with Hockett and Betz's ideas, while it also builds on the conceptual understandings of Krumboltz (Lent et al., 2002). The SCCT converges with Krumboltz's idea that an individual's interest in, and pursuit of, a major largely depend on his or her direct and vicarious learning experiences (Krumboltz, 2009). At the same time, these two theories differ in their conceptualization of cognitive processes, constructs, and specific outcomes. It is important to note that the theoretical understandings of Krumboltz's social learning theory emerged from the earlier premise of Bandura's (1986) social cognitive theory which views humans as emergent interactive agents of experiences rather than passive receivers of experiences. As active agents, people play a major role in their self-development, adaptation, and self-renewal with changing times. They can successfully navigate through the complex world around them only by making good judgments of their capabilities, predicting the probable effects of their actions, understanding the social environment around them, and regulating their behavior accordingly to achieve the desired outcomes (Lent et al., 2002). Therefore, the physical and social environments people select and construct influence the nature of the experience.

The SCCT views human functioning as the product of an active interaction between personal, behavioral, and environmental influences. In other words, the theory rests on the assumption that humans are both producers and products of their environment (Bandura, 2001; Lent et al., 2002). People produce experiences by regulating their motivation and redirecting their behavior (Bandura, 2001; DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Zhu, 2007). In other words, people are perceptive, focused beings who, when faced with predetermined task demands, act mindfully to produce desirable outcomes (Bandura, 2001; DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Zhu, 2007).

Bandura (2001) identified the core features of human agency as intentionality, forethought, self-reactiveness, and self-reflectiveness. Agency refers to intentional actions. Unlike prediction or expectation, an intention represents a deliberate desire for a future course of action. Therefore, it is more meaningful to look at intentions as grounded in self-motivators affecting the probability of actions occurring in the future. People set personal goals and motivate themselves to achieve them either to impress others or for their own self-satisfaction.

When they encounter a problem, people motivate themselves into overcoming the problem successfully. If they perceive their failure to reach goals as personal deficiencies, then they re-double their efforts to succeed. On the other hand, if they believe they are being exploited, disrespected, or manipulated, then they respond in a hostile manner. Bandura (2001) considered such motivational and self-regulatory factors as important causal structures that governed the manner and level of personal engagement of people in prescribed activities. DiBenedetto & Bembenutty (2013) advocated for the idea that both personal and social factors influence human behavior. Thus, it can be concluded that schools, as social environments, strongly influence students' overall perceptions.

The three basic building blocks of SCCT are self-efficacy, outcome expectations, and personal goals. Central to personal agency is one's belief in their ability to exercise control over their own functioning and other environmental agents. This unique ability is often referred to as self-efficacy (Bandura, 2001; DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Zhu, 2007). Self-efficacy beliefs determine how people feel, think, motivate themselves, and behave (Bandura, 2001; DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Zhu, 2007). Bandura's (1986) social cognitive theory views people as self-organizing, proactive, self-reflecting, and self-regulating rather than as reactive organisms shaped and shepherded by environmental forces, or driven by concealed inner impulses (DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Pajares, 2002; Zhu, 2007).

Mastery experience, emotional/physiological states, social persuasion, and vicarious experience, are the four major sources of self-efficacy (Bandura, 2001; Gaffney, Gaffney, Usher, & Mamaril, 2013; Lent et al., 2002; Lin & Tsai, 2013; Zhu, 2007). Mastery experience relates to the extent to which an individual succeeded or perceived success with a previous experience

(Trujillo & Tanner, 2014). These interpretations of previous experiences influence students' beliefs in their abilities to engage in subsequent tasks. However, success that results from overcoming challenges better supports a resilient sense of self-efficacy than a success easily won (Bella & Crisp, 2015; Britner & Pajares, 2006). Emotional or physiological states refer to internal feelings a person experiences during a task such as joy or frustration, satisfaction or fear (Trujillo & Tanner, 2014). Positive physical states encourage confidence in individuals, while physical states that are perceived negatively inhibit success (Bandura, 2001; Britner & Pajares, 2006; Gaffney et al., 2013; Lent et al., 2002; Lin & Tsai, 2013; Zhu, 2007). The present degree of self-efficacy along with the complexity of the task and similar previous experiences, influence the physiological state of an individual (Britner & Pajares, 2006; Gaffney et al., 2013; Lent et al., 2002; Lin & Tsai, 2013). Social persuasion refers to positive, encouraging feedback received from teachers, peers, or other community members (Trujillo & Tanner, 2014). Britner and Pajares (2006) noticed that feedback which provides suggestions for further improvement has a greater facilitative effect on self-efficacy rather than simply telling a person they need to improve. Finally, vicarious experiences of observing others performing similar tasks are also a source of self-efficacy (Gaffney et al., 2013; Zhu, 2007). People identify models for vicarious experiences based on characteristics such as ethnicity, gender, and ability (Trujillo & Tanner, 2014).

Students construct self-efficacy beliefs through cognitive processing and integration of information from all four sources (Britner & Pajares, 2006; Mills, 2009; Zhu, 2007). Despite the different sources of self-efficacy, Bandura (1986) hypothesized that mastery experiences would prove to be the strongest indicators of academic self-efficacy. During a study, Zeldin, Britner, and Pajares (2008) observed the idea of mastery experiences as strong predictors of science self-efficacy correlated to gender. For males, interpretations of previous personal experiences impacted their self-efficacy beliefs, whereas in females vicarious experiences had a greater effect on their self-efficacy beliefs. Additional research further observed that the self-efficacy of children is enhanced when they are motivated to achieve by exposing them to positive social and academic settings and by teaching them strategies to overcome challenges (Schunk & Mullen, 2012).

The construct of self-efficacy is domain-specific and task-dependent (Bandura, 2001; Lin & Tsai, 2013; Lent et al., 2002; Moakler & Kim, 2014; Zhu. 2007). In science, students who believe they can succeed in science tasks and activities will more likely select such tasks and activities, and are more inclined to work hard to complete them successfully when met with obstacles. Alternatively, students with weak belief in their success in science-related activities will either avoid them, or will put forth minimal effort if the task cannot be avoided. Such students, when faced with challenges, will more likely experience anxiety, stress, and quite often give up (Britner & Pajares, 2006; Brown, Lent, Telander, & Tramayne, 2011). In high school students, science self-efficacy correlates with science achievement and is a better predictor of achievement and engagement with science-related activities in and out of the classroom than are gender, ethnicity, and parental background (DiBenedetto & Bembenutty, 2013; Heilbronner, 2013; Kupermintz, 2002; Lau & Roeser, 2002).

All students take at least one year of science in high school. Yet, only 60% of students take two years of science, and only 25% take three years. Even fewer students take advanced science courses: 16% take AP biology, 6% AP chemistry and only 4% AP physics (Britner & Pajares, 2006; DiBenedetto & Bembenutty, 2013; Hazari, Sonnert, Sadler, & Shanahan, 2010). Strong gender disparities were noticed in higher level sciences such as physics. In a Civil Rights

Data Collection (CRDC, 2012) report which explored equity and educational opportunities for boys and girls in elementary and middle schools across the nation, 51% of boys and 49% girls were found to be enrolled in one or more high school science courses. Girls and boys represented equally in biology (50:50), females outnumbered males in chemistry (52:49), but were underrepresented in physics (46:54). In a six-year longitudinal study of undergraduate women, Brainard and Carlin (1998) found lack of self-efficacy was a major barrier in their persistence of degrees in science and engineering. However, after almost 15 years, several studies (Lee et al., 2015; Reigle-Crumb & Moore, 2014; Vogt, Hocevar, & Hagedorn, 2007) examined factors that influenced women's pursuit of science and engineering and reported self-efficacy as the best predictor of their overall success in the field.

A person's beliefs about the possible consequences of an action or behavior are called outcome expectations (DiBenedetto & Bembenutty, 2013). Outcome expectations can take the form of extrinsic reinforcement such as tangible rewards, self-pride in mastering a challenging task, or gratification from performing the task (Bandura, 2001; DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Lin & Tsai, 2013). These outcome expectations are informed by learning experiences similar to those that inform an individual's self-efficacy. Outcomes are the consequences of agentive actions (Bandura, 2001; Lent et al., 2002; Moakler & Kim, 2014). However, actions that are intended to serve certain purposes may produce unexpected outcomes (Bandura, 2001; Davidson, 1971; DiBenedetto & Bembenutty, 2013; Lent et al., 2002). For example, a child might lie to parents with an intention to escape consequences. But, when caught lying, the child might face much worse consequences than initially anticipated. People often resist behaviors that yield undesirable outcomes. Therefore, while experiences of success elevate chances of recurrence of the behavior, repeated failure might have negative connotations.

A personal goal is the determination of an individual to engage in a particular activity such as majoring in physics (Atadero et al., 2015; Bandura, 1986; Lent et al., 2002). By setting personal goals, people organize and guide their actions to sustain their pursuit through extended periods of time (Bandura, 2001; DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Moakler & Kim, 2014). Personal goals foster tenacity, thus empowering individuals in their pursuit of a major (Duckworth & Eskreis-Winkler, 2013).

People set goals and plan future actions to achieve desired outcomes after evaluating possible consequences and avoiding detrimental ones (Moakler & Kim, 2014; Lent et al., 2002; Locke & Latham, 1990). Through this kind of forethought, people motivate themselves by guiding future actions, reorganizing priorities, and restructuring their lives (Bandura, 2001; DiBenedetto & Bembenutty, 2013). Bandura (2001) explained that "by being represented cognitively in the present, foreseeable future events are converted into current motivators and regulators of behavior" (p.7). This means future goals and anticipated outcomes motivate people's behavior. However, people develop outcome expectations based on relationships they observe between environmental factors around them and outcomes produced by given actions (Bandura, 1986). As a result, they modify and adjust their behavior to obtain desired positive outcomes and reject negative or unrewarding outcomes. Once people set personal standards for themselves, they self-direct and regulate behavior through self-evaluation of the outcomes that override the influences of external rewards and punishments (Bandura, 1986; Bella & Crisp, 2015; DiBenedetto & Bembenutty, 2013; Lent et al., 2002). Therefore, agency not only refers to one's ability to make choices and design plans for future action but also the ability to regulate execution of these plans. According to Bandura (2001), this multifaceted self-directedness operates through numerous self-regulatory processes which link thought and action.

Motivation, effect, and action are self-regulated through a set of self-referent practices such as self-monitoring, self-guidance, and corrective self-reactions (Bandura, 1986; DiBenedetto & Bembenutty, 2013). People engage in activities that are rewarding to them, giving them a sense of pride and self-worth while refraining from others. He also insisted humans are not simply agents of action but are also self-examiners of their functioning and therefore self-reflectors. People constantly evaluate their motivation, value-systems, and the meaning of their life choices (Bandura, 2001; Brown et al. 2011; Scheuermann et al., 2014). During this complex meta-cognitive process of self-reflection, "people judge the correctness of their predictive and operative thinking against the outcomes of their actions, the effects that other people's actions produce, what others believe, deductions from established knowledge and what necessarily follows from it" (Bandura, 2001, p.10).

The SCCT framework organizes career-related academic interest, choice, and performance into three interlocking models. However, all three models posit on a complex interplay of self-efficacy, outcome expectations, and goals (Lent et al., 2002; Moakler & Kim, 2014). The theory assumes the association between these three major elements as bidirectional over time (Lent et al., 2002). For example, the self-efficacy of a person determines his or her interest for a task and the interest, in turn, impacts elf-efficacy. The SCCT interest and choice models advocate for environmental and cognitive factors that determine interests and thereby, choice of pursuit. People derive their interests and choices from their interpersonal environments. It is largely through repeated practice, feedback from others, and modeling, that individuals develop skills and set performance standards, informing their self-efficacy and outcome expectations (DiBenedetto & Bembenutty, 2013; Lent et al., 2002). These developed self-efficacy beliefs and outcome expectations play a major role in enduring interest and encouraging individuals' choice of pursuit (DiBenedetto & Bembenutty, 2013; Mills, 2009).

The SCCT is concerned with a number of personal and contextual variables such as gender, race, aptitudes, and values. However, these are construed as factors attributing for self-efficacy and outcome expectations of individuals which in turn inform their interest in, and pursuit of, choices such as a STEM major (DiBenedetto & Bembenutty, 2013; Lent et al., 2002; Zhu, 2007). Perceived values such as autonomy and status are thus presented as outcome expectations in the model. It is noteworthy that SCCT understands gender as a socially constructed concept which includes the psychological, social, and cultural implications of the sex. The theory therefore takes into consideration the social and cultural factors that shape learning opportunities and the interpersonal reactions of individuals, specifically females (Gonsalves, 2014; Gotschel, 2014; Lent et al., 2002). For example, gender and cultural biased access to limited resources for observing and practicing certain behaviors such as science can hinder the self-efficacy and outcome expectations of girls (Bella & Crisp, 2015; Gonsalves, 2014; Götschel, 2014) funneling them into art and domestic-oriented tasks such as cooking and sewing. Therefore, externally imposed barriers such as educational access and confining cultural norms are internalized by women, impeding their interests and carrier choices in the areas of STEM.

The framework of SCCT was widely utilized in numerous quantitative studies to understand the interrelationship between different variables contributing to the interest and career choices of individuals in STEM fields, especially engineering. Lee et al., (2015) conducted a longitudinal study using the SCCT persistence model with 350 engineering students to examine the effects of past academic performance and social cognitive predictors on their persistence in engineering. A path analysis was performed to analyze the data. Lee et al. (2015) found that the results strongly supported the SCCT persistence model. Engineering students with strong cognitive abilities exhibited high levels of performance and confidence in their abilities. They also found that self-efficacy and engineering goals were significant predictors of the students' future persistence actions.

Scheuermann et al. (2014) extended the SCCT framework by testing the choice model with variables of self-efficacy, outcome expectations, interest, and choice, quantified in terms of the level of prestige attributed to the occupation. This quantitative study also implemented path analysis to test their hypothesis with 198 African-American college women. Scheuermann et al. (2014) found that both prestige self-efficacy and prestige outcome expectations predicted vocational interest. Prestige outcome expectations and the prestige of vocational interest predicted the choice of goals.

Atadero et al. (2015), using the structure of SCCT, studied the effects of group design projects on engineering students' content knowledge and intentions to persist in engineering. No significant gains in self-efficacy, outcome expectations, content knowledge or intentions to persist were observed with the use of group design projects. However, Atadero et al. (2015) noticed strong positive relationships between self-efficacy and outcome expectations, and between intention to persist and the students' content knowledge.

Inda et al. (2013) researched gender differences in predicting the engineering interest and major choice goals of 579 sophomore engineering students. The results from Pearson correlations and multivariate analysis of variance confirmed the SCCT model as a good fit to the data across gender. Inda et al. (2013) reported the self-efficacy beliefs of women and men determined their interest in engineering activities which in turn predicted their learning expectations, informing future goals.

Ali and Menke (2014) utilized SCCT to investigate the career development of 94 ninth grade students from two rural high schools in a predominantly Latino immigrant community based on the students' responses to measures of vocational skills self-efficacy, career decision outcome expectations, career aspirations, and barriers to postsecondary education. Using hierarchical linear regression analysis, the results of the study revealed higher self-efficacy beliefs for Latino students than the White. The Latino students also reported higher perceived barriers which did not correlate with their career aspirations. Overall, Ali and Menke (2014) found that the Latino students who perceived they were more likely to encounter barriers felt more efficacious about achieving their career goals.

Thompson and Dahling (2012) evaluated the relationship between perceived social status, learning experiences, self-efficacy, and outcome expectations using 380 undergraduate students. Structural equation modeling was used to develop and test the relationship between each of the variables. Thompson and Dahling (2012) reported the investigation supported the different paths proposed in the SCCT. They noticed the perceived social status correlated positively with learning experiences. These enhanced learning experiences mediated the relationship between perceived social status and self-efficacy, and between perceived social status and outcome expectations.

The study conducted by DiBenedetto and Bembenutty (2013) measured the effects of gender, childhood, and adolescent socialization experiences of 113 undergraduate students enrolled in a large New York public collage, on their self-efficacy and self-regulated learning strategies. The paired *t*-tests of the pre and the post assessments indicated self-efficacy and outcome expectations had a significant effect on their performance and on the implementation of self-regulatory strategies. DiBenedetto and Bembenutty (2013) observed that while boys engaged more in autonomous activities, girls demonstrated more help-seeking behaviors. Childhood and adolescent socialization experiences were strongly related to motivation and use of self-regulatory strategies.

Mills (2009) applied the SCCT to a group of 245 college science majors and pre-medical students at a large mid-western university to study the relationship between background factors such as learning experiences, aptitudes, and parental support, on the development of self-efficacy, interests, and goals. Structural equation modeling was used to assess the SCCT model. Mills (2009) affirmed the outcomes supported the strong structure proposed in SCCT.

Hazari et al. (2010) carried out a gender study in which they explored how students' physics identities are shaped by their high school experiences and career outcome expectations. Multiple regression techniques were used to examine the responses of 3,829 college students. It was found that physics identity strongly predicted their intended career choice of physics. Physics identity also strongly correlated with their desire for intrinsically more fulfilling career possibilities. However, high school physics experiences such as a focus on conceptual understanding, real-world connections, students' active participation in class discussions, peer instruction, and most importantly encouraging teachers, predicted the students' physics identity. In particular, girls reported a lack of sufficient real-life connections and conceptual focus experiences in their high school physics classes.

After reviewing the quantitative studies discussed above, it can be argued that the interest in and choice of, STEM majors such as physics are primarily the functions of self-efficacy beliefs and outcome expectations. People pursue a major when they feel self-efficacious about their success and that the pursuit of the major would yield desirable outcomes. When they perceive difficulties in overcoming barriers, they are less willing to transform their interests into goals and their goals into actions. Therefore, the social cognitive career theory would serve as an appropriate theoretical framework to examine the learning experiences of female undergraduates that contributed to their current disposition, interest in and pursuit of physics.

STEM Education

In the 1990s, the NSF coined the acronym *STEM* to represent science, technology, engineering, and mathematics (Beede et al., 2011; Breiner, Harkness, Johnson & Koehler, 2012; Sanders, 2009). However, people have only recently become aware of the term, when it was reported that China and India might overtake America in terms of global economic power. The 2007 report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, captured Congressional interest in STEM education (Gonzalez & Kuenzi, 2012). As a result, *STEMmania* set in and funds began to pour into all areas of STEM (Gonzalez & Kuenzi, 2012; Sanders, 2009). While *STEM without education* refers to the part of the world where scientists, mathematicians, and engineers sweat day in and day out, science, math, and technology teachers fall under the umbrella of *STEM education*. Although for the most part science, technology, engineering, and mathematics are viewed as distinct parts of STEM, STEM education refers to the interaction among the stakeholders (Breiner et al., 2012; Sanders, 2009; Thornburg, 2009). Therefore, STEM education signifies integrating all four disciplines and teaching it as one cohesive entity that more closely relates to the work of real-life scientists and engineers (Breiner et al., 2012; Sanders, 2009; Thornburg, 2009)

While the need to expand the STEM workforce has been increasingly pressing, the percentage of U.S. STEM undergraduates has remained between 30 to 35% for the past four decades (Bottia et al. 2015; Gonzalez & Kuenzi, 2012). Furthermore, with the steep decline in the number of high school students expressing interest in becoming a scientist or engineer, it is anticipated that less than 2% of high school graduates would be receiving a STEM degree from a four-year university (Moakler & Kim, 2014). Another area of concern for STEM educators is the underrepresentation of women in the field. The American Physical Society (2014) reports that only 36% of STEM undergraduate degrees were awarded to women in 2013. The *STEM pipeline problem* addresses the decline in the number of students pursuing STEM fields (Griffith, 2014; Sanders, 2009).

Despite the independent efforts of each one of the four STEM disciplines, too many students have losing interest in math and science at an early age and exiting the STEM pipeline. A large percentage of students have been opting out of advance level science and math classes and graduating high school with relatively minimum abilities (DiBenedetto and Bembenutty, 2013; Sanders, 2009; Semela, 2010). This change raised concerns among federal and state policymakers and legislators about the ability of the United States to sustain its position as a global leader. Therefore, they called for the national efforts to create strong STEM pathways from high school to college in an attempt to expand the STEM-capable workforce in the United States (National Governors Association, 2011). The National Research Council (NRC) released a report with 14 indicators that would monitor growth in STEM teaching and learning. These indicators were developed primarily with the following goals: (a) to expand the number of students pursuing degrees and careers in STEM fields, (b) to broaden the number of women and minorities in the STEM-capable workforce, and (c) to increase science literacy for all students (National Research Council, 2011). As a result, the Next Generation Science Standards (NGSS) were developed based on a framework that identifies broader ideas and practices in the areas of natural sciences and engineering that all students must master before graduating from high school (Next Generation Science Standards, 2013).

High rates of attrition among STEM majors and inadequate pre-college mathematics and science preparation were identified as two main reasons for the leaky STEM pipeline (Gonzalez & Kuenzi, 2012). As a result, policymakers focused on improving the quality of K-12 science and math teachers, creating more robust accountability and standards, increasing opportunities for remediation and retention of students entering college, and broadening participation of females and minorities (Gonzalez & Kuenzi, 2012; Regle-Crumb & Moore, 2014; Thornburg, 2009). One of the strategies to increase retention in STEM fields is by improving student learning in science and engineering through implementation of effective instructional strategies (National Science Board, 2014). With a primary goal to promote STEM education and scientific literacy, organizations such as the American Association for the Advancement of Science (AAAS) have initiated special programs such as the Senior Scientists and Engineers (SSE) STEM volunteer program and Project 2061. The SSE STEM volunteer program aims to spark student interest in science and potential STEM careers by using retired professionals as role models in K-12 classrooms (American Association for the Advancement of Science, 2004). Project 2061 provides research based instructional tools necessary for STEM educators to produce scientifically, mathematically, and technologically literate American citizens (American Association for the Advancement of Science, 2013). Despite many efforts, disparities persist in the form of unequal outcomes for men and women in science and math fields (Patrick, 2012). Hazari et al. (2010) affirmed female students' science identity is strongly associated with their learning experiences in school. Therefore, it is essential to explore the nature of science education and existing teaching practices to better understand the ways to motivate more female students to enter and persist in STEM Fields such as physics.

Science in STEM Education

Children are naturally curious and passionate about learning. From birth, they are constantly experimenting in their pursuit of knowledge (Kazempour, 2014; Heilbronner, 2013; National Science Teachers' Association, 2002). Attitudes of young children reveal they are engaged in scientific thinking through natural curiosity even before they enter a classroom. This is why the traditional presentation of science education as memorization and regurgitation of facts has become antiquated. Learning science must involve a design cycle of asking questions, probing for answers, conducting investigations, and collecting data. However, the experience of learning science in today's classroom is confined to mere memorization of factual information. This traditional style of learning explains why leading the world in science, as revealed by the recent PISA results, still remains a challenge for American students (National Science Board, 2014; OCED, 2010).

A historical review of science education portrays scientific literacy, the outcome of science education, as people's understanding of science that is very open-minded and ever-changing. Therefore, no single correct way of teaching science prevails (DeBoer, 2000). With growing competition in the global market, the US is in desperate need for more scientifically literate citizens who can maintain competencies and make informed decisions on science-related public policies (National Science Teachers' Association, 2011; Duit & Treagust, 2003). Therefore, it is essential for educators to teach the fundamental concepts of scientific reasoning in order for students to thrive as lifelong learners in our modern knowledge-oriented societies (Radovanovic & Slisko, 2014). The most important aspect of teaching science is that students must learn in ways that spark a meaningful interest to pursue science both formally and informally throughout life (Lin & Tsai, 2013; NSTA, 2004; DeBoer, 2000). It is essential for science education to undergo change in order to prepare the workforce with high-levels of technical understanding and effective problem-solving skills for the modern economy to thrive (National Science Teachers' Association, 2011; Wieman & Perkins, 2005).

Despite a spike in college enrollment from 51% in 1975 to 68% in 2011, many students unprepared for college-level work were seeking remedial help to address their skill deficiencies (National Science Board, 2014). Poor performance of U.S. high school students in science was evident from the PISA (2009) scores. Despite improvement in scores from 489 in 2006 to 502 in 2009 (one point above OECD average), U.S. 15-year-olds scored below 12 OECD nations (OCED, 2010). Large gaps in mathematics and science performance have been noticed as early as kindergarten (National Science Board, 2014). On the NAEP science assessment, the average science score of 8th graders went up from 150 in 2009 to 152 in 2011. The percentage of 8th grade students who performed at or above proficient level went up from 30% in 2009 to 32% in 2011 (National Science Board, 2014). Nevertheless, these gains are insignificant in relation to the amount of funds invested in various initiatives to improve performance in the areas of mathematics and science.

Although the primary goal of high school is to prepare students to be successful in college and beyond, these statistics clearly indicate students are not successful. The poor performance of students is largely attributed to their lack of interest in subjects which disengage them from learning science (Allaire-Duquette et al., 2014). Therefore, the paramount interest of science educators is to reform science education and explore new strategies to make science more relevant and meaningful to present day students.

Physics as Science

Science literacy in physics is not viewed as mere memorization of definitions of words and concepts. Rather, it is the capability of doing physics using the language of physics and mathematics (Brekke, 2002; Gok, 2014). While conceptual understanding, transfer of information, and the beliefs about physics are longstanding goals of instruction, the traditional approach to teaching physics is still confined to the teacher lecturing the students, assigning homework from the back of the book, and assessing students' understanding by using similar questions (Gok, 2014; Lin & Tsai, 2013; Taasoobshirazi & Carr, 2008; Wieman & Perkins, 2005). It is sad but often true that teachers end up lowering the standards by readjusting their tests for students to be successful, thereby removing the word *understanding* from the definition of successful learning. The requirements for high stakes testing in the US and the expectations for students to master concepts in science under these pressured conditions have created some decline in students' interest in science, especially in learning physics (Jaladanki & Bhattacharya, 2014).

Physicists believe the beauty of physics is that a few fundamental concepts can be used to explain a wide range of phenomena. Therefore, they developed several instruments such as the Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992) to measure students' conceptual understanding in physics. To their dismay, the results compiled from various traditional physics classes both at high school and at university level, where the primary mode of instruction was through lecturing, indicated that students master no more than 30% of the key concepts that they did not know at the beginning of the course (Allaire-Duquette et al., 2014; Hazari et al., 2010; Wieman, 2007). This problem is mainly the result of traditional physics instruction which fails to take into consideration the system of students' beliefs about phenomena that they bring with them into the classroom, which is a major determinant of learning (Caliskan et al., 2010; Fencl & Scheel, 2004; Hazari et al., 2010; Lin & Tsai, 2013; Redish, 2004).

The success of a small fraction of students majoring in physical sciences in college is attributed to their ability to tolerate traditional approaches to science instruction more than their ability to do science (Lin & Tsai, 2013; Wieman & Perkins, 2005). According to Wieman and Perkins (2005), effective physics instruction calls for students to think like experts about physics as they engage problem-solving behaviors in physics. While experts view physics content as overarching concepts that describe nature, novice students view it as regurgitation of isolated pieces of information handed down by some authority, unrelated to the real world (Caliskan et al., 2010; Gok, 2014; Wieman & Perkins, 2005). In fact, most information learned by rote is lost within a short time. In a study conducted by Semela (2010) with 14 sophomores, 11 senior students, and five instructors in the department of physics at Hawassa University, Ethopia, they found that inadequate pre-college preparation, lack of required mathematical skills, limited job opportunities outside the teaching professions, and shortage of qualified teachers were the main reasons for low enrollment in physics. Therefore, it becomes important for educators to come up with instructional approaches that encourage meaningful learning and active engagement with the information to foster long-lived understanding (Allaire-Duquette et al., 2014; Gok, 2014; Lin & Tsai, 2013; Bernhard, 2000).

Traditionally, introductory physics in college is taught through problem-solving. Problem-solving is a linear, hierarchical process of formulating new answers which go beyond the simple application of previously learned rules to create a solution (Caliskan et al., 2010). For most physics instructors, the aim of physics teaching is to train students to develop logical thinking to understand and analyze phenomena and apply it to solve real-world problems (Chen, 2002; Gok, 2014; Lin & Tsai, 2013). However, students in most physics classes dread problem-solving because the problems are presented in purely scientific contexts which involve logical thinking (Allaire-Duquette et al., 2014; Chen, 2002). It was noticed that while experts use concept-based problem-solving in physics, novice students look at it as just matching the pattern of the problem to certain memorized recipes (Li & Demaree, 2013; Lin & Tsai, 2013; Wieman, 2007). Each step in the problem-solving process is the result of the previous step and the precursor for the next. Defining, investigating, reviewing and processing the information regarding the problem are the different skills required for problem-solving (Caliskan et al., 2010). However, many teachers discuss the role of concepts in solving problems and they end up writing down the resulting equation alone on the board while demonstrating the solution to the class. Even the problems presented to the students in class, on homework assignments and tests require a precise quantitative solution. Hence students often concentrate on the quantitative aspects (formulaic approaches) that do not foster conceptual understanding (Li & Demaree, 2013; Lin & Tsai, 2013; Mestre, 2001; Taasoobshirazi & Carr, 2008). Although, the students' desire to actively engage in the problem-solving process is essential to overall learning, teachers lack an understanding of how to develop interest in the discipline, such as physics (Allaire-Duquette et al., 2014). According to Allaire-Duquette et al. (2014), when a person is engaged physically, cognitively, and symbolically with the subject of their interest, he or she is more likely to develop an interest for it.

One of the reasons for failure in problem solving is because of a difference in the approaches of the instructors and students. While students concentrate on the superficial features of the problems, experts use the principles of physics to analyze and solve problems (Allaire-

Duquette et al., 2014; Hollabaugh, 1995; Zhu, 2007). Teaching students to become proficient problem solvers, especially in a subject like science, is a daunting task as it involves several major tasks such as: 1) the ability to understand physics principles and concepts, 2) the ability to recognize which concepts apply to the given situation, 3) the knowledge of the procedures for applying the concepts, 4) the knowledge of the relevant mathematical equations for the concepts, and 5) the proficiency in the math principles necessary to solve the equation for solution (Caliskan et al., 2010; Mestre, 2001). Mestre (2001) also explained that a sophisticated mental management scheme which several possible courses of action might prove to yield fruitful results, as well as piece all the necessary steps together to arrive at the solution.

One of the remarkable attributes of human intelligence is the ability to convert a problem into a familiar representation based on previous knowledge (Novemskey & Gautreau, 1997). Redish (2004) observed that the activation of one knowledge source can activate other related resources. These preconceptions of students can serve as a crucial precursor in their physics learning process and learning outcomes (Lin & Tsai, 2013). Redish (2006) emphasized that educators need to understand the cognitive processes involved in physics problem solving and find activities that help students build knowledge and understanding rather than simply developing manipulation skills. Brekke (2002) supported the views of Redish by saying that just knowing algebra or calculus is not enough to solve a physics problem. Rather, students must have specific information about the problem itself such as knowing the constants, methods of isolating important factors in the problem itself, and ways of putting together a proper equation to solve for the unknown variable which is possible only if they are able to comprehend the problem successfully. Evidence exists that the curricula designed to emphasize the direct building of students' conceptual knowledge and problem solving skills promote better conceptual understanding and more expert-like problem solving skills (Allaire-Duquette et al., 2014; Yerushalmi, Henderson, Heller, Heller, & Kuo, 2007).

Blending of physical meaning with mathematical symbols not only affects how we interpret particular symbols but also affects how we view equations (Redish, 2006). The two major ingredients in problem-solving instruction that Mestre (2001) refers to are: a rich cross-referenced, well organized knowledge base and qualitative reasoning based on conceptual knowledge. The effective learner is an active problem solver who engages cognitively around the problem at hand and understands the processes surrounding the solution (Curwen, Miller, White-Smith, & Calfee, 2010). Mestre (2001) suggested the use of open-ended problems to encourage the use and integration of conceptual knowledge. Redish (2006) emphasized that crucial steps to the art of doing physics are deciding what the critical elements of a complex system are that must be preserved, and the trivial elements that can be ignored. Based on these crucial steps, Redish (2006) explained a problem solving strategy that includes: creating a mathematical model with relevant physical characteristics described in the problem, solving or deriving the equation, interpreting what the results say about the system, and evaluating whether the results adequately described the physical system, or if there is a need for modification of the model. Lin and Tsai (2013), in their study involving 488 Taiwanese high school students, found that those students who perceived learning science as understanding and applying scientific knowledge in new situations expressed higher levels of confidence in their learning while students who considered it as preparing for tests and exams held lower self-efficacy beliefs in their abilities.

Many traditional instructors invest their time teaching factual information while expecting the students to think like experts. But cognitive science tells us students develop different ways of thinking based on prior knowledge and through extended and focused mental effort (Allaire-Duquette et al., 2014; Bella & Crisp, 2015; Gok, 2014; Lin & Tsai, 2013; Wieman, 2007). Research suggests interventions that encourage students to work in more challenging and rigorous learning environments involving critical thinking can actually help the brain grow (Bella & Crisp, 2015). However, physics education for the most part focuses on abstract concepts devoid of real life connections, which in general favors males (Zhu, 2007). As a result, the unfriendly physics classrooms in both high school and college can have strong negative consequences on the self-efficacy beliefs of female students, filtering them out of majors such as physics. Therefore, the experiences of participants in my study will illuminate ways in which students develop new ways of thinking by making meaningful connections between what they are presently learning and their prior knowledge. The findings of the study might also highlight potential strategies these female undergraduate students use to successfully navigate through different aspects of physics learning.

Females in STEM

Although women have made great strides in education over the past 50 years, they have remained underrepresented in various STEM fields, especially in the areas of physics and engineering (Figure 1). This lack of representation is puzzling to many because women make up half of the United States population with almost 57% receiving undergraduate degrees from a four-year university (Yates, 2012). In 2011, men received most of the undergraduate degrees in engineering, computer sciences, and physics, whereas the number of women earning the degrees in these areas declined by 2%, 10%, and 2% respectively (National Science Board, 2014). Therefore, organizations such as the NSTA advocate for gender equity policy in preK-12 science education to ensure equal learning opportunities for both male and female students (National Science Teachers' Association, 2003).

Gender disparities in science can be noticed starting in grade school. Jones, Howe, and Rua (2000) examined the attitudes and experiences related to science for 437 sixth graders. They found significant differences between males and females in terms of science experiences, attitudes, and perceptions of science courses and careers. While males reported outside school experiences dealing with a variety of tools such as batteries, electric toys, fuses, microscopes, and pulleys, females' experiences were limited to bread-making, knitting, sewing, and planting seeds (Jones, Howe, & Rua, 2000). Males indicated an interest in atomic bombs, atoms, cars, computers, x-rays, and technology, whereas females reported interest in animal communication, rainbows, healthy eating, weather, and AIDS. In addition, males opted for careers that included controlling other people, becoming famous, and earning lots of money, while females wanted to find careers involved in helping other people. Jones, Howe, and Rua (2000) also noticed that females perceived science as more difficult than males. The study conducted by Patrick (2012) using a sample size of 637 biology, chemistry and physics education students at the university level revealed similar gender disparities. While males dominated enrollment in physics, females took over in the area of biology. Enrollment in chemistry was equal for both males and females.

A similar study was conducted by Hong and Lin (2013) in Taiwan, where they studied differences in students' self-efficacy and their involvement in learning science. Their sample consisted of 922 fifth graders, 499 eighth graders, and 1,455 eleventh graders. Analysis of variance and independent *t*-tests were used to compare the groups across grade levels and genders. Results indicated that while the self-efficacy of both boys and girls sharply declined from elementary to high school, boys in 11th grade were found to have higher self-efficacy than girls. Also, students who reported greater involvement in science learning had higher self-efficacy scores. Hong and Lin (2013) noted that girls, in spite of significantly higher performance reported low self-efficacies. These low self-efficacy beliefs of Taiwanese girls were associated with their lower self-esteem and self-worth during their high school years.

Lubinski, Benbow, Shea, Eftekhari-Sanjani, and Halvorson (2001) used a longitudinal study to follow a group of mathematically-gifted students. When they compared SAT scores of males and females in the group, females were found to be more balanced in both math and verbal abilities on the SAT. Tracking this group of students through college, Lubinski et al. (2001) found that more male students were likely to major in math and science compared to females. Surprisingly, mathematically-gifted females pursued degrees in life sciences, more specifically, careers that involved human interactions. Allaire-Duquette et al. (2014) in their study compared the emotional engagement of 13 female college and university students solving physics problems involving either technical or human body context. The results indicated that the emotional engagement of female students was significantly higher and more positive for problems involving human body context rather than a technical context. This interest in helping others explains the flux in the number of females obtaining degrees in psychology and social sciences. In past 20 years, women's participation in social and biological sciences has surpassed physical and engineering at most degree levels, while it remained less than 30% in engineering and computer sciences (National Science Foundation, 2013). Despite having the required math and science skills to pursue fields such as engineering, females choose people-oriented disciplines (DiBenedetto & Bembenutty, 2013; Garelik, 2000).

Griffith (2014) used data from National Longitudinal Survey of Freshmen and the National Education Longitudinal Study of 1988 to examine factors that contributed to the persistence of all students in STEM field majors, focusing mainly on females and minorities. Descriptive statistics indicated that a smaller percentage of women and minorities persisted in STEM fields compared to men and non-minorities. The difference in persistence rates was explained by the differences in the learning experiences and preparation of the students. A higher percentage of female graduate STEM majors impacted the persistence of female students (Griffith, 2014). Blue, Mills, and Yezierski (2013) surveyed 88 students from four colleges: one men's college, two women's colleges, and one co-education college, to determine if attending a single sex college had any effect on motivation, attitude, and self-efficacy. The scores of men attending the co-ed college were the highest followed by the women who attended women's colleges. However, women from the co-ed college scored lowest on motivation, attitude, and self-efficacy. Speaking about the strategies that female students use to survive in fields such as physics and engineering, Blue et al. (2013) described them as confidence in their abilities, assertiveness, being more open and direct in expressing their opinions, not taking criticism personally, being able to relate easily to male counterparts, learning to not be too self-critical about everything, being less intimidated by faculty, and being mentally prepared to take on the challenges posed by the major.

Using a physics department as a case study, and individual participants as embedded cases, Gonsalves (2014) used a sociocultural approach to examine ways in which doctoral students constructed narratives of their experiences about becoming physicists. Through observations, photo elicitations, and life history interviews, 11 men and women shared their experiences with physics and how contexts enabled or restricted their path to the physics doctoral program. The findings of the study revealed the importance of recognition in the constitution of physics identities. Often, recognition for these females was associated with responding to the dominant discourse of gender norms. Although there was a need for technical, analytic, and academic competencies, recognition also came with negotiation of gender roles by adopting the stereotypical behaviors of a physicist.

Riegle-Crumb and Moore (2014) used nationally representative data from the National Longitudinal study known as Academic Achievement Transcript Study to examine the effect of context of students' local communities on the inequality in high school physics enrollment. They found the percentage of women who were employed in STEM fields within the community had an effect on the gender gap in physics. They found the odds of girls taking physics increased with an increase in the percentage of females employed in STEM occupations. Therefore, with a goal to increase diversity in the STEM fields, NSF has directed funds into initiatives to stimulate participation in these fields. Examples of these initiatives include: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE) programs that focus specifically on women in science and engineering careers, and the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) that strives to increase the overall number of STEM graduates (Yates, 2012).

The American Association for University Women (AAUW, 2010) has generated a large body of research for the last 20 years. In their research, they found that social and environmental factors play a major role in the underrepresentation of women in the areas of STEM. In order to understand the ways in which social and environmental factors influence women's interests in, and pursuit of, physics it is important to examine the meaning making process of these individuals as they interact with different factors in their lives.

Symbolic Interactionism for Personal Meaning Making

In one's quest for truth, people tend to ask the question: What really happened? However, it is difficult to obtain the absolute truth. Charon (1979) explained that it is impossible for anyone to tell the absolute truth because each individual approaches the situation with a different perspective; therefore, a different reality is interpreted. However, Charon (1979) emphasized that some of these individual perspectives might capture at least a part of that reality. Perceptions sensitize an individual to certain aspects of the reality while desensitizing others. According to Charon (1979) perspectives are made up of words used by the observer to make sense of an experience. The reality for an individual therefore depends upon these sets of words that make up his/her assumptions and value judgments about the experience. These perceptions can influence the action of an individual in the world (Charon, 1979). Symbolic interactionism stems from the theory of interpretivism which believes in multiple truths (Crotty, 2004). Symbolic interactionism is a perspective of social psychology that is often used as a theoretical framework in sociology.

Within social science, many perspectives coexist depending on how they view and approach the human being. Social psychology is one such perspective of social science that examines the influences of people on other people's behavior and beliefs (Aronson, 1976). Aronson (1976) explained humans are social beings, influenced by others. Social psychology assumes that an individual's set of beliefs and feelings toward an object, often called attitudes, influence the manner in which one acts when encountered with that object. In other words, social psychology assumes attitudes are constantly changing due to social forces encountered in any situation, which shape an individual (Charon, 1979).

Symbolic interactionism is unique in the sense that, instead of concentrating on the individual or the social situation, it focuses on the nature of the interaction between people (Charon, 1979). In the 1930s, George Herbert Mead laid the foundation for symbolic interactionism. Mead's philosophy of pragmatism influenced the ideas of symbolic interactionism. One of the four underpinnings of pragmatism is that truth is possible for human beings only through their own individual interventions (Desmonde, 1957). In other words, truth does not exist without our interpretation of the situation. Secondly, knowledge for human beings is based on usefulness. Humans constantly test their hypotheses in all situations and act accordingly (Desmonde, 1957). They change their knowledge according to what works in the given situation. Thirdly, objects we encounter are defined according to their use for us. The meaning we assign to an object depends on how we intend to use it. As the use of the object changes, so does the meaning we assign to it. The fourth principle of pragmatism is that the understanding of a human being must be inferred from his observable actions. However, there is more to a human being than the mere external activity that you can see. This unobservable side of the human being is often inferred based on observable behavior (Desmonde, 1957).

Based on these for strong underlying principles of Mead, his student Herbert Blumer (1969) developed the premise for symbolic interactionism. Symbolic interactionism rests on three simple assumptions: people act toward objects based on the personal meaning they have for them, meanings are derived from social interactions, and meanings are modified based on the individual's interpretive process when engaged with the object. Blumer (1969) emphasizes the importance of meaning which, in contemporary social and psychological sciences, is often ignored as a passive link between environmental factors and human behavior.

Two schools of thought about the origin of *meaning* prevail. One of them is that the meaning of an object is inherent in the object. Meaning is viewed as an intrinsic property of the object that emanates from it. This view of meaning reflects the deeply entrenched traditional position of realism" The other view of meaning is that it is a "psychical accretion brought to the thing by the person for whom the thing has a meaning" (Blumer, 1969, p. 4). Psychical accretion constitutes of elements such as feelings, sensations, ideas, memories, motives, and attitudes. In other words, meaning is an expression of psychological elements. However, meaning, according to Blumer (1969), is developed during the process of interaction among people. The actions of other people define the object for the person. Thus, symbolic interactionism views meaning as a dynamic product that is informed by social interactions and personal interpretations. Blumer (1969) emphasized that interpretation is not simply interplay of psychological elements stated above, but it is the process of conversation that the person has with self.

Symbolic interactionism is the interaction between different minds and meanings that characterize human society (Meltzer, Petras, & Reynolds, 1975). Interactionists view human beings as self-reflective beings. They do not passively respond to social stimuli but are active parts of the society that interact, interpret, and guide the social situations. For interactionists, everything about the individual is not fixed. However, Blumer (1969) emphasized that this role of a human being as a dynamic actor and the idea of not being fixed but constantly changing must not be confused as *not becoming anything* but must be understood as a continuous *act of becoming*. Society, for interactionists, is shaped by a group of individuals who are constantly communicating and developing shared perspectives. Symbolic interactionism contends a human has many selves, each related to the interaction the person is presently involved in, and is constantly redefining one's self based on these interactions.

For Mead, humans were emergent beings who used symbols to reason. He focused on three major concepts to understand a human being: mind, self, and society (Huebner, 2012; Charon, 1979). Humans see reality as something that is socially constructed, and according to Charon (1979) what one sees *out there* and within one's self is developed through interaction with others. Nonetheless, Charon (1979) also reminded us of some social scientists who insist that there is an objective reality, free of social definition. People respond to this objective reality through socially constructed meanings. Apart from physical and social reality, a personal reality subsists, based on our differing views about the world around us. People depend on society for symbols and language which make them dynamic, creative, and complex individuals necessary for society to exist.

The methodological framework of symbolic interactionism was apropos for understanding the experiences of female undergraduate physics students. It was an appropriate lens to understand how they viewed themselves as female undergraduate physics majors and how others in society viewed them. Symbolic interactionism helped us to understand how the participants made meaning of their experiences as they interacted with different members of society such as parents, siblings, peers, and teachers and how their personal meanings changed with their own interpretation, informing the female undergraduates' current dispositions toward, interest in, and pursuit of, physics.

Summary

In this chapter, I examined Social Cognitive Career Theory as a model to explain the factors that directly influence a person's interest in a major or career (Lent et al. 2002). I described how SCCT evolved from Bandura's (1986) Social Cognitive Theory which assumes humans, as active agents, playing a major role in their self-development, adaption, and self-renewal with changing times. I also highlighted the present situation in STEM education emphasizing the need for changing the instructional methods especially in sciences such as physics to encourage more females to enter the field. I reviewed the reasons for the underrepresentation of females in STEM fields and emphasized the need for my study. I also explained the beliefs and assumptions of symbolic interpretivism as a lens to understand the meaning making process of the female undergraduate physics majors.

CHAPTER III

METHODOLOGY

The purpose of this study is to explore how the educational experiences of three female students contributed to their current dispositions toward, interest in, and pursuit of, physics as an undergraduate major at a large southern research university. The specific research questions are:

1. What are the critical moments in all of the educational experiences of female undergraduate physics majors that contributed to their interest in, and pursuit of, physics?
2. What college experiences of the female undergraduate physics majors contributed to their current dispositions to physics?

Subjectivity/Positionality Statement

Subjectivity "is an amalgam of the persuasions that stem from the circumstances of one's class, statuses, and values interacting with the particulars of one's object of investigation" (Peshkin, 1988, p. 17). Peshkin refers to subjectivity, as a garment that can never be detached from the person wearing it. The values and beliefs that I bring with me, have informed my study. Therefore, it is important to disclose my position as a researcher upfront, in order for the reader to understand the lens through which I interpreted the experiences of my participants.

I am a high school teacher with 15 years of experience teaching physics. I have an undergraduate degree with triple majors: math, physics, and chemistry. I grew up in the midst of many engineers and scientists as my father served in the department of Indian space research. Most of my childhood experiences were scientific in nature. As a young girl, I stood on the terrace of my home and watched rockets being launched, wondering why there was absolute silence in the dark sky as the rocket soared toward it. Thinking scientifically was not an option but a requirement for me to fit into the community in which I grew up. As a young girl, I jumped and cheered as I saw all my dad's friends congratulating each other on the success of a satellite launch. As an elementary school student, I had the privilege of listening to noble laureates such as Dr. Abdul Kalam, who was then the chairman of the Indian Space Research Association and later became Prime Minister of India. As I grew, my love for science grew with me. I enjoyed spending weekends working on science fair projects with my brother and sister. Science and math have always been in my comfort zone. When I started teaching physics in the United States 12 years ago in January of 2003, I asked my first group of graduating seniors, "How many of you are planning to major in physics?" It was shocking to see less than five hands raised, none of which belonged to females. Taking a deep breath, I asked "What are you all planning to major in?" While most of them said business, a few chose music or history. This scenario has repeated itself year after year, with no increase in the number of hands for physics majors. What was more depressing was to see a decline in the number of female students opting to take physics in high school. I wanted to motivate more girls to enjoy physics but sadly, I noticed a fear in their eyes revealing they thought they were not good enough to tackle physics, which broke my heart. When it came to this point of my dissertation study, physics education for female students became my passion. I wanted to find a research site for my study. After considering the logistics involved in a dissertation study such as the time, and money, I tried to find participants at the university where I am currently pursuing my doctoral program. While the university offered physics only as an undergraduate minor, no students were enrolled in the program. I tried contacting another university larger than ours in a neighboring city with a hope of finding some physics majors. But, I was surprised to find they had no physics majors either. The physics department at that university served the needs of students enrolled in engineering and bioscience programs. The acute shortage of undergraduate physics majors was evident in

South Texas. Suddenly, I was reminded of my former student who was in his second year physics honors program at a large, southern, research tier one university in Texas. I contacted him immediately to see if he could help in finding the participants for my study. During the conversation, he mentioned that 20% of the undergraduate students majoring in physics at his university were females. He also told me about a student organization at his university called Undergraduate Women in Physics that served female physics majors. I was delighted to learn the program had 20% females, and curious to know what motivated them to pursue physics as a major. This group of females represented the potential to inform the purpose of my study.

Qualitative Research Paradigm

Unlike quantitative research, the qualitative paradigm is subjective in nature. It assumes inquirers will reveal the process of meaning making and clarify what and how the meanings are personified in the language and actions of the social actors. Qualitative researchers subscribe to the notion that the researcher's subjective experience of a phenomenon conforms to the meaning assigned to the phenomenon through their lived experience of it (Crotty, 2004). However, they have been facing challenges to legitimize their studies in a predominantly positivist world. Tracy (2010) commented in her work that applying criteria of a quantitative study such as generalizability, objectivity, and reliability to qualitative studies is like, as described by Guba and Lincoln (2005), "Catholic questions directed to a Methodist audience" (p. 202). Therefore, it became important for qualitative researchers to develop a set of core values in order to produce a systematic and structured work that can encourage scholarly dialogue with the members of scientific community.

The design for my study model followed Tracy's (2010) eight *Big-Tent* criteria for an excellent qualitative study: worthy topic, rich rigor, sincerity, credibility, resonance, significant contribution, ethics, and meaningful coherence. A worthy topic is a relevant, timely, significant, and interesting topic that often emerges from disciplinary priorities and is theoretically or conceptually compelling (Tracy, 2010). Therefore, my interest in studying the unique experiences of females majoring in physics is a topic worthy of study because women are underrepresented in the areas of science and engineering (Sawtelle, 2011). The findings of this study can potentially contribute to the existing knowledge base in the area of women in STEM fields. I implemented multiple methods of data collection and analysis in order to achieve richness and rigor in my study (Tracy, 2010). The data were collected through interviews, object elicitations, photographs, and documents. I have implemented inductive, narrative, and arts-based analysis to interpret the data effectively using various lenses to make meaning of the participants' experiences and to represent their voices fairly and candidly in the study. Sincerity is marked by the honesty and transparency of the researcher throughout the study (Tracy, 2010).

Self-reflexivity and transparency were achieved by attending to my subjectivity upfront, and examining my assumptions and beliefs at every point of the study including, but not limited to, data collection, analysis, and representation of the participants' experiences. Credibility refers to the authenticity and trustworthiness of the research findings (Tracy, 2010). Qualitative researchers legitimize their findings by triangulating their data. This process builds coherent justification for the themes by examining the evidence across different data sources (Creswell, 2007). Therefore, researchers collect non-numerical data in qualitative research through various methods such as interviews, photographs, documents, object elicitations, and researcher's reflections. Credibility for this study was obtained by providing a thick description that allows the readers to see the complex specificity and circumstantiality of the data, thereby avoiding the possibility of divorcing meaning from its context, which could compromise the intended meaning (Tracy, 2010). The findings of the study were presented as interesting narratives that provide multiple entry points for the reader to connect with the experiences of individual participants, thereby resonating with the study.

The experiences of the participants enhance the significance of the study because the hold the potential to inform science educators of ways to motivate and enable female students to meaningfully engage with the subject and encourage more females to enter STEM fields. I, as a researcher, closely attend to procedural, situational, relational, and existing ethics throughout the study to ensure the process is as transparent and fair as possible (Tracy, 2010). I accomplished the purpose of the study by attentively interweaving the existing literature, research questions, methods, and findings in creative and meaningful ways to sustain the attention and interest of the reader, thereby making the study more meaningful and coherent (Tracy, 2010).

Since the focus is to explore the varied and unique individual educational experiences of female students which contributed to their current dispositions toward, interest in, and pursuit of, physics as an undergraduate major, the paradigm of qualitative inquiry was an appropriate method of research. According to Peshkin (1993), interpretation not only generates new concepts but elaborates on the existing ones, thereby potentially contributing to the knowledge available on the educational experiences of females majoring in male-dominated STEM fields.

Methodology

As the study explores in depth the experiences of individual female students majoring in physics, it can be referred to as a case study (Glesne, 2011). In a case study, the emphasis is on understanding the complexity within the case, its uniqueness, and its connections to the social context of which it is a part (Yin, 2006). Creswell (2007) defined case study research as a “study of an issue explored through one or more cases within a bounded system” (p. 73). Merriam

(1998) described case study as a means to provide vivid, lifelike experiences of the participants with in a contextual situation. She emphasized that the knowledge of the case under study is dependent on the meaning making process of the readers. Merriam (1998) also stated that case studies can lead to inductively discovering new relationships, concepts, and understandings of a phenomenon. According to Stake (1995), three types of case studies exist: intrinsic, instrumental, and collective. Intrinsic case study is one in which the researcher has an invested interest in a particular case. In instrumental case study, the focus is on an issue, and one case is used to illustrate the issue. Multiple cases are used to study one issue in collective case study. In case studies, the researcher explores a case or cases over time, through in depth data collection procedures involving multiple sources of information such as interviews, object elicitations, photographs, researcher's reflections, and documents (Creswell, 2007).

Although the origin of social science case study methods can be traced back from anthropology and sociology, case study methods have been very popular in the fields of psychology, medicine, law, and political sciences (Creswell, 2007). While Stake (1995) observes case study as not a methodological choice but a choice of what is to be studied, Yin (2006) sees case study as a method to examine in-depth a case within in its real life context. Case studies can be used to test hypotheses, particularly by examining a single exception that falsifies the hypothesis (Stake, 1978).

Case study methods can be applied when the research is addressing a descriptive question such as what happened or an explanatory question such as why it happened (Yin, 2006). Stake (1978) emphasizes that in a case study, one is more responsible to pay attention to details rather than less. Yin (2006) also addresses three important steps in designing a case study: defining the case that is being studied, justifying your choice of single-case study or multiple-case studies, and adopting or minimizing theoretical perspectives to develop data collection and analysis strategies. One of the challenges with case study method is for the researcher to identify a case or cases worthy of study (Creswell, 2007). If the study involves multiple cases, then the question on the researcher's mind will be how many. Creswell (2007) also stresses the need for researchers to set adequate boundaries for case studies that do not have a clean beginning and end.

The value I found in Yen's and Merriam's ideas of case study influenced my decision to use it as a method of inquiry and as an end product in studying the experiences of three female undergraduate physics majors. Specifically, the multiple-case study technique enabled me to provide a rich, in-depth description of the experiences of the females majoring in physics. Exploring the experiences of more than one case allowed me to produce more robust results. This research specifically focused on the critical incidents in the lives of the participants that contributed to their interest in, and pursuit of, physics as a major. Data were collected in multiple forms such as interviews, object elicitations, photographs, researcher's reflections, and documents.

Research Design

Although the study followed the basic design of problem, question, method, and findings, it was framed within the assumptions of qualitative inquiry: evolving design, presentation of multiple realities, researcher as data collection instrument, and a primary focus on participants' views (Creswell, 2007). As Creswell (2007) explains about any qualitative inquiry, the study might appear as a comprehensive whole rather than fragments because of the interconnectedness of the purpose, questions, and methods of research. A good case study design involves defining and selecting the case for study (Yin, 2006). The underlying criteria for selecting an information-rich case must be one from which others can learn a great deal about matters of importance and therefore worth of in-depth study (Patton, 2002).

Participant Selection

Unlike quantitative studies, no predetermined number of participants is stated for a qualitative study. Marshall (1996) stated the appropriate sample size for a qualitative study is the one that answers the research questions. If the goal of the study is not to generalize then the researcher must outline the theory in terms of the particular participants, setting, context, location, time, incident, activity, experience, and processes. "If the interpretations and theories remain strictly localized, then the size of the sample is not crucial" explained Marshall (1996). As a novice researcher, the key question I asked was how many participants I must have for this study.

Even though Creswell (2007) recommends a sample size of three to five for a case study, Morrow (2005) emphasizes that sampling procedures such as quality, length, and depth of interview data, and variety of evidence are more important than the sample size in case of a qualitative study. However, in order to capture the voice of the participant, sample size, where the sample represents the data collected in the form of words and body language during an interview, is more important than the number of cases (Onwuegbuzie & Leech, 2007). Failing to collect large enough samples of data can hinder the representation and legitimation of the findings in a study (Lincoln & Guba, 1985). Lincoln and Guba insisted on prolonged engagement and persistent observations of the participants in the social context, to increase the understanding of the underlying phenomena, events, or cases. Seidman (2006) identifies two important criteria for a good sample size: sufficient numbers to represent the range of population under study, and obtaining saturation of information. To sum it all up, Marshall (1996) recommended the sample sizes must not be so small that saturation, redundancy in the data, cannot be reached nor should it be so large that it becomes cumbersome to delve deeply into the experiences of the participants. Therefore, I restricted my sample size to three, keeping in mind the purpose of the study, availability of the participants, and the amount of data that need to be collected and analyzed within the available timeframe. I selected all three participants from the same university, with as much variation in their experiences as possible, to acquire unique individual stories.

Since the purpose of the study was to explore the in-depth experiences of female students pursuing physics as an undergraduate major, it was essential for me to select individuals who were accessible, interested in providing information, and willing to shed light on specific issues under study (Creswell, 2007). Therefore, criterion sampling was used to purposefully select information-rich cases central to the purpose of the study (Patton, 2002). In criterion sampling individuals are selected based on pre-determined criteria defined by the researcher (Marshall, 1996). Informed by the purpose of the study, I had determined four criteria for recruiting the participants for this study. The participants needed to: be female undergraduate students, willing to participate in the study; be at least 18 years old; have had declared physics as an undergraduate major; and lastly, but most importantly, in order to provide rich and varied experiences, the participants had to have completed at least two years in the physics program. Table 1 *Pre-determined Criteria by Participant* represents how the participants met the criteria set for the study.

Table 1

Pre-determined Criteria by Participant

Criteria	Valeria	Ana	Lee
Female undergraduate student	√	√	√
At least 18 years of age	20 years old	20 years old	22 years old
Undergraduate majors	Physics and Mathematical Science	Physics and Astronomy	Radiation Physics and Computational Mathematics
Years completed as physics majors	2	2	3

Research Site

The study was conducted at a large, southern, research tier one university which offers undergraduate and graduate programs for students all around the world. The university has a total undergraduate enrollment of 39,979 with 48.3% males and 51.7% females. The university offers more than 170 undergraduate fields of study, 154 master's degrees, and 86 doctoral programs. More than 1,000 scholars come to the university to conduct research every year and over 5,700 international students are enrolled here. The university provides an environment where diverse groups of people can live, learn, and thrive. Gender equality among faculty is also a primary goal of the university. They offer special programs such as Women in Engineering, Recruiting and Retaining Men in Nursing, Equal Opportunity in Engineering, Intellectual

Entrepreneurship Cross-Disciplinary Consortium, and Women in Natural Sciences. In the fall of 2014, a total of 723 students were enrolled in physics undergraduate and graduate programs. The physics graduate program at the university is ranked 4^{th} in the country by U.S. News & World Report for the year 2014. Three female undergraduate physics majors from this university were selected to participate in the study.

Gaining Access

Gaining access involves acquiring permission "to go wherever you want, whenever you want, observe whatever you want, obtain and read whatever documents you require, and do all of this for whatever period of time" (Glesne, 2011, p. 57). My former student who is currently attending the university served as a gatekeeper and helped recruit participants for this study. The trusted relationship between my student and his female peers facilitated my rapport with the participants. Several informal and friendly conversations with my participants allowed me to share the purpose of the study and the reasons for my genuine interest in their experiences as female physics majors. Spradley (1980) recommends being sensitive to your participants can take you through rough seas in the interview process, encouraging them to share even their most personal experiences.

After obtaining approval from the Internal Review Board (IRB) (Appendix A) for conducting the research study, I contacted my former student via email, and explained the study. I asked him if he would be interested in helping recruit the female undergraduate physics majors from his university. Because of his regard for me, he readily agreed. I sent him a summary of my study which he promised to present to his female peers who attended a student-run organization named, Undergraduate Women in Physics. In a week's time, he was able to obtain a list of seven female students who were interested in participating. However, when I tried matching them against the criteria listed above, I had to pare the list down to only three students. I contacted each one of the three shortlisted volunteers via email, explained the purpose of the study in detail and my expectations of them, if they chose to participate. Seidman (2006) encourages the researcher to directly contact potential participants because, "once having introduced the subject, she can seldom respond to questions that naturally might arise" (p.46). All three female students responded positively to the email saying that they were excited about participating in the study. We then exchanged phone numbers, and I called them individually to establish a friendly rapport with them. After few friendly conversations on the phone, I setup the first face to face interview with each one, in a place of their choice. I met each woman in person to obtain their informed consent (Appendix B), after reiterating the purpose of the study clearly and explaining they were free to not answer a question during an interview, or opt out of the study if they became uncomfortable at any point, and assured them their identities would be protected (Creswell, 2007).

Membership Role

My primary role as a qualitative researcher was to carefully construct a research design, conduct the research ethically and honestly, and analyze the data conscientiously to provide a rich description of the participants' experiences (Borman, Clarke, Cotner, & Lee, 2006). In this study, I played the role of a participant observer, actively listening to the stories of the participants and noting their physical reactions as they narrated their experiences (Spradely, 1980). Because of my background as a physics major and a physics educator, I observed myself silently reacting to their stories. Spradley (1980) calls this, the process of introspection, where in the observer probes herself to assess how she feels about a particular experience.

The participants shared critical moments in their lives that influenced their current dispositions, interest in, and the pursuit of, physics as an undergraduate major, in great depth during multiple interviews that were administered over a period of nine months. They also provided other forms of data such as documents, photographs, and other artifacts which helped with the process of making meaning of their experiences. The participants also played an active role in the data analysis and representation by performing member checks and providing feedback as needed. According to Glesne (2011), obtaining the reactions of the participants to the data collected helps the researcher verify that she is reflecting their perspectives appropriately and can also guide in developing new ideas and interpretations.

Data Collection Procedures

The purpose of the study often dictates the most appropriate procedures for data collection (Seidman, 2006). Seidman strongly advocates for interviewing, when the purpose of the study is to explore subjective understandings of people's experiences. Therefore, the primary source of data collection for these case studies was through semi-structured and structured interviews conducted over a period of nine months. However, "Good case studies benefit from having multiple sources of evidence" (Yin, 2006, p. 115). Hence, other forms of data included photographs, objects, documents, participant observations, and a researcher's journal. Multiple data collection methods can enhance the trustworthiness and authenticity of the research work (Glesne, 2011). Table 2 *Data Log by Participant* presents the different forms of data collected from the participants.

Table 2

Data Log by Participant

Data Source	Valeria	Ana	Lee
Critical Incident Interviews	3	3	3
Photographs	13	10	1
Objects	1	1	6
Documents	2	__	3
Participant Observations	__	1	1

Critical Incident Interviews

Interviews are conversations which take place between the researcher and the participant. They are conducted in one of the following formats: in-depth interviews, semi-structured interviews, unstructured conversations, serendipitous conversations, or elicited conversations (Bhattacharya, 2008). Qualitative interviewing assumes that that the perspective of other individuals is meaningful, knowable, and can be made explicit (Patton, 2002). In-depth open-ended interviews provide the participant with enough room to express meaning in his or her own words and to give direction to the interview process (Brenner, 2006). Since the purpose was to explore how the educational experiences of female students contributed to their current dispositions, interest in, and the pursuit of, physics as an undergraduate major at a large, southern research university, it was appropriate to use interviews as the primary source of data.

Critical incident interviews invite the participants to tell a story and explain why those moments are significant in the given context (Kain, 2004). They help provide full and precise details of the topic under study. This technique can help both the researcher and participants to stay focused on the topic under study. Flanagan (1954) described an incident as one where the participant actually reports the behavior, explains the relationship between her and the behavior, and provides relevant facts with a clear justification as to why the incident is critical. Critical incident interviews allowed me to explore the emotional truth of the participants as they described why and how that particular event contributed to their current dispositions, interest in and the pursuit of physics as an undergraduate major.

All three participants chose to have the interviews conducted on campus, a familiar and comfortable space to talk. Although the interviews were mostly conversational and involved story-telling, they were guided by some pre-formulated open-ended questions. The goal of these open-ended questions was mainly "to have the participants reconstruct her experience within the topic under study" (Seidman, 2006, p.15). DeMarrais (2004) states that such probing questions can provide information to the participants, encouraging them to engage in meaningful conversations. Despite having prepared the pre-formulated questions, I often had to pose new questions to gain additional clarity of their thoughts. According to Glesne (2011), "qualitative researchers begin with some interview questions and remain open to reforming and adding to them throughout the research process" (p. 102). The pre-formulated open-ended questions for the interview were:

1. Tell me about the first time you fell in love with science.
2. Describe your journey as a female physics major.
3. Describe the role of your family in your life as a physics major.
4. Describe the role of your teachers in your life as a physics major.
5. Tell me about your experiences with your peers in physics.

6. Describe the incident when you experienced success in physics for the first time.

7. Tell me about the incident when you felt proud as a female physics major.

8. Tell me about the incident when you felt discouraged as a physics major.

9. Describe the best experience as a female physics major.

It is important to note that the questions were not asked in any set order. When I asked a question, there were times when the participants narrated long stories encompassing many questions on the list. At that point, I asked a different question that was not addressed in the previous response. Each interview lasted between 60-90 minutes, and a total of three interviews were conducted with each participant. I audio-recorded each one of the interviews and saved them under separate file names for each participant. I made a note of the key points such as body language of the participant, while remaining vigilant to the process, and the substance in their story (Seidman, 2006). I also audio-recorded several short informal conversations between the participants and me, for the purposes of clarifying thoughts during the process of data analysis and representation. Using the audio-recordings, I later transcribed the interviews into word documents which I sent out to individual participants to ensure I represented their stories accurately.

Photographs

Harper (2008) emphasizes that the visual documentation such as photographs becomes a part of the triangulation process because they can argue the visual traces of the world, adequately describing the phenomenon under study. Photos can affectively reveal the opinions of the symbolic world created by the participants (Denzin, 1989). Therefore, in order to develop a better understanding of the meaning-making process, I asked the participants to provide me with photographs that were influential, or that reflected their experiences as female physics majors. I used Spradley's (1980) matrix to analyze emotional truths hidden in the photographs. Upon presenting the photographs, participants reflected on the powerful connections they made with them as female physicists. Human experiences are often so complex that photo elicitation can take understanding to a different level that may be out of reach with text alone (Bhattacharya, 2005). Valeria provided the following photograph (Figure 4).

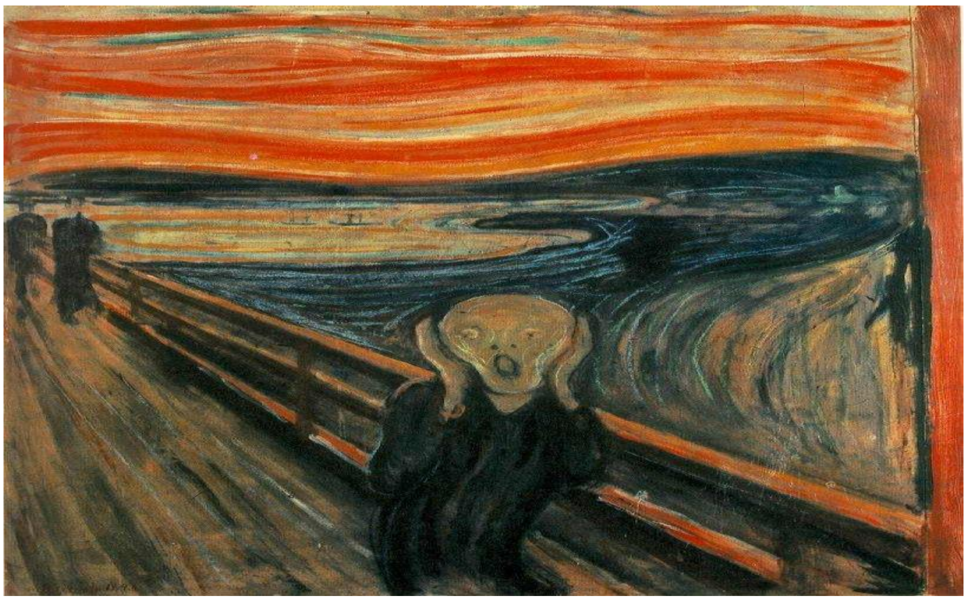

Figure 4. Photograph provided by Valeria.

I paid close attention to the people and the environment present in the photograph above such as facial expressions, body language, and the action that is taking place. I used descriptors such as HORROR, PAIN, FEAR, LONELY, CONFUSED, SOMETHING FOLLOWING, TRYING TO ESCAPE, to analyze the photograph. I later reflected on it after I asked Valeria what the picture meant to her. Following is the story she told me.

> I would spend too much time crying, thinking about these things until I would put myself to sleep. I would starve myself most of the days. I was not in peace with myself. As a result, I lost my friends. I hated myself. I thought, I was good for nothing.

The pain and fear I noticed in the picture through the use of colors and strokes, along with Valeria's narrative allowed me to construct the emotional truth associated with her experience.

Object Elicitations

Participants negotiate their experiences through several circumstances and events, producing the need to use creative reflective practices to elicit information that cannot be relayed using nothing more than verbal responses (Bhattacharya, 2005). Glesne (2011) says that objects shared by participants are bestowed with meaning and history in that context, giving the researcher insights into how meaning is constructed. Hence, I asked my participants to present objects that were meaningful to them as female physics majors. They brought in several objects such as books, pins, a back pack, and a pencil case. The participants intimated the conversations as they associated the objects with their experiences as physics majors. For example, the following (Figure 5) is an object elicitation from Ana.

Figure 5. Lollipops provided by Ana.

> My AP chemistry teacher gave us these little lollipops because they are sticky and like every six weeks because it was like a six week grading period, she gave us like gum or sticky things and said remember to just stick with it.

The story Ana related helped me to understand the sentimental value those lollipops held for her. I analyzed the objects themselves using Spradely's (1980) matrix, for their appearance, how they were used, and the context in which they were used by the participant.

Document Analysis

Another important source of information used by qualitative researchers is analysis of documents such as official records, letters, newspaper accounts, diaries, reports, and published data uncovered in a review of literature (Hoepfl, 1997). The documents shared by the participants such as their resumes, personal journals, and class notes provided rich data and a new dimension to understand their experiences. The documents added a new layer of complexity and understanding which not only facilitated the triangulation process between various data sources but added a degree of rigor to the analysis (Glesne, 2011; Patton, 2002).

Participant Observations

Unlike an ordinary observer, the goal of a participant observer is not only to observe the activities, people, and physical aspects of the situation but to engage in activities appropriate to the situation (Spradley, 1980). I joined my participants for lunch, where we had casual conversations, ranging from Lee's preference for vegan food to my experiences as an International Baccalaureate teacher. By participating in this activity, I was able to observe my participants more closely in a public setting which provided me with rich data necessary to describe their individual profiles in detail. It also allowed me to establish a credible relationship with them. According to Glesne (2011), participant observations can provide opportunities for the researcher to acquire the status of a trusted person. Upon returning to my car, I quickly made condensed notes which I later expanded in my researcher's journal.

Researcher's Journal

I documented my thoughts and reflections throughout the research process in my researcher's journal. Glesne (2011) emphasizes the need for the researcher to capture analytic thoughts as they occur. I made brief notes on post-it notes as I reviewed and analyzed the data. Later, I expanded my thoughts in my journal. I used the journal to free-write around the prompts, describe my participant observations, and record the suggestions from the peer review sections and member checks. For the most part, my journal contained analytic memos developed during the data analysis process, which were later used to generate narratives for each one of the participants.

Data Management

Working with large amounts of qualitative data requires some form of management, organization, description, analysis, and interpretation of data. Miles and Huberman (1994) suggest five general ideas for storing and retrieving qualitative data. They are formatting, cross-referral, indexing, abstracting, and pagination. All data collected during the interviews was treated confidentially and stored in a safe place. The interviews were audio recorded using a Sony audio recorder with a USB. The audio files were then downloaded to my password protected personal computer as mp3 files and stored under different participant pseudonyms for easy retrieval. The files were also backed up on a password protected external storage device for safety. The transcripts of the interviews were saved as word documents and backed up on the external storage device separately labeled for each participant. All photographs and documents were scanned and saved on to my personal computer and backed up on the external storage device as well. Photographs were blurred, names on the documents were masked, and pseudonyms were used for the participants to maintain confidentiality.

Along with the electronic copies, I also maintained a paper-based binder of all my data. Copies of the transcripts, documents, and pictures were made on different colored paper for each individual participant for easier access. The printouts of the transcripts were filed and labeled as interviews 1, 2, 3…separately for each participant. Other forms of data that were received from each participant such as photographs, pictures of the artifacts, documents, signed consent forms, and email correspondences were filed and dated separately for future reference. The external storage devices, all the hard copies of the data, my researcher's journal, and the artifacts were all stored away in a locked cabinet at my home.

Data Analysis and Representation

According to Creswell (2007) analysis of a case study involves making a detailed description of the case and its setting. Stake (1995) suggests three forms of data analysis for a case study: categorical aggregation, direct interpretation, and naturalistic generalizations. Categorical aggregation is a collection of instances from data. Direct interpretation involves drawing meaning from a single instance and naturalistic generalization is where people can learn from the case either for themselves or apply to a population of cases. I used categorical aggregation, to collect instances from the data of each case in which the case presents itself. Merriam (1988) describes this type of analysis as being rich and robust. I analyzed each individual case in great detail, looking for critical moments that addressed the research questions. Then, I looked for the big overarching themes across the cases called cross-case analysis (Yin, 2006). However, that was easier said than done.

Data analysis, for me, was a complex, interwoven, difficult to describe, intimidating process, involving several cycles of coding. It is important to note that the process of data analysis had started during my first conversation with the participants. I officially started the process by first reading the interview transcripts of the participant. Although I did not start coding the data until later, reading the transcripts allowed me to see the big picture of the participants' lives. This process gave me an opportunity to reflect on my own experiences that were either similar to or different from that of the participants. I was also able to reduce the data using Moustakas' (1994) data reduction method where all the events were reported only once regardless of how many times they were discussed or observed during the data collection process. This method helped me to condense the data into smaller, more meaningful chunks. I then listened to the recorded conversations, paying close attention to the participants' tone of voice, laughter, and silences that occurred during the conversation. I asked myself, what does it mean? I began to free-write around the ideas and the silences, weaving in my subjectivity as a female and as a science educator. The initial analysis permitted me to connect with the participants' experiences in the contexts that they occurred, thus helping me identify the critical moments in their journey as female physics majors.

As anticipated with analyzing qualitative data, the process evolved from the initial quest through the journey to find answers to my research questions. The research questions guided the process of data analysis and representation for the study, while the theoretical and conceptual frameworks were used to make meaning of the participant's experiences. As, I read the interview transcripts, I realized that each experience the participants shared was a story in itself and therefore chose to use narrative analysis to process the data.

Narrative Analysis

Connelly and Clandinin (2006) believe humans lead individually and socially shaped storied lives. "By electing how an experience fits with other experiences, people create individual narratives; by deciding how their individual experiences make sense in relation to each other, they create their personal grand narrative" (Varbelow, 2015, p. 6). These lived stories can be captured through different means such as interviews, photographs, personal journals, and artifacts which can then be used to construct a rich narrative of the person's storied life (Connelly & Clandinin, 2006). Narrative analysis is often used to foster an in-depth understanding of the participant's experiences with respect to a particular phenomenon, especially to voice the perceptions of underrepresented populations (Reismann, 2002). Andrews, Squire, and Tamboukou (2008) believe, when working with narratives, one can bring various contradictory layers of meaning into useful dialogue to better understand the participant. Since the purpose of the study is to understand the critical moments in the lives of female undergraduate students which informed their interest in, and pursuit of physics, retelling the storied lives of these individuals can encourage more women, who are often underrepresented, to pursue STEM fields.

Reismann (2008) recommends four different analytic approaches to composing narratives. They are thematic analysis, structural form, dialogic/performance analysis, and interpreting images and words in parallel. I approached the data for this study with thematic analysis. When conversing with the participants, I encouraged them to retell stories of the critical moments in their lives as female physics majors using narrative elements of introduction, orientation, complicating action, and resolution. Below is an excerpt from an interview that demonstrates the elements of a narrative.

> In tenth grade, I read *Das Kapital* by Karl Marx and *The Communist Manifesto*. A lot of people didn't like that, because I was in Texas at that time. If you even read anything about that sort of thing they call you names. So I kept a lot of what I learned to myself although it taught me logic and gave me a fundamental understanding of how the world works kind of.

These codes generated from different data sources such as interviews, photographs, were used to develop rich narratives with a beginning, middle and ending, which portrayed the lives of these female physics undergraduates. Every time I noticed a gap in the participants' narratives, I approached them again with more questions, thus gaining a better understanding of their experiences. In case of Valeria, I had to conduct three interviews before she could share some of the stories necessary to construct the narrative of her journey as a physics major. As much as I tried to create Figure 6 *The Process of Data Analysis,* to represent my analytic thought process in a linear fashion, it was, in fact, much more complex and cyclic in nature. Analysis and coding proceeded simultaneously throughout the process, making it difficult to state which step came before and which one was later. However, I tried my best to detail the process of data analysis with examples in the next few paragraphs.

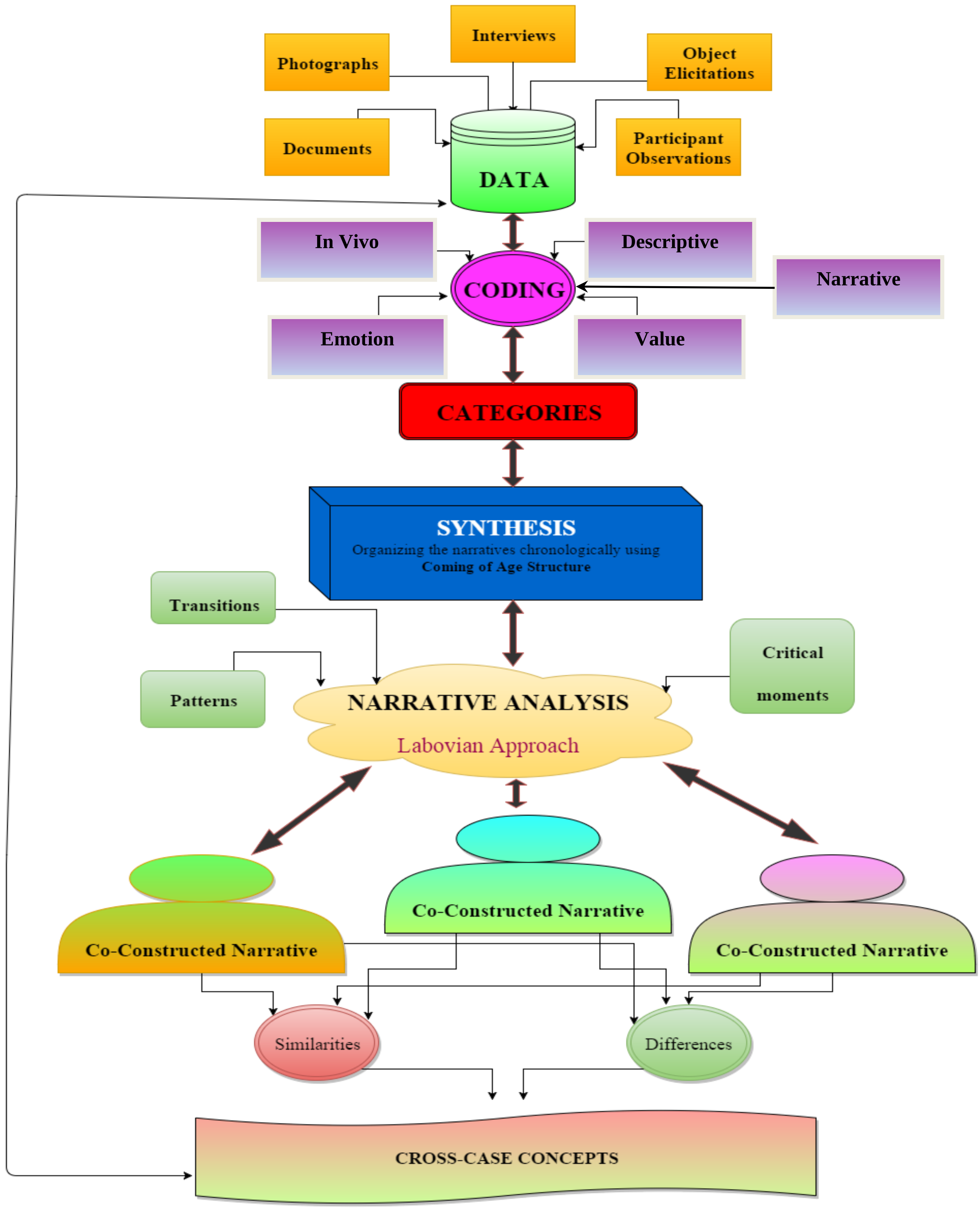

Figure 6. The Process of data analysis.

Coding

I began analyzing the data collected from different sources such as interviews, photographs, object elicitations, documents, and participant observations, in greater detail. I used In Vivo, descriptive, emotional, and value coding techniques recommended by Saldaña (2013). In Vivo coding refers to the verbatim words or phrases as used by the participant (Saldana, 2013). Saldana (2013) emphasizes using this type of coding honors the voice of the participants. Therefore, I used In Vivo coding to identify the strong words and phrases the participants used to describe their experiences. In Vivo coding allowed me to understand the unique vocabulary used in the culture of physics majors (Saldaña, 2013). Table 3 *In Vivo Coding* demonstrates the process of coding a document, feedback on Lee's lab physics lab report, provided by a male teaching assistant.

Table 3

In Vivo Coding

Transcript	**Code**
You need to justify this assumption. What you have is [1] circular logic. So while it is a plot it [2] adds only little understanding. Avoid broad [3]sweeping statements like consistent with classical literature, it makes you [4] sound vague and doesn't add anything for the reader. One acquires data, extracting [5] sounds funny. Your end result here is very [6]underwhelming. The [7] real kicker is that you say this is confirmation of Schockley's equation but this says [8] NOTHING about saturation current!	[1] "CIRCULAR LOGIC" [2] "ADDS ONLY LITTLE UNDERSTANDING" [3] "SWEEPING STATEMENTS" [4] "SOUNDS VAGUE" [5] "SOUNDS FUNNY" [6] "UNDERWHELMING" [7] "REAL KICKER" [8] "NOTHING"

Not only did these In Vivo codes facilitate my understanding of the expectations set forth for physics majors, but they also allowed me to gauge the sarcasm in the male TA's voice that questioned Lee's intellect.

Descriptive coding summarizes the content of the passage into a word or a short phrase, allowing us to see what is going on (Saldaña, 2013). Saldaña (2013) insists the use of descriptive coding allows the reader to see what the researchers see and hear what they heard.

Table 4

Descriptive Coding

Transcript	Code
[1] My science teachers were absolutely amazing. One of them was kind of scary but still really great.	[1] AMAZING SCIENCE TEACHERS
[2] remember one of our physics project. We had to build a little roller coaster.	[2] PHYSICS PROJECTS
[3] So it was a little tube and we could make it go around and it was demonstrating kinetic and potential energy.	[3] DEMONSTRATE PHYSICS CONCEPTS
[4] That just really stuck with me and it was actually with the scary teacher.	[4] MEMORY OF THE PROJECTS
[5] That was a really cool assignment.	[5] COOL ASSIGNMENT
[6] I love doing such things.	[6] LOVE SCIENCE PROJECTS
[7] You could also be creative with it too.	[7] ENCOURAGES CREATIVITY

Table 4 *Descriptive Coding* describes the process for analyzing an excerpt from the interview with Ana. The descriptive coding technique helped me to understand that Ana had amazing science teachers who used projects to teach physics concepts. Ana enjoyed learning science through project-based methods. This understanding of Ana allowed me to present her narrative more accurately and in greater detail.

Since emotions cannot be separated from humans in action, it is important for a researcher to focus on emotion coding. Emotion codes project “the emotions recalled and/or experienced by the participant” (Saldaña, 2013, p.105). The emotional codes generated from an excerpt shared by Lee during an interview are presented Table 5 *Emotion Coding.*

Table 5

Emotion Coding

Transcript	**Code**
Our interactions were different. [1] One professor was more approachable, [2] but the other was most intimidating to go talk to just because she was so smart, and she has a reputation in the department of being like brilliant. Like, people know her. [3] That just made me intimidated, because like I don't want to embarrass myself in front of this really smart, cool like professor that I admire. So I was a little, I was scared,	[1] AT EASE [2] SCARED [3] DOUBT

By using emotion coding, I was able to get a stronger feel for the interpersonal and intrapersonal experiences of the participants.

I used value coding recommended by Saldaña (2013), to gain an understanding of the participants’ values, beliefs, and attitudes. Such understanding can help the researcher present the perspectives of participants more accurately (Saldaña, 2013). The value coding presented in Table 6 *Value Coding* helps identify Valeria’s belief systems, thus providing insights into her meaning-making process.

Table 6

Value Coding

Transcript	**Code**
[1] I feel that men are better at presenting themselves. [2] They show more confidence. [3] I thought they were always right. I knew I didn't want to be embarrassed. [4] I didn't want them to be like oh she doesn't know this.	[1] MEN ARE GOOD PRESENTERS [2] MEN ARE CONFIDENT [3] MEN ARE ALWAYS RIGHT [4] MEN ARE JUDGEMENTAL

Narrative Coding involves analyzing in the form of stories, using conventions of literary elements (Saldaña, 2013). With each experience being a story in itself, I used a six-part Labovian (Saldaña, 2013) model to understand the meaning of the experience, as presented by the participant. The model helped recapitulate the past experiences of the participants by matching a verbal sequence of clauses to the sequence of events which actually occurred in the narrated incidents (Labov, 1972). The Labovian model has six elements: abstract (A), orientation (O), complicating action (CA), result (R), evaluation (E), and coda (C) (Patterson, 2008). The abstract is the summary of the story that can be optional depending on the context in which the story is told. Orientation provides the setting, complicating action relates the events of the story, result tells how the story ends, evaluation mediates the crucial point of the story, and coda links the present world of storytelling to past world of the story (Patterson, 2008). The narratives were coded manually using different colors to highlight the six elements. The following Table 7 *Six-Part Labovian Model of Narrative Coding* shows the process when analyzing a narrative shared by Valeria.

Table 7

Six-Part Labovian Model of Narrative Coding

Transcript	Code
[1] I struggled a lot with confidence.	[1] A
[2] It was kind of hard to me to argue with people.	[2] O
[3] But when I got to this really hard class which is waves and optics, I was one of the people that knew the most.	[3]CA
[4] In study groups, people would usually argue and they always wanted to be right, but most of the times, I was right.	[4] CA
[5] Then I was like, oh my gosh, I love physics.	[5] R
[6] So, I began gaining some confidence.	[6] E

Data Representation

Data analysis and representation were ongoing simultaneous processes in this study. The codes obtained from all data sources were grouped to form categories which were used as the plot titles within the narratives. Each plot was developed carefully using the major literary elements of introduction, orientation, complicating action, and resolution. Since one of my major goals for the study was to bring the participants' voices into the limelight, I chose to represent the journey of each participant as a rich narrative. I free-wrote around the incidents narrated by the participants, weaving in my analytic understandings informed by my personal experiences. In order to provide a rich description of the event that took place, I supported it with data across different sources such as photographs, and documents. As a result, the mini narratives for different incidents in the life of the participant began to shape up as distinct yet discrete stories. Finally, it was time to organize the mini narratives of different critical incidents into one major narrative of their journey as a female physics major, still maintaining the conventions of the literary elements of a narrative discussed above.

There was a chronological order in the way the participants chose to identify the critical moments which were major turning points in their lives, leading to their present dispositions, interest in, and pursuit of physics. I decided to use the coming-of-age framework suggested by Boes (2006) to develop the final narratives of their journeys. In literary studies, this framework is referred to as bildungsroman which represents the social, psychological, and moral maturation of the main character in the story over time (Boes, 2006; Watson, 2014). Knoetze and Stroud (2012) identified some main characteristics for a coming-of-age or Bildungsroman narrative: a chronological order in experiences from childhood into adulthood; as a result of the adversity with in the plot, the protagonist undergoes a rite-of-passage, embracing the attributes and values of their society. Having noticed these attributes in the stories narrated by the participants, I organized the mini narratives, starting with their childhood experiences (K-8 years of school), followed by high school, leading to freshmen year of college and into the present, creating a rich narrative of the participant's storied life as female physics major. This organization strategy allowed me to compare the cases not only across similar critical incidents narrated by the participants but also across time frames.

Reporting the findings of a qualitative study involves a rich description that takes the readers into the setting that is being provided by the participants (Patton, 2002). To construct the meaning of the experiences that was not obvious, I approached the data using arts-based techniques. Arts-based inquiry is a method of using different art forms that include performing and visual arts to understand and construct meaning of human experiences (Finley, 2008). Some of the arts-based techniques include nonlinguistic forms of art such as painting, photography, collage, music, video, sculpture, film, and dance (Barry, 1996). Arts-based researchers not only help the world see the reality that is obvious but create a visual reality of the unnoticed through images (Smithbell, 2010). Cueva (2011) observed that arts add dimensions to learning in several ways such as knowing self, uncovering hidden knowledge, image making to deepen understanding, learning from cultural perspectives, and a means for social change. According to Barrone and Eisner (2006) the aim of art-based educational research (ABER) is not to search for certainty but to suggest new ways of viewing educational phenomena.

While arts-based inquirers create open hermeneutic texts that can create spaces for multiple interpretations by a diverse audience (Finley, 2003), and Barrone and Eisner (2006) stress that arts-based educational research is more interested in the number and quality of questions that the work raises, than the conclusions that readers come to believe. Barrone and Eisner (2006) describe three important aspects of ABER: its ability to reveal the unnoticed, promote new questions, and focus on educationally salient issues and questions, and relevance to phenomena outside the field of research.

I used Cahnmann's (2006) idea of scholARTistry to analyze the experiences of one of my participants to not only gain an in-depth understanding, but also to help readers actually see her in action. Barry (1996) noticed that, while words mean what they mean, poems, drawings, paintings, and sculptures, seldom allow room for unambiguous interpretation. Therefore, I prefaced Ana's narrative with a found poem composed of In Vivo quotes obtained from different data sources, providing a strong visual effect for the audience to interpret the participant's experiences.

After creating the final narratives of the three participants, I went back to analyze the major narratives for cross-case themes. I compared the cases for in and out of school experiences at different turning points in their lives to obtain categories. These categories were then compared in the contexts of the critical incidents that happened in the participants' lives, formulating mini-themes. I began to free-write around the mini-themes looking for an overarching cross-case theme. Table 8 *Cross-Case Analysis across Turning Points* and Table 9 *Cross-Case Analysis Across Critical Incidents*, give an example of the complex process used to construct cross-case themes for the study.

Table 8

Cross-Case Analysis across Turning Points

Participants	Environments	Turning Point (K-8 Years)	Category
	In school	No qualified Teachers	
		No hands-on learning	
		No resources	
Valeria		Independent learning from books	
	Out of School	Conservative and sexist family	
		No dad	
		Mom with no job	Formation of self-image
		Raised with expectations away from school	
		College not an option	
	In school	Amazing science teachers	
		Hands-on activities and projects	
		Few math hiccups	
Ana	Out of School	Caring and invested parents	
		Treated special	
		Expectations for pursuing science beyond school	
		Science related toys and videos	
	In School	Montessori program	
		Hands-on activities	
		Process information differently	
Lee		Identified gifted	
		Engaging science teachers	
	Out of School	LEGOs and Bionicles	
		Not pushy parents	
		Loves reading	

Table 9

Cross-Case Analysis across Critical Incidents

Case	Category	Critical Moments (Plot Titles)	Mini-Themes	Overarching Themes
Valeria	Formation of Self-Image	Roles assigned by tradition	• Doubting the existing space	Carving New Spaces
		Dying existential self	• Questioning the existing spaces	
Ana		Weird is the New Normal	• Questioning the existing spaces	
		Receding into a Shell	• Doubting existing spaces	
Lee		Building an Empire	• Questioning existing spaces	

Ethical Considerations

IRB (Institutional Review Board) approval was obtained prior to starting the study. According to Creswell (2007) "permission needs to be sought from human subjects review board, a process in which campus committees review research studies for their potential harmful impact on and risk to participants" (p. 123). As a researcher involved in qualitative research which makes both the researcher and the participants more vulnerable, I was transparent with participants regarding the nature of my study and explained my vested interest in it. This helped to build rapport between the participants and me (Creswell, 2007). I explained in detail how the participants' confidential identity would be maintained by using pseudonyms. I informed the participants they could resign from the study at any point with no questions asked, or choose not to answer a question, if they were uncomfortable at any time. Participants were then asked to sign the consent form, agreeing to participate in the study. With my role as participant observer, I shared my stories of common interests with the participants, developing a trusted relationship. I approached the participants only at their convenience, allowing them to share their experiences when ready. While interviewing, I used my personal empathy to make the respondents feel more at ease, and thereby more willing to tell their story (Fink, 2000).

I definitely was mindful of my subjectivities and pointed to them clearly throughout the study. I used free-writing as a technique to reflect on the co-constructed meanings of the participants' experiences and periodically checked with my participants and peers to reflect on my data analysis and representation, making sure I was presenting the participants' voices accurately. Since "no inquiry is ever without initial values, beliefs, conceptions, and driving assumptions regarding the matter under investigation" (Ladson-Billings, 1997, p.146), I clearly stated my subjectivity and beliefs about the topic of study upfront and then approached the data wearing the lenses of the participants, continuously uncovering the emotional truth throughout the process. I made a conscious effort to present the findings in the participants' voice as carefully as possible, by referring back to the data at every point and minimizing the influence of my subjectivity. I presented the data to the participants at various points throughout the study, to make sure I offered a co-constructed understanding of their experiences. To gain a deeper understanding of my participants' experiences, I analyzed the data collected in different forms, using various lenses such as narrative analysis, and arts- based inquiry, focusing on the research questions.

Academic Rigor and Trustworthiness

According to Gonzalez and Forister (2015), four criteria are used to determine the trustworthiness of a qualitative study. They are credibility, transferability, dependability, and conformability. Credibility of a study can be established through the researcher's prolonged engagement in the study (Gonzalez & Forister, 2015). I spent time establishing a healthy rapport with the participants before I met them in person to schedule an interview. I established trustworthiness by clearly stating the purpose of the study and my invested interest in it. I also took a closer look at my subjectivity, beliefs and assumptions about the topic of my study. In this way, I started to analyze the data through the lens of the participants, focusing on the research questions. One of the best sources of corroboration is the participants that you worked with and watched because they are bound to know more than the researcher about the realities under investigation (Miles & Huberman, 1994). Miles and Huberman explained that member checks can be used for confirming the findings of a study and help the researcher know better what she knows. Working with other researchers to help think about the complexity and ethics of the work is highly recommended both during the research process and prior to publication (Freeman, deMarrais, Preissle, Roulston, & St. Pierre, 2007). Bracketing helps researchers become aware of their subjectivity and its influence on the study. In bracketing, the researcher permits a peer to interview him or her so that she can become conscious of values, assumptions, and beliefs that inform the research (Bhattacharya, 2008). Therefore, I established trustworthiness through constant member checks, peer debriefing, bracketing, multiple data sources, and triangulation (Gonzalez & Forister, 2015).

I triangulated the data collected from multiple sources to cross check the findings of the study, since no one source of information can be trusted to give a complete picture of the idea under study (Patton, 2002). Since the interview data can be affected by the emotional state of the interviewee at the time of the interview, other data sources can help check what is reported in an interview. The strength of one method can compensate for weakness of another and therefore explains the need for multiple data sources (Patton, 2002) which are used for triangulation. The purpose of triangulation is to test for consistency by using different methods, sources, analyses, and theories (Patton, 2002). Triangulation supports a finding by showing that an independent measure agrees with, or at least does not contradict, results. It is not only a way to confirm the findings of a study but a way to get to the findings themselves (Miles & Huberman, 1994). Therefore, I triangulated my findings across different sources such as interviews, participant observations, photographs, artifacts, and documents.

Proper auditing procedures for storing the data such as transcripts of the interviews, artifacts, documents, photographs, and the reflective journals in a meaningful and easily retrievable form assured dependability and conformability of the study (Gonzalez & Forister, 2015). Research is a reflexive process that requires continuous scrutiny and reflection on the data, the researcher, the participants, and the environment they are in (Guillemin & Gillam, 2004). Therefore, journaling before, during, and after the study is extremely important to establish trustworthiness and rigor (Bhattacharya, 2007). I used free-writing to reflect on my analytic understandings of the participants' experiences. Qualitative researchers immerse themselves in the study for extended periods of time because the relational aspects of qualitative work are so important to assure trustworthiness and rigor (Freeman et al., 2007). I spent almost nine months collecting and representing data in different forms. For each case, I provided a thick and rich description with high interpretive value using narratives including photographs and poems to establish transferability of the study.

Summary

In this chapter, I presented my subjectivity as a physics major and as a high school physics teacher thereby clarifying the lens through which I will interpret the experiences of the participants in this study. I explained in detail the case study as a methodology to examine the experiences of the female undergraduate physics majors. Further, I detailed the methods which will be used to select and recruit the participants, collect and analyze the data, and for representing the findings in the study. I also described the techniques used to meet the criteria of an excellent qualitative study: worthy topic, rich rigor, sincerity, credibility, resonance, significant contribution, ethics, and meaningful coherence (Tracy, 2010).

CHAPTER IV

FINDINGS

In this chapter, I represent the data for my study preceded by the research questions. I have attempted to present the voices of my participants honestly and candidly, while being aware of my subjectivity as a physics major and educator. Remember, the purpose of this study is to explore how the educational experiences of three female students contributed to their current dispositions toward, interest in, and pursuit of, physics as an undergraduate major at a large, southern, tier one research university. The specific research questions for the purpose of this study are:

1. What are the critical moments in all of the educational experiences of female undergraduate physics majors that contributed to their interest in and pursuit of physics?
2. What college experiences of the female undergraduate physics majors contributed to their current dispositions to physics?

The chapter is divided into four major segments. The first three segments contain stories, describing the journeys of three female undergraduate physics majors: Valeria, Ana, and Lee. The major themes that surfaced from the cross-case analysis of the three participants are presented in section four. I chose to paint the rich and detailed portraits of my participants through their unique, individual stories. This form of representation can help readers connect with the participants directly while understanding the lens with which I, as researcher, interpreted the experiences of each one of the cases.

Metamorphosis - Valeria's Comeback

She gently touched ENTER on the keypad. In split seconds, sequences of several thousand numbers began chasing one another, trying to show their power. She looked at her watch; it was 2:10 a.m. Taking a deep breath, she leaned back in the chair and closed her eyes. The dark circles under her eyes were the result of 18 hours of hard work. Valeria, a 20 year old international undergraduate student is double majoring in physics and mathematical sciences. She researches high energy physics. She is currently a junior and is now known among her peers as an "intelligent, knowledgeable, and humble person." But, this was not Valeria three years ago.

Roles Assigned by Tradition

Valeria was born into a large family in Mexico. "My uncle was kind of like a father in my early years," she says, implying that she never saw her dad. "Life in Mexico was relaxed and truly more enjoyable. I was always surrounded by people that loved me," she says, sharing several pictures (Figure 7) of her family.

Figure 7. Life in Mexico.

> My family is conservative and a bit sexist. In Mexican culture, girls are raised with different expectations, far from academics. My uncles and grandparents constantly said that it was extremely important for me to learn how to cook and clean for when I got married. Attending college was never an option for me.

The tremor in her voice gave away the injury she felt about the role assigned to her by tradition.

I caught myself nodding in agreement with Valeria as the past flashed in front of me. For a very long time, the notion that girls are more confined to the kitchen was prevalent in the Indian culture as well. I remember my grandfather insisting how important it was for me to learn how to cook, because he was almost certain that despite my degrees I would be the one cooking for my family someday. He even argued with my parents when they decided to send me off to another state for college. Luckily, I had supportive parents who had high aspirations for me far away from the kitchen. I can never forget one of my friends saying, “Wow! That is very interesting,” when she noticed my 1-year-old daughter playing with a toy car. An inexpressible feeling crept through my body as I quietly smiled, remembering the words of Beauvoir (1989), a WOMAN is not born, but is made by the society. It is not surprising anymore to notice the girls in my class, scared to death of getting electrocuted by a 1.5V battery, when boys will orally test a 9V battery using their tongue. Learning is a process governed by experience, stated Dewey (1938). Boys are often presented with toy cars and video games, while girls are given Barbies and kitchen sets to play with. Although present day women question their roles, it is a struggle to change the grand narrative of a WOMAN. Girls who do not fit this grand narrative of a WOMAN are often ridiculed. Valeria was one such WOMAN who constantly doubted her role.

Valeria was thirteen when her mom lost her job in Mexico, forcing them to move in with their family in the United States. Valeria, with a deep sigh, remembers, “To find a job, she did not have any real skills. So she thought life in America would be better, especially since school in the US is free.” She sounded as though she was in total disagreement with her mom’s idea to move. Valeria was not left with much choice other than to leave the people she dearly loved; her sister and her friends, back home in Mexico and come to the United States.

Valeria was enrolled in eighth grade at a large suburban public school in Houston, Texas. Less than six months into the American public school system, Valeria stepped into one of the most important phases of student life, high school. Recalling some of her initial high school experiences, Valeria says,

> Even here, when I went to high school, I witnessed that it was different trying to join the sciences being a girl. I cannot forget the all-boys UIL math club, where usually one of our mentors would have parties and dinners and self-coordinated summer programs for

the math club which, from his point of view, consisted of four to six guys. It took me almost three years to have a decent relationship with him, and this was clearly because I was a female.

The stress on "Even here" indicated the disappointment when she noticed that the grand narrative for WOMAN in America was not very different from that in Mexico. It was apparent that Valeria expected a more welcoming space for females in the fields of science and math. To her dismay, she was a misfit for the "all-boys math club." Valeria was initially unsure why she was deprived of certain privileges. Questioning her role, she forcefully gained entry into an uncomfortable zone with strictly defined norms.

With aspirations for a bright future, Valeria began to strongly question her role assigned by tradition. As a result, she had a rough home life. She recalls the years of never-ending arguments between the members of her family:

> We had so many conflicts with my uncles that it got to a point where we did not have a real place to live. I knew my uncle really disliked me. One day, completely intoxicated, he chased me upstairs with a knife. I had to jump roofs to run away.

Valeria looked away, in an attempt to hide her tears from me. She was left with no one to support her, including her mom. Describing the relationship with her mom, she says, "When I was in primary school, she always helped me with my homework; she helped me have the best handwriting in my class. But that habit disappeared once we were here." Valeria's mom was too afraid to question her role of a perfect Mexican female. But Valeria had different expectations of her mother, "I was expecting her to just talk to me." She wanted her mom to support her in changing the existing paradigms. However, her mom chose to silence her voice. The anger toward her mom became evident, when I presented Valeria with the picture (Figure 8), she had shared via email. It was a cartoon of a bug with the words "GOOD GRIEF! WHAT'S HAPPENED TO ME?" A small smile crossed her lips, making me more curious as to what the picture meant for Valeria.

Figure 8. Metamorphosis by Franz Kafka.

> When I read it in high school, I felt a connection with the main character. The book basically talks about his life after he turns into a beetle. It was kind of an existential book. It talked about his loneliness and his anguish. His family could not even look at him and was embarrassed that their son was a beetle. After a while, they had him in his room, forgot about him, forgot to feed him, and then he dies. The family was so much happier without him, because he was a burden.

Upon reflecting, it seemed Valeria was non-existent to her family. For the family, she was metamorphosing into a beetle, no longer suiting the character of a true Mexican female. She experienced failure of her *self* when she says, "I was even embarrassed to speak in English at home." Tears rolled down Valeria's delicate cheeks. But she still stood straight and strong, wiping off the tears. "I want to show my family that I can do this," she says. The intent to challenge her position, refuting the role assigned by tradition, encouraged Valeria to pursue a non-traditional major such as physics.

Bigger Sense of Freedom

"I got to this point because of all of my teachers. They helped me with my school and I always felt the support, mostly from my physics teacher," Valeria said, pointing to the lady in the picture (Figure 9), taken in a restaurant.

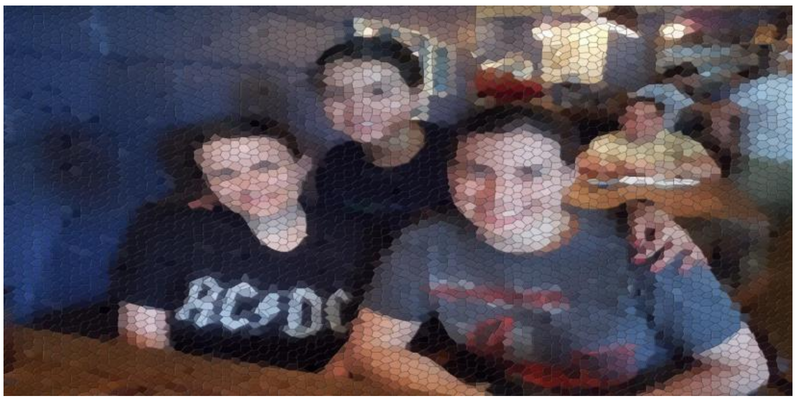

Figure 9. Valeria with her physics teacher.

"I don't want to say I wanted to be like her because that will be kind of weird but um…" Valeria paused. The hesitation in her pause clearly indicated that she wanted to be like her physics teacher. Reasoning out the admiration for her physics teacher,

> She would always make sure I was well mentally and physically. She would always talk to me about my problems. She always gave up her weekends to help us study for AP exam, or when we had trouble with a problem. She will always be there for me.

For Valeria, her teacher had exceeded the expectations of an ordinary teacher. While the strict rules of the society restrained her outer self of a WOMAN, Valeria's inner self experienced a bigger sense of freedom when her physics teacher talked to her about the physics programs she was interested in, and the colleges she wanted to go. "She was the first one to have ever talked to me about this!" exclaimed Valeria. Someone had actually talked to Valeria about college, which was never an option in her culture and therefore, “the physics teacher is the one that made the difference” for her. The teacher, for the first time, freed Valeria from her suffocating traditional outfit of a WOMAN, recognizing her true self. She dared to do that because she herself had broken the norm of the society, as a female physics teacher.

For her physics teacher, Valeria was not just another warm body sitting in a corner of her class. She was now an important and integral part of classroom culture. Valeria was no longer silenced when she says, “She would be very persistent. She would always expect an answer and would never let me be quiet.” Valeria, for the first time, was not *othered* in her physics class, becoming a critical moment for her to appreciate and pursue physics later on in life.

I desperately wanted to be that physics teacher, who cared for her students’ heart first, before caring for their minds. How many Valerias would have left my class, feeling disappointed and ignored, because I was too busy trying to teach the curriculum and worrying about my test scores? The thought broke my heart. I felt defeated as a teacher. I began to reflect on my own practices as I continued talking to Valeria. As a teacher, I was transforming every second.

Dying Existential Self

Valeria beamed when she told me about the happiest day of her life – the day she was accepted into one of the tier one universities in the state with all tuition paid. College was now a sure thing for Valeria. Leaving troubles, dismissals from the family for being who she is, and unmet expectations caused by outdated traditions behind her, she left happily for college in another large city.

The discoloration of the brick on the buildings and the enormously large trunks of lush green trees depicted the age and pride of the university. It was a huge campus filled with the hustle and bustle of several thousand students. The campus looked like a city in itself with bus services, several shops, and restaurants. Valeria quickly walked to the university administrative building. It was the admissions section. The lady at the desk greeted Valeria with a big smile. After a brief conversation, the lady handed her an application to fill in. Valeria sat at a desk and quickly began filling out the long application. She reached the part of the application that asked for a major. Valeria stopped for a second. Her physics teacher's words echoed in her head.

> My teacher said I had the potential. Physics was just the best options for me, because it just had the things I liked. I think that if I had stayed in Mexico and had gone to college, I would have done art history and Spanish literature, or economics. I realized that society in general tends to appreciate the outcome of money from science degrees.

It was interesting to note that science was never even an option for females in Mexican culture. Women probably were not considered smart enough for science. However, Valeria was always curious about how nature worked, when she vividly remembers questioning her 7th grade teacher about "friction." "I did not understand it. So I asked my teacher," she says, proudly thinking about the first time she changed the paradigm. But now physics was the "best option" for Valeria probably because of the teacher who encouraged her to change the existing paradigms. Without much thought, Valeria put down physics as her major, handed the application to the lady at the desk, and walked out, knowing she made the right choice.

College was a brutal awakening to harsh realities. Valeria recalls, "freshman year definitely. Yes, it was mostly because of lack of background. I just knew very basic stuff like how to solve some equations." Valeria realized that she was unprepared for college. The meaning of physics suddenly began to transform as she interacted with it in college. It was no longer plug and chug when she says, “I knew math, but that did not connect the physical concepts.” Valeria refers to her problem as a “lack of theoretical understanding.”

The tag under one of the pictures (Figure 10) that Valeria emailed me read, “UIL people--They were my family,” showing the strong bond, she had developed with her friends in high school.

Figure 10. UIL people --They were my family.

Valeria was hoping to find a new family, among strangers in college. But, most of them were “hostile” toward her.

It was a lab day. Valeria hurried to the lab station to get started on the harmonics lab. She noticed a guy at her desk, busily prepping for the lab. She quickly understood, he was her assigned lab partner for the day. The guy was doing most of the lab work independently. Valeria tried to follow along, but kept falling behind. “May be you should help me with this. We are required to do this together,” said Valeria. He continues to do the lab, completely ignoring her. “I understood that he was not interested in working with me,” she says. But, she must get him to cooperate, since it might be difficult to conduct the experiment all by herself. Softening her tone of voice, she tried again, “Could you please help me? I really do not know how to do this.” Sure enough, he responded, and soon they were working on the lab together.

Valeria, in her words, assumed "dumb" in order to gain entry to the world of physics. She began to realize her place in this social circle of physics majors. According to the norms of this existing social circle, wanting to be a physics major was not her right, but a privilege that she had to earn. Such intimidating moments did not stop here for Valeria. She remembers,

> It happened again in a study group. I was working on a problem. The guy was explaining it incorrectly and I knew what the right answer was. So, I was like, "I don't think that's how you do it. I feel like it's this way but I'm not sure." They were like, "how could you know? Are you sure? They gave me that kind of an attitude like I don't know if I should trust you. Another time, I give an answer to one of the questions that a student had in my study group. Couple of minutes later, another guy just gave the same answer but different explanation and they said they understood it better. It was just because it came from a guy. Are you kidding me? I was just so mad that one time.

Valeria's peers questioned her intellect. She is a WOMAN, and therefore could not be correct. She was judged harshly for who she was, a WOMAN. Valeria's self-image, built in her high school physics class, began to collapse once again, when she responded to her peers, "Oh no! I don't know. But that's just how I think." Her confidence as female physics major began to suffer when she says, "I feel like you have to keep some modesty because you're not always one hundred percent certain." She no longer mattered in these special social circles of intellectuals. Valeria was forced to silence her voice and accept the role of a WOMAN as described by society.

> I felt that men were better at presenting themselves. They show more confidence and then you start believing that they are right all the time. I didn't want to be embarrassed. I didn't want them to think that I did not know stuff.

The situation worsened when she noticed that most of her professors were old white men, who assumed students to think like them, and understand physics with absolutely no questions asked.

> I would go to his office hours. The thing about this professor is, he is one of the smartest people you are ever going to meet. Going to his office hours was kind of discouraging because he's smart. You don't know what he expects you to know. If you ask him a question then he would say, that should be obvious or you should know this already. They usually would rather want you to be quiet and not ask as many questions. I feel like they just don't want to be bothered.

The meaning of physics was no longer a sweet, caring teacher, who encouraged her to ask questions and patiently waited for a response. Valeria was once again lonely and deserted. She was worth nothing to her family, and now the same was for her peers and professors, all for one reason: she was failing to match the definition of a WOMAN. The nightmares of disregard and disrespect began to haunt Valeria again (Figure 11).

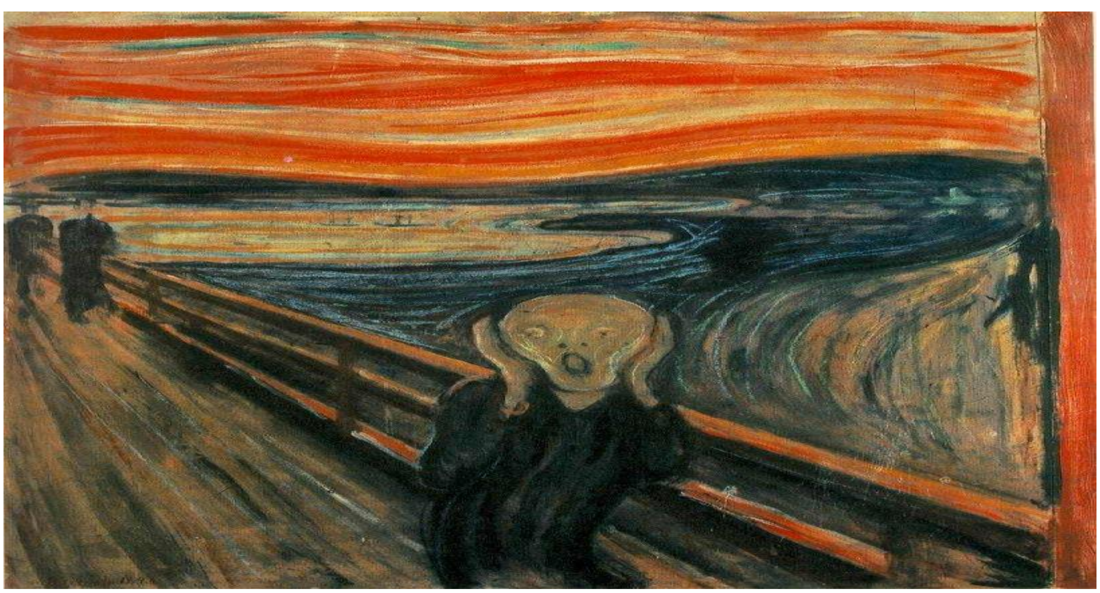

Figure 11. Dying existential self.

I would spend too much time crying thinking about these things until I would put myself to sleep. I would starve myself most of the days. I was not in peace with myself. As a result, I lost my friends. I hated myself. I thought I was good for nothing.

She presents the picture (Figure 12) that expressed her feeling of abandonment.

Figure 12. Feeling of Abandonment.

Several unanswered questions began to ruin Valeria's peace of mind. She had stopped believing in herself when she says, "I got into the mentality that grades don't matter." Physics meant nothing to her, as she was nothing to physics and soon, she was drifting away from this world of physics.

Valeria began to second guess her choice of majoring in physics. "I was not sure if physics was my thing. I felt like everyone was smarter than me. I began to ask myself, am I going to get to grad school? I thought I was not good enough for physics" she says. She was fighting desperately to save her dying existential self. Valeria was struggling, she was neither ready to accept the way her family defined her, nor by the male-dominated society of physics majors.

Assuming Multiple Faces

Valeria was at that point of her journey and had only two choices: either to give up the dream of becoming a physics major and settle for minimum or to fight back and prove that she is the maker of her destiny. However, giving up for Valeria was to accept that the female is designed for traditional roles of: cooking and cleaning. The urge to fight back and prove to her family and to the physics community that she was worth more than a mere Barbie girl became the impetus for becoming physics major. Valeria decided to keep her existential self alive when she says, “I started accepting to live with it rather than fighting it.” She decided to regain control of her life. Valeria reflects on her past, “My life in Mexico, I can't help it. So I don't think about that anymore. I wanted to focus on school work. I push myself forward and remind myself to eat and at least get three hours of sleep.”

Those extremely powerful words left me thinking for a while. The new transformed Valeria became apparent at that time. Valeria realized, who she was in the past was no more in her control, but who she wants to be, for sure could be determined by her. It was as though she had walked into a shower. She felt so much lighter as the water cleansed her body and mind. “B’s are no longer good enough” for her. She “expects more for herself.” Valeria, who once doubted getting into graduate school, is now confident of it, “Definitely, I think Stanford is always one of the good schools. But, other schools are Cornell, The University of Rochester in New York, and Columbia. But my dream school would be Oxford.”

From several pictures that Valeria had shared, it was obvious that art was close to her heart. But one of the pictures captured my special attention. It was the painting (Figure 13) with a lady sitting in front of a box containing multiple masks. Several masks were on the floor and it appeared as though she was testing them carefully to decide which one to put on her face.

Looking at the picture, I had two questions for Valeria: Who is this lady? What do these masks represent? Unable to control my curiosity, I pulled it out of the folder and placed it on the desk in front of us. Valeria smiled nodding her head the minute she saw it, as if she knew that was coming.

Figure 13. Lady of Multiple Faces.

> Every time I meet someone, I act a certain way depending on the people I interact with. I feel like I am a different person each time. I use to struggle with whether I want to be assertive or nice. It was annoying, because I really cared about how others perceived me. I was really self-conscious even though I said I didn’t care about people's opinions. I didn't want to be weak. So I started to mix different personalities. As a result, my confidence rose to a degree where I am now more confident about the things I say. I am more persistent about an answer I give.

Valeria, who was for the most part struggling to believe in herself, has now learned the art of negotiation. She had mastered the skill of closely observing the culture around before adapting it, without compromising her real self. This skill of negotiation has helped her, not only gain access to difficult spaces, but navigate through them with ease when she says, “Now they listen to me." Today, Valeria perceives herself as a successful female physics major and says, "I have a long way to go." This art of negotiating that helped her gain confidence as a physics major is detrimental to Valeria's current disposition to physics. Confidence echoes in her voice when she says,

> When I got to this really hard class which is waves and optics, I was one of the people that knew the most. In study groups, people would usually argue and they always wanted to be right but most of the times, I was right. One of my goals was to feel better with myself and be like, I can actually do this. It's not like they're smarter than you are. It is nice to know that you are working hard and getting there.

Valeria had learned to intrinsically motivate herself to move forward and strive hard to succeed. She wanted to prove to the physics community that she mattered. She not only learned to find space in this male dominated world of physics but she had actually managed to carve a special space for herself that did not exist before. She became an expert at navigating through these spaces independently. In the process, Valeria began to work with a highly successful female professor on a research project, and she insists, "I work with her because I like the study."

The research work provided a platform for her to not only gain access to the world of physics, but also for her to contribute her knowledge to it, thus leaving behind her foot print.

> I like the community my professor has built among her research group. It is always about learning more and improving one's knowledge. They give an assignment to figure it out on my own, which is not something I would learn in a physics class. I like that you can collaborate with others. You have to work together to come up with good results that are not only true to you. I usually learn a lot from talking to other physics majors and postdocs. It's enjoyable because it doesn't feel so much like someone is telling me how to

do something, but rather sharing a perspective of why things are happening. I have a feeling; I am contributing to the field, as small as it can be.

The "cozy" community created by her professor informs Valeria's current disposition to physics. Physics, which at one point had no meaning for Valeria, now means the world to her when she says, "the mind-blowing facts you encounter every now and then are the realizations of why things happen." It became apparent to me that Valeria had made her place in the world of physics. Through her contributions to the research project, Valeria feels recognized in the world of physics.

Pointing to the young girls in the picture (Figure 14), Valeria says, "I want to show them everything," meaning, she is now a stronger person, determined to help other females like her, recognize and appreciate their true selves.

Figure 14. Valeria's nieces and cousins.

She wants to be that positive and encouraging teacher, like the physics teacher that recognized her strengths and believed in her, showing the path to success. The strongly written resume reflects the leader in Valeria. She counsels several students in "their pursuit of personal growth" through service in the community, and in the development of leadership skills. She is also serving as an officer for Undergraduate Women in Physics where, she “develops mentoring programs to encourage young girls interested in STEM fields”.

Just then, the scrolling numbers on the computer screen suddenly came to a standstill as though the referee had blown his final whistle. The results were declared. Valeria walked to the printer and grabbed a whole bunch of papers. The way she held those papers close to her heart indicated how special they were to her. Valeria grabbed her bag and slowly made her way out. I kept thinking about the transformed Valeria, myself, physics itself, and the distinct spaces we hold in this world.

Suddenly, I noticed the paper with a golden rim hidden in mist of several other documents that Valeria produced. It was a certificate of merit awarded to Valeria for her academic excellence. I looked in the direction that Valeria had left. She had already disappeared into the hustle and bustle, leaving behind her strong voice for fellow females:

> If you have experienced some form of sexism that has discouraged you from doing science, fight back and keep going. Don't be afraid to ask questions. Be assertive and show confidence in the work you do.

Ana’s Magic - Stick With It

Watching Magic School Bus,
Putting together skeleton toys,
I thought, paleontologist someday.
Clapping hands, picking me up,
“My princess, future scientist” he said.
Flabbergasted, as the balloon began to rise,
Couldn’t believe the hands that made it,
Hot air is lighter, I learned.
Proud making marble go up and down,

Round and round,
Though it was a little tube
So what!
Competing with Kingda Ka,
World's tallest rollercoaster,
Demonstrating the same laws of energy.
Creativity and exploration
Hands-on experiences
Making meaningful connections
Left me thinking
Science is so much fun

Ana, an enthusiastic young lady from Denton, Texas, recalls her childhood memories of "doing" science. Ana is twenty years old and is currently a third year student, majoring in physics and astronomy at a tier one university in Texas.

In You, We Believe

Ana attributes her initial interest in science to her "super supportive parents." She proudly describes, "My parents always encouraged me to be a scientist. They were always like, you are going to grow up to be very successful." The enthusiasm and confidence Ana exhibited answering the questions reflected the freedom and support provided by her family. She never hesitated to voice her opinion about different ideas during our conversation.

Having encountered several students who come to school without a pencil or a journal, I could not agree enough with how lucky Ana was to have such a supportive family. I can recall countless situations, when students would come to class with no homework because they were either working 30 hours a week to support their family, or taking care of their siblings at home since parents were busy working. The undisturbed smile and expressive body language when talking about her parents conveyed Ana's love for her parents, especially her dad. In attempts to explain the relationship with her father she said:

> I always struggled with math a little bit. My dad would make these little homemade sheets of problems and he would say you should work on these. So I would practice a lot on those and honestly it was just the basics. Now I know, I love math and enjoy doing it.

I smiled as I recalled the math worksheets my mom used to make when I was a kid, for me to practice at home. Those small attempts that parents make, to help their children, can have a profound impact on the relationship between them. For Ana, the time that her father took to make those worksheets, to help her get over what she calls as "the little math bump," demonstrates his interest in her success. Therefore, it became a sweet memory for her, to reminisce throughout her life.

Ana portrays her middle school science teachers as "absolutely amazing,", when she suddenly began to laugh aloud, "One of them was actually kind of scary. But she was still really great. We did a lot of hands-on activities in her class. That was fun." Ana distinctly recalls almost all of her middle school projects in great detail, evidencing her love for "doing" science. Ana's curiosity to explore nature was encouraged in these teachers' classrooms. As a physics teacher, I almost always noticed that students, who never would put their pencil on paper, are the ones that always surprise me with their best rollercoasters, mousetrap racers, and catapults. I can never forget how proud Joseph was when his Popsicle catapult launched the gummy bear into the basket 10 meters away. The rewarding experiences from my students have encouraged me to believe that hands-on experiences become minds-on experiences that can be truly rewarding for most students.

Ana, who was smiling until then, all of a sudden became serious as she began to talk about high school. Her eyes were filled with tears and her strong voice suddenly weakened as she briefly talked about her father's passing. The sudden departure of her loving dad at the end of her freshmen year in high school left Ana devastated. Ana took a deep breath as she brought to mind those tough times of her life.

> That was a hard time in my life, after my freshman year, my dad died and I was going through things. That was when I took AP chemistry and I just was like well I'm probably going to end up dropping this class.

It is not difficult to understand Ana's struggle to cope with the huge loss. It was as though she was on a boat caught in a typhoon and had lost her sight of destination. She almost lost her self-confidence when she heard a voice saying, "stick with it."

> Throughout high school, I completely loved chemistry. It was because of my chemistry teacher. I won't lie, she was absolutely great. One of the things that she really stressed was that you just need to stick with it. You can't just give up on this. You have to keep on doing it even if it gets hard. She definitely inspired me. She was so dedicated. It was crazy.

I was surprised, when I noticed Ana pulling out lollipops (Figure 15) from her purse. Placing them on the table, "She gave us these little lollipops because they are sticky. Every six weeks, she gave us gum or sticky things and said remember to just stick with it. It was the cheesiest thing ever, but it was adorable."

Figure 15. Lollipops: Stick with it.

Ana’s strong voice was back on a roll. She found a strong paddle: the magic slogan, “stick with it,” to row her almost drowning boat safely to the shore. The excitement in her voice as she talked spoke volumes about the respect she had for her teacher. I sat still, admiring the extent to which Ana adored her chemistry teacher until this day. The teacher made an effort to understand the students in her class, providing them with a challenging, yet not intimidating learning environment, using “words such as quizzy poos, and testy poos.” She inspired her students to thrive as successful learners, despite the hurdles they experienced in the process, making it the critical moment for Ana to appreciate and pursue science beyond high school.

Ana dates her appreciation for physics, especially astronomy, to her uncle who is an astrophysicist. She says, “I would talk to him and he'd tell me about different things.” However, in high school, she was strongly influenced by the negative attitudes of her physics teacher, “This sad jaded man with unfulfilled dreams of becoming an astronaut.” Ana was scared away from her interest to pursue physics because her teacher said, “Think twice before going into a physics major.”

It was heartbreaking for me to hear about the negative attitudes of a teacher towards the subject he was teaching. Not having a passion for the subject you teach can permanently shun students away from the subject. Physics, for Ana, suddenly transformed from a successful astrophysicist at a reputed university, to an unsuccessful sad jaded man. She was confused with her choice of pursuing physics as major in college.

However, the major factor that informed Ana's appreciation and admiration for physics came from the "words of wisdom" of her professors at the university. With her eyes sparkling Ana says,

> It was just great in talking to my professor. He is such a great guy. He always spouts out wisdom. He talked about his experiences. Another thing that helped was listening to the only female professor I had. Whenever she was talking to us about her journey to being a physicist, she was like I was not like this in physics to begin with. But I just kept on going with it. I stuck with it. She did give up quite a bit to be successful. It was pretty crazy listening to her entire life story. But she loves what she does and she is so happy. She has done some cool things.

Ana's face was turning red with excitement the whole time she was talking about her two professors, placing them on top of this pedestal of knowledge. The magic phrase "stick with it" appeared again, now from the mouth of a successful female physicist. The success stories of the female physicist were living testimonies for Ana, reassuring her to "stick with it" as a physics major. Ana's respect for her chemistry teacher grew by leaps and bounds, she says, "It was hard to top her." I learned that in order to engage students with physics or any other subject for that matter, you have to be an authentic, passionate person who cares about the human being, the student. Through their passion, her chemistry teacher and the physics professors gave Ana the confidence to believe in herself.

Exploring Her Place in Universe

It was not until she went to college that she rediscovered her love for physics. She went into college wanting to major in chemistry because of the positive experiences she had in her chemistry class, “I loved chemistry. It was cool.” However, in college, the cool “petawatt lasers” in the physics department, described by her friend, seized Ana’s attention more than the “gross and disorganized” chemistry labs. Ana squeals in excitement as she describes the “petawatt laser,” rediscovering her love for physics. The deep sigh accompanied by a sarcastic laugh, when describing chemistry as “mildly interesting,” explains beyond doubt that Ana always adored the great chemistry teacher, not the chemistry itself. It was interesting to note that Ana confused her love for physics with chemistry because of the attitudes of teachers she had. It was obvious that the attitudes teachers bring into classrooms strongly impact the career choices of their students.

For Ana, the meaning of physics changed once again, from a sad, jaded, unsuccessful man, to amazingly cool pettawatt lasers. “I don’t regret it one bit,” says Ana, when talking about her choice to become a physics major. Ana is enchanted with physics:

> I love knowing how and why things work. That is just what physics really is. So you're getting to the nitty gritty of the very basic principles of universe. It’s like a puzzle to me. You are just figuring things out. I honestly think that's really interesting.

Although the appealing experiences that a friend shared initially informed Ana’s choice to switch majors from chemistry to physics, it was not until later in the freshmen year of college, that she truly developed a passion for the subject. Thinking about the first time she fell in love with physics, Ana says,

> I was in an astronomy group, explaining the universe with white dwarfs. We got to go out to the observatory in west Texas, beautiful place out there. I had never really seen the Milky Way before because I always lived in the suburbs. Seeing it for the first time was a humbling experience. It really makes you think about your place in the universe. I just think that it's so interesting and I want to look out there and I want to study that. That is what I want to do.

Ana was proud, sharing the picture of the observatory (Figure 16), taken by her during a summer internship. It was a white dome on the top of a lush green hill. It looked as though the dome was reaching for the sky.

Figure 16. The observatory: place of Ana's internship.

Looking at the picture (Figure 17) of the Milky Way, it is hard to resist the thrilling experience of viewing it directly. I noticed Ana standing next to the giant telescope with the Milky Way in the background, making a strong statement "I found my place." This rewarding experience of coming so close to the Milky Way was critical to Ana's passion for physics, astronomy in particular.

Figure 17. Ana with the Milky Way.

Weird Is the New Normal

Like most students, Ana struggled with time management and study skills through her first year in college. However, because of her limited math skills, she began doubting her role as a physics major. She had not taken calculus in high school which was a requirement for university physics.

> Honestly, I use to think that perhaps I wasn't cut out to be a physics major. I would meet all sorts of people in the same class that knew so much more than I did. I was intimidated by how much everybody else seemed to know. I felt really out of the loop. In the early physics courses, people would laugh at how easy all of the material was while I was working hard to get grades that matched theirs. I ended up barely passing the first semester. The second semester, I was able to pull myself together and started studying

like crazy for calculus. I passed that class with an A. It helped me realize, I am a smart person.

The magic slogan of "stick with it" reminded Ana, not to give up hope and fight diligently to create a space of her own. Ana learned about herself that if she tries hard enough, she can accomplish success. With that experience of failing and then acing calculus the next semester, she learned to trust herself. This experience also increased her self-efficacy, motivating her intrinsically to pursue physics. Ana grew stronger not only as a female physics major but also as an individual. She had learned to pick herself back up, every time she fell through the cracks caused by intimidation and fear of failure. I began to realize that it was more than self-motivation for Ana. It was her strong will to retain her Ana-ness and yet be successful, was a critical experience that informed her current dispositions to physics.

She works hard to constantly prove her place among the "competitive" community of "weird physics majors." Ana clearly explains her idea of "weird":

> It was weird at first. They are really competitive and I am not a very competitive person. I do things because they are fun to do. But once you kind of get used to that atmosphere, you realize that these guys are pretty cool and it is less weird. Now I really got used to this.

It sure was a big change for Ana. I remember Ana mentioning she was one of the four girls out of 24 in her high school physics class. The mostly male dominated high school physics class probably helped her gauge the kind of world she was entering, as a physics major. As a result, she was more accepting of the competitive culture of what she calls "weird physics majors." The support from her dad, chemistry teacher, and physics professors encouraged Ana to navigate through the competitive world of physics with ease and carve a space for herself as physics major.

Ana had strong dispositions toward the community of physics majors:

> Once you get physicsy minded people together, they suddenly turn into these weird people. They are like the jocks of science, I am so great. I am physics major. I am so cool. They look down on other sciences as well.

It was interesting to note that Ana was able to adapt to the community of "cool," "great," "jocks of science." According to Ana, who was ensured of success since a little girl, was she entitled to a spot among this elite group of physics majors.

Ana had learned to negotiate her space with more confidence, breaking the shell, and invading the world of physics.

> In high school, I was a really shy person. But college forces you out of that shell. Ever since that happened, I have been getting more confident with in myself as a person. I realized that stupid questions aren't really stupid, other people are wondering about the same thing. I think it is the posited syndrome, I am so dumb, and why am I here! But once you realize that I am not the only one that feels this way, then it kind of makes you feel better.

Ana had a great realization in that she reconciled her Ana-ness and physics by thinking of herself as part of a community with common problems rather than segregating herself from the culture of physics majors. This realization has allowed Ana to gain confidence to demand her space in the community as a female physics major when she says, "I feel that you are given equal opportunity, as long as you can show, you know what you are talking about. I don't feel there is a difference." In her words, she is not a "unicorn" anymore, signifying the special place she holds in the male dominated domain. In an assertive voice, she shares:

> I never noticed that I am a female in physics myself. It was this semester; I was sitting in, spectral calculus class. My friend turned to me and said there aren't very many girls in this class. I stopped to think about it. I just looked around and I could count them on my one hand.

It was interesting to notice that Ana never treated herself differently from her male counter-parts. Obviously, Ana is really not concerned with how she fits into the world. Females in general are keenly aware of themselves and their femininity. Nonetheless, Ana seems to be totally driven by interest when she says, "I do physics because I like it." According to Ana, the WOMAN in her does not define the kind of physics major she is, and therefore commands respect.

"It depends on who you are," was a strong statement that spoke volumes of Ana as a person. She has a strong will power and an urge to succeed. Ana, as a physics major, created a strong network of people who supported each other. In this small community, not only did she connect with people at a subject level but also at a personal level. The people in this group support each other educationally and emotionally:

> It is a really good support group. They are a group of people who are doing similar things as you. They are going through the same experience as you, so you can help each other out. Having upper class men too is really nice. Sometimes, I talk with my friends. This class is so hard. I don't know if I can deal with this. They would be like we know this is intense but we can get through this. Think of the end goal and what you are learning is really cool. May be we may not get all A's but we will be through it.

At that very second, I realized how important it was for me to create a learning community for my students to better prepare them for college. This could take the form of a physics Facebook page for my students. Social media is strong and must be used to our advantage as educators.

Wait…She is Our Guide?!

Although Ana hated the thought of being pointed out as a "unicorn" in the world of physics, times existed when she could not avoid what she calls as "stupid stereotypes." However, she has the courage to face such situations with confidence and command respect as a female physics major. Ana, with a big sigh, recollects one such situation, "I was learning how to use this telescope from this older guy. He was like wow, you are a woman! I was like yes, I am, is there a problem with that." The anger from being called out a WOMAN, evident in her voice was a clear measure of the self-esteem she had for herself. Ana confronted another such situation during her recent internship as a tour guide at the observatory.

> The looks of confusion that they would give each other at times to say, wait, she's our tour guide! I did actually have a few people say that to me, as if it were a big surprise. By the end of the tour, people were happy and thanked me profusely for all of the information that I gave them. I did get quite a few people cheering me on for being a female physicist, which was really cool. There was one guest who kept on trying to get me to admit that the Sun was causing global warming. He basically disregarded everything I said that was different from his very poor and misled understanding of science. He was probably the only guest who didn't take me seriously at all.

With great command over the subject and confidence within her, Ana was successful in breaking the traditional stereotype of a physicist as a "serious-looking old white guy." Although sad, it is important to note that, it is difficult for society to associate intelligence, especially in a subject like physics, with a WOMAN, when Ana reports, “Few people actually told me about how surprised they were that I was so knowledgeable about astronomy.” In one of the pictures (Figure 18), I noticed Ana sharing her experiences as a budding female physicist to encourage more female students into the field.

Figure 18. Ana with young children.

Ana is determined to break the stereotype:

> I was happy to hear that a few visitors were surprised to see a physics major as outgoing and expressive as me. I especially enjoyed shattering those stereotypes for the many young girls that went on my tours. I was happy to enforce the idea that anybody can become a physicist, and many girls that went on my tours responded to that. One girl, who was either in late elementary school or early high school, gave me a hug after the tour because I was excited and responsive to each of her questions. That really touched me and made me feel like I was making a difference.

Ana was so moved with the scenario, because she had become the inspiration for the young girl, like the female professor did for her. She not only doubted and questioned the awkward spaces that she confronted as a physics major; she is now inspiring other females to question existing paradigms. Even though no single, specific experience exists, society strongly believes in the idea that intellect and beauty cannot co-exist in the same body. In the past, society has promoted a single image for the ideal scientist: an old, nerdy white guy. Despite an increase in women and minorities entering the field, the age old idea of an ideal scientist still prevails in society. Young girls may see it as difficult or pretty much impossible to match up with the image of the "typical scientist," scaring them away from the field. Ana, who is friendly, approachable, yet knowledgeable, might help reassure other females to enter the male-dominated field of physics and still embrace their femininity. Instead of feeling shunned for being so dramatically different from what may be considered the norm in the scientific community, Ana dared to question this social stigma associated with a physicist.

The meaning of physics underwent several transformations for Ana during the course of her life as a student. It went from being fun hands-on experiments with supportive parents and enthusiastic teachers, to a sad jaded old man who discouraged his students from taking physics, to interesting petawatt lasers, to the breath-taking Milky Way, to failing grades, to acing physics. Physics took different forms and with it brought different mixed emotions. Ana went from being a strong young girl, to not believing in her abilities, back to being a strong advocate for physics. Today, Ana thoroughly enjoys doing physics. She is a strong proponent of physics for females and believes in seizing every opportunity that comes her way, to break existing stereotypes of physics majors, encouraging more females into the field. This enabling experience was crucial to Ana’s current dispositions towards physics. As a closing comment, Ana said without any hesitation, Physics in general makes me feel really proud of myself. Because it is hard and I know it is hard. I sit there and I struggle. But I am really doing science and even when I get a step closer to the answer, it just makes me proud as a physics major.

From Pencils to Pens - Lee's Revelation

"How long is this interview going to last?" my husband asked, dropping me off at the coffee shop. "Should not last more than an hour," I said, not knowing what to expect. My husband left to go meet his friend. I picked up some coffee and quickly settled down at an unoccupied table in the corner. It was 11:30 a.m. I was supposed to meet her at this coffee shop that she suggested. Just then my phone buzzed and a message popped. "I am here," she said. Involuntarily my eyes looked around. Because the coffee shop had free WiFi, several girls were at the tables with their heads buried in their laptops. "Where are you?" I asked as if I could not wait to see her. "Walking in," she said, right when I spotted her opening the door to the shop. A tall white girl in blue jeans and white shirt walked through. She had a denim jacket on, with at least ten buttons of different kinds pinned on it, and a cross body bag that said "DOCTOR MANHATTAN" on it. Her hair was dyed purple. "Vani! Hi...Lee" she introduced herself to me, shaking my hand. "Yes! Thanks for coming, Lee," I responded. Lee is a senior at a tier one research university in Texas. She is double majoring in radiation physics and computational math. She was introduced through a former student of mine who is also majoring in physics at this same university. I had emailed her a couple of times to introduce myself and my study, but never met her in person. Because the coffee shop was packed and noisy, we left for the university campus to do the interview.

In less than 15 minutes, we were in front of a tall white building. It was one of the buildings in the College of Natural Sciences that hosted the physics and engineering departments. We walked into a quiet room on the third floor. It was not a very large room. Two computers were on a table, right as we walked in through the door. A big white board was on one wall with some mathematical equations written on it. We sat at a large table in the center of the room with a few chairs around it. “I meet up with my study group here,” Lee explained, implying that she spent a lot of time in this room. We sat down on either side of the table with the audio recorder in between us. Reminding Lee of the purpose of my study, I turned on the audio recorder.

Lee was born in Opelousas, Louisiana. Since the state’s public education was not that great, she was sent to a Montessori school for her beginning years. Elaborating on her early school years, Lee says, “Montessori school is different. You're actively engaged with subject matter that you're learning. I did a lot of hands-on activities and always asked questions. We learned about instruments and art.” It was not until she moved to Florida that she was introduced to public school education. Lee remembers the time she spent playing with LEGOs, Bionicles, and video games that she thought were “marketed toward boys.” However, that presumption never stopped her from building interesting structures out of little parts. Lee unknowingly began to break the stereotypes, even when she was little.

It was in middle school when Lee was placed into the ‘gifted’ program. “I thought it was a really good fit for me. I was around people that were like me in personality,” she expressed as if she was different from the general population. When Lee was identified ‘gifted’, she was told indirectly that she was now special. Probably, this was a critical moment in her life that explains her pursuit to becoming a physics major. Society in general assumes physics to be the science for the intelligent.

Cool Scientist

For the first time, Lee fell in love with science in her eighth grade year.

> It was totally Socratic. Any question I asked, my teacher would answer with a question. So I was forced to think critically about what I was doing. We went out to the lake that was behind the school. We measured the pH of water, and then took couple of samples and looked at stuff under a microscope, and there were like little things swimming around in there. That to me was so cool. I always remember that.

Lee's little blue eyes grew big as she explained those exciting moments of doing "real" science for the first time. Teachers provided Lee with a thought-provoking yet nurturing environment, for her curiosity to grow and flourish over time. As part of the International Baccalaureate program, she was enrolled into standard level chemistry class her sophomore year of high school. Lee remembers that year as the best time of doing science in K-12 years.

> We did so much wet lab work, which I had never done before. I got to make aspirin in class. I liked my SL chemistry class so much that I took the high level chemistry with the same teacher. I just really learned to love chemistry and the idea of doing research. My chemistry teacher had a bigger influence on me than my physics teacher. We didn't get to do a lot of labs in physics. They were simulated labs in physics but actually working with chemicals was fun. I really liked it. I had a lab coat that had my name on it. So it was really fun. So that's when I made my decision to go into science in college.

Wearing the lab coat with her name on it made her feel like a "cool scientist." She enjoyed the prestige of a scientist, special and recognized by the world, which she was used to as a gifted child. Even as a little kid, she wanted to explore the nature around her. Lee's immense interest in exploration became the impetus for her becoming a physics major.

Lee pulled out a book (Figure 19) from her bag. The book cover read “WATCHMEN.” Lee placed the book on the table. With a big bright smile, she says,

Figure 19. The watchmen book.

> I bought this comic in high school, and it really sort of propelled me. Dr. Manhattan is a nuclear physicist during the time that the Manhattan Project was around. That's why he was called Dr. Manhattan. He was in an accident that basically altered him, and now he's blue, and he essentially can do anything. There's a lot of stuff between chapters about Dr. Manhattan, his research, and the science behind what he's doing, and nuclear stuff. When I was in high school this was really cool. He is still one of my favorite super heroes.

‘Dr. Manhattan’ explains Lee’s special interest in radiation physics. Lee displayed pens and buttons that she collected as a mark of admiration for her super hero.

Although Lee loved chemistry, because of her chemistry teacher who allowed her to explore the world through experimentation, she decided to specialize in physics which offered a similar opportunity. Unlike chemistry majors, freshmen physics majors were invited to do research in various areas. However, this opportunity “was mostly for students who achieved a decent amount in high school,” and Lee was among them. Research was always central to her love for science. With no hesitation, Lee said “Yes” to a major in physics. As a physics major, Lee enjoys contributing her knowledge to the world of physics through her research projects. She developed a personal online blog named, "Probability, Possibility: Musings of a (Pseudo) Mathematician" in which she shares her knowledge on different physics concepts, emphasizing the underlying math concepts to the world. Lee shared her resume which reflects the immense amount of work she has done as a budding physics and math major.

Lee perceives chemistry as a specialized branch of physics and therefore recognizes more career options as a physics major. In response to a frequently asked question by several high school students: What can I do with a physics major other than teaching? Lee highlights some of the skills on her resume, "My majors have prepared me with technical skills such as data analysis, nuclear engineering physics, technical writing, and programming in a variety of languages." With all the different skills, Lee has gained as a physics major, she is assured with a bright and successful career.

Receding into a Shell

Lee enjoyed reading books as a little girl and this interest grew with her. Her desire to pursue physics came from her interest in philosophy. Entering high school, she began reading more books on philosophy and reasoning in search of answers to her questions.

> In tenth grade I read *Das Kapital* by Karl Marx and *The Communist Manifesto*. A lot of people didn't like that. I was in Texas at that time, if you even read anything about that sort of thing, they call you names and stuff. So I just kept a lot of what I learned to myself. It really taught me logic and gave me a fundamental understanding of how the world works.

Lee recognized that she was not fitting into the existing surroundings. She began to question the surroundings. With her revolutionary ideas, she broke the mold of a WOMAN. That posed a threat to the existing paradigms and therefore the 'name calling.' It was an attempt to silence her voice. With no one to stand by her, she learned to silence her voice by receding into her shell. Afraid of ridicule, she kept her opinions to herself, which made her lonely. The quest to find answers to her philosophical questions from reading the books "by Jim Al-Khalili, and Carl Sagan, tailoring toward the physics of the universe," explains Lee's interest to major in physics. But the intimidating experiences had a profound impact on her self-efficacy as a physics major.

Today, after many years, Lee calls this the "struggles of an introvert." On her personal blog, Lee writes,

> I got to know a good number of people this week; you really get to bond with others when you're under a lot of stress and in an isolated environment such as this. My world became pretty insular in that regard and I spent almost every moment of my day around these people from the time I woke up, to when I went to sleep. I of course made time to spend by myself, and I did this by going on long walks fairly late into the evening every night. I did this so I could feel refreshed the next day, and so I could handle all the social interaction I knew I was going to be doing tomorrow.

As much as Lee acknowledges the need for networking to survive in this world, she also reflects on her wanting to recede back into her shell that she has carved for herself; an introvert. Lee probably is searching for new answers to her never-ending questions in the silence of being an "introvert."

Lee recollects her first encounter with physics majors,

> When I mentioned, I wanted to do physics, this guy just started talking about everything he learned. Oh yeah, I think the Higgs Boson is such a cool thing. The Higgs field is such a mysterious like thing. We don't know much about it. It was just so hard to engage

> in a conversation about my interests, because I felt like there was just so much I didn't know.

The guy was intimidating Lee, reminding her that physics was a male domain. She felt lonely and *othered* in this new world that she says was “pretentious.” The male intellect silenced her FEMALE voice, shattering Lee’s self-esteem as physics major into pieces when she helplessly says, “I didn't even know what that was.” She sadly calls it as “the knowledge gap.”

Another significant experience that influenced Lee’s disposition towards physics was when she received the feedback for her first formal lab report. It was the first lab report she had written in college. Not knowing what to expect, she turned it in for feedback. The teaching assistant was a male physics graduate student. Lee, sharing a part of his feedback, describes it as “harsh, rude, and not a constructive criticism.”

> You need to justify this assumption. What you have is circular logic. So while it is a plot it adds only a little understanding. Avoid broad sweeping statements like consistent with classical literature, it makes you sound vague and doesn't add anything for the reader. One acquires data, extracting sounds funny. Your end result here is very underwhelming. The real kicker is that you say this is confirmation of Schockley's equation but this says NOTHING about saturation current!

Lee, identified as gifted very early on, never faced a harsh criticism like this one. Like most gifted students, she was probably a likable student for all teachers. Suddenly, her intellect was questioned by the male TA. The sarcasm in his comments: “circular logic,” “sound vague,” “sounds funny”, “underwhelming,” “real kicker,” and “says NOTHING”, damaged her morale and challenged her place within the community of physics majors.

Building an Empire

Presenting the cross body bag (Figure 20) she said, “My brother presented this for my birthday in tenth grade. I have been using it since then,” says Lee, looking at her bag. The image on the bag reminded me of the part of the story that Lee narrated from the Watchmen book, explaining the symbol on Dr. Manhattan’s forehead.

Figure 20. Dr. Manhattan bag.

> The government tries to harness Dr. Manhattan’s ability for the Cold War. They try to make him wear a uniform for a propaganda type figure, and they make him wear a helmet with a symbol of an atom symbol kind of like this. But, he's says, If I'm going to wear a symbol, I'm going to wear something that I respect.

Dr. Manhattan’s decision to wear a symbol of respect was significant for Lee, in her choice to major in physics. Regardless of her abilities and drive, Lee was perceived only as a WOMAN and forced to silence her voice. Therefore, she decided to embrace her superhero, Dr.

Manhattan and bear the prestige of a physics major. Lee accepted the responsibility of her success. Subsequently, she *othered* the part of the pretentious community that *othered* her, building an empire of her own. She avoided every situation that intimidated her including the professors, whose intellect she adored. She says that the professors were pretty much "non-existent" for her.

Lee began to build an empire of her own. She called it a study group. Anyone was invited into this new territory. No king or queen ruled this empire. Age or area of interest was not a barrier to join the group when Lee describes, "Two of them are military vets, 29, 31, and another one is 24. But he was a philosophy major for a long time. Another student is 28." People respected the differences among the members and lifted each other's spirits when they were down. Everyone in this new space had an equal opportunity to succeed. They all had a voice that was appreciated and valued. With pride, Lee says,

> My study group is my friends. I look up a lot to my friends and peers that I work with. They strive to be the best that they can. That really inspires me to be the best that I can. We help each other and we want each other to succeed. I want to be like them in the sense that I want to be passionate about what I'm doing, and really put myself out there, the go get 'em attitude.

The encouragement and support that Lee received from the new empire became the driving force for her as a physics major. Her attitude towards physics majors and physics in general transformed as a result of this support.

Walk Over Mistakes

Lee was taking two math classes and two physics classes one semester. One of the physics classes was "Waves and Optics." It was the first physics class that she thought was difficult. Lee never had to work extra hard for a class up till then. Remember, she is identified gifted and therefore failure was out of the question for her. Despite more time being dedicated to her most demanding math classes, Lee thought that she would be able to pass ‘Waves and Optics’ easily. However, Lee experienced failure for the first time. “I didn't pass the course and that was like never. I've always been a high achieving student. That's never happened to me before,” she says. At that moment, I was Lee. I remember it was my eleventh grade year in high school. I was shaking in my shoes. “Vani,” Mr. Sharma called. As much as I did not want to hear my name, I walked to his desk. Wiping of my sweat-drenched palms, I quickly grabbed the paper from his hand. Fifteen out of 50, it said on the very top in red ink. I walked to my desk and broke into tears, a similar pain that sounded in Lee’s voice.

Society always directly relates one’s giftedness to his or her intellect. When a gifted person fails, the failure is attributed directly to his or her intellectual abilities more so than other factors. Unable to take the failure, like most other gifted students, Lee decided to drop the physics major when the support system that she established came to her rescue. They cheered her up and supported her as they understood what it was like to fail because of similar experiences they shared.

Lee placed a magazine of Wonder Woman (Figure 21) on the table. “I also have this button,” she said, pointing to one of the buttons (Figure 21) on her jacket, it was the picture of a lady saying “Never under-estimate the power of a Woman!”

Figure 21. Wonder Woman magazine and pin.

> She's super powerful and can do anything she wants. She always tries to see the bright side of situations. She does extraordinary things all the time. I obviously don't want to be like beating people up and like fighting. So, look up to Wonder Woman a lot. Anytime I am stressed out, I ask myself, what would the wonder woman do?

It was obvious that Lee perceives herself as a wonder woman, majoring in physics. Failure for anyone is a harsh reality, especially for a student like Lee, who was identified gifted all her life. Not only did Lee accept failure, but came back and continued as a physics major, making her a wonder woman. With the support of friends that cared, and the encouragement from Wonder Woman, Lee retook the course and made a B+ which was a highly rewarding experience that re-established the relation between Lee and physics. This was more than just a grade; it was a measure of her self-confidence when she claims, “I feel a lot better now in my abilities to succeed. I know I can succeed.”

Remembering the extra pressure that she took on herself to prove her place among peers, Lee laughs, “I felt this pressure that I had to perform well to prove that I knew just as much if not more than my peers. I wanted to let them know that I am a physics major like them.” Lee has discovered her new self and established a new place for herself as a physics major. She has not only redefined her position as a 'Woman' in a male domain but also in physics, when she says, "I was reading astronomy based physics and cosmology because of my interest in philosophy, but now I like the math involved in different aspects of physics. I appreciate it differently. I think semiconductors are cool now." Lee is now confident and ready to take on new challenges. Right as we were about to leave Lee handed me something that looked like a pencil holder (Figure 22).

Figure 22. Lee's pencil holder.

The holder had two pens in it. She confidently said,

> I always used to have pencils in here. I used to erase my mistakes because I didn't want others to see them. Now I have pens in it. I don't care anymore. I am not afraid to simply cross out my mistakes, walk over and move on.

Cross-Case Themes

As I started free-writing around the journeys of Valeria, Ana, and Lee, several questions began to come up. What is special about these ladies? What is common among them? How are they different? Were they just adapting to the existing cultures in these elite social circles of physics majors? How were they adapting? I felt my head exploding with thoughts. Consequently, I decided to have a dialogue with my peers. "They definitely were not simply adapting, Vani. I think it is much more than that. Dig deeper," advised my scholarly friend. After the peer review, I spent hours, reflecting and reorganizing my thoughts. Upon free-writing around the similarities and differences noticed in the experiences shared by the three participants, the fog slowly began to clear up. In the following section, I present the three broad themes which emerged from the cross-case analysis.

Carving New Spaces

I realized that these female physics majors in a non-traditional setting are individuals that dared to question and doubt their positions in the existing spaces. The process started with them questioning: What is this? Why did he not want to work with me? Why do they not want me in their group? Why are they not listening to me? Why can't I learn how to use a telescope? When searching for answers like these and many more, they began doubting their spaces. They now asked the questions: Is this really the way it is supposed to be? Says who? I belong here-how can I fit in with others? Resulting in anger and frustration, the strong doubt transformed into intrinsic motivation in these females, driving them forward to pursue exclusive and male-dominated fields such as physics.

Valeria began to doubt the spaces early on as a little girl, when she wondered about her dad. She did not understand why she had to clean dishes when the boys in her family were reading books and doing homework. She began to wonder why her uncle was unhappy with her, and why her mom would not encourage her when she excelled academically. To her dismay, Valeria's male counterparts and professors questioned her intellect in study groups and college classes. Sadly, she had no one by her side to stand up for her. Valeria did not meet the needs of a WOMAN for her family, nor did she meet the requirements of a physics major for her male counter-parts. She miserably "dated a different person each semester to feel complete. But it did not work out. They had strong opinions and did not want to listen to me." Valeria was stereotyped, humiliated, and silenced, in several situations at home and at school. In the words of Beauvoir (1989), she was *othered*.

Othering is a process of identifying oneself or another person as different from the mainstream, thereby creating positions of domination and subordination (Beauvoir, 1989). Valeria struggled to define her space and herself, as a Hispanic female and as a female physics major. Naturally, as her existential self was suffocating, she went into depression. At this point, she had only two options: to die or to adapt. To die for Valeria was to accept the role assigned to her by tradition and to agree with the fact that intellectuality was a male domain. The refusal to surrender herself to the worldly definition of WOMAN resulted in a critical moment of questioning her role. She chose to survive the tension posed in a non-traditional setting of physics majors to redefine her space for her family, her cultural heritage, the world, and mainly for her dying existential self. As a result of this struggle, Valeria successfully carved a new space for herself in which she grew as a person and as a physics major. She learned to be more "self-sufficient." She assumed multiple faces to negotiate her space among physics majors. She learned to better appreciate and enjoy doing physics, actively and proudly, contributing to the field through her research work.

Unlike Valeria, Ana was raised in a protected culture where success was assured. Her father, who had better ambitions for his daughter than a kitchen, raised her to challenge her boundaries. The little worksheets of basic math concepts made by her dad, the inspiring speech by her chemistry teacher to "stick with it," and the words of wisdom from her physics professors gave Ana the confidence to see the hurdles in her journey as small "hiccups" that she could easily surpass. Her choice of words when describing self: princess, scientist, awesome, and unicorn clearly shows that she always perceives herself as special. She never viewed herself differently from her male physics counter-parts, until someone pointed it out to her. She encountered the circumstances with a positive attitude. She pretty much felt entitled for a spot among the so called elite group of physics majors. Ana was never *othered* because she never viewed herself as the *other*. The word WOMAN never silenced her. Ana stood up for herself and demanded her place as a female physics major. When she experienced failure for the first time she questioned her existence among the elite, but her strong self-image never allowed her to accept defeat. The tension to gain back her spot among the elite group became the critical moment for her to thrive as female physics major.

Lee did not begin to doubt her space until she was in high school. As a child, Lee was identified intellectually gifted. However, with neither one of her parents having attended college, they could not support her much in her unique interest for science. She explains, "I really did not get pushed to do science." As a teenager, Lee was in constant search for answers to several existential questions that stemmed from her interest in philosophy. But she was forcefully silenced; she was too smart to fit the grand narrative of a WOMAN. That was the first time she began to doubt the spaces around her. With no one to support her, it was difficult for her to question the strongly inscribed norms of the society. Helplessly, she receded into a shell, calling herself "an introvert."

Lee's immense interest in philosophy paved the way for her to major in physics. But once again, her "pretentious" male counterparts silenced her for the same reason: a WOMAN in a male domain. To her surprise, Lee, who was always a gifted student, suddenly experienced failure, compelling her to question her space as a physics major. She attributed the failure to her intellect, which is often the case with gifted students. It was almost impossible for her to believe that failure could ever touch a gifted female like her when she repeatedly says, “That had never happened to me.” It was a “devastating” moment for Lee. As much as she wanted to quit, she chose to fight her defeat. Breaking the shell of an “introvert,” she began to build an empire. In this new space, she rediscovered her true self, growing stronger day after day. The desire to prove her space to herself and to the world around her became the impetus to her pursuit of physics.

While Ana wanted to prove her position within the elite group of physics majors by acing tests and passing her courses, Valeria and Lee wanted something different. Valeria says, “I wanted to feel better about myself,” meaning she wanted to prove her self-worth to the world within her dying existential self, whereas Ana wanted to prove it to the external world of physics and win back her special spot. Lee wanted the best of both worlds; she wanted to prove to herself that she was truly gifted while showing the physics world that nothing could stop her from becoming a successful female physics major. Regardless of their varying childhood and college experiences, Valeria, Ana, and Lee, had one trait in common; the strong will to doubt and question their existing spaces as female physics majors. As a result, these females changed the paradigms by carving new spaces. They created their own groups of like-minded people, in the form of study groups or as student run organizations. In these newly carved spaces, people supported them by lifting up their fallen spirits, cheering them on, sharing stories of success and failure, and reminding each other of the common goal they have ahead of them.

Authoring an Empowered Self

Each one of the three participants: Valeria, Ana, and Lee, chose to write their own stories in which they owned the main characters. Regardless of how the society defined their roles, in terms of what they could or could not do as females, they took the ownership of who they wanted to be. These three strong females refused to play the character of a helpless WOMAN, passively accepting the roles assigned by tradition. They recognized that success was the best revenge when Valeria says, "I want to show my family and others that I can do this, even when they did not support me." However, it is important to note that the success of these women was not an accident; they challenged themselves by becoming active authors of their own stories as female physics majors. Each of these women chose to use their success stories to break the gender and cultural biases existing in the society.

Although the experiences of failure and abandonment temporarily silenced their voices, it provided them the opportunity to grow stronger as individuals and question their roles as female physics majors. As a result, they discovered their true selves and changed their circumstances. Valeria, who once struggled with low self-esteem, is now working as a teaching assistant for the department of physics, providing assistance to her peers in various topics. Recalling those moments of how she regained her confidence,

> I was afraid to ask questions because I didn't want to be the annoying, stupid person in the class. But once I started asking my peers about concepts that were unclear to me, I realized that they were as confused as me. Then, I started getting help from graduate students and my professors. Some professors are so smart that when you ask simple questions, they scoff at you. This was discouraging at first. But at some point I stopped caring and thought that was kind of the norm, besides it helped me deal with difficult

> people. I became more aware of my limitations. This helped me prepare myself to the point where I was able to discuss and even teach these concepts to others.

Ana's and Lee's failures did not stop them from pursuing physics either. During the process, they in fact recognized failure as a step closer to success and therefore redesigned pathways to reach their goals. They learned to reflect on their personal strengths and weaknesses, revising their roles as empowered authors of their new life stories. Remember, the knowledge of their male counterparts intimidated Valeria, Ana, and Lee so much they almost wanted to quit as physics majors. But very soon they recognized that with perseverance and hard work, they were on par with their peers. Valeria proudly says,

> In the past, when people did not appreciate me, I thought I was good for nothing. But now I really don't care for others. I learned to appreciate and feel good about myself. And now, my peers see me as one of the more intelligent and humble people.

Lee looks back with a smile at the course she failed, "I thought I got it all. I did not know enough in-depth to what was expected. But I knew I could do it. I just had some catching up to do." Today, Lee tutors young kids, predominantly at high school level in math, physics, and chemistry, explaining complex concepts using non-technical vocabulary. She shares her knowledge of physics and math with the world through her online blog. Lee is currently serving as the president of a student-run organization called Undergraduate Women in Physics, where she supports and mentors other females in physics. Ana is a strong advocate for women in physics. She says, "I don't like to be pointed out that I am a unicorn. I am a female in physics. So what? Does that make a difference? I am a smart person that likes physics and I enjoy doing it." She has stronger self-esteem as a physics major and can stand up for herself at any point. Her goal is to become an educator in hopes of encouraging more female students to choose

STEM fields. Ana, by sharing her knowledge in "bubbly and enthusiastic ways," wants to prove to young girls that "they don't have to be nerdy white guys in order to enjoy physics." She is a strong proponent of retaining her fun-loving self and yet through her intellect, demand her space in midst of the "weird" physics majors.

Show Me You Care and So Will I

Ana recalls the inspirational words of her high school chemistry teacher, "You can't give up on things in life because they're hard. You just work through it and in the end you will be a bigger person for it." These strong words from a strong lady marked Ana's journey as a physics major. She had an encouraging dad, who taught his daughter that setbacks you face in the process of learning are just little "hiccups." They can be overcome through hard work and perseverance. The "homemade sheets" of math problems that her dad made and the encouraging words of her teacher to "stick with it, no matter how hard it gets," made her to realize that she "does not have to be a genius to be successful as a physics major." The stories of successful female role-models such as her physics professor reassured Ana that she was not alone in this often intimidating journey of a female physics major. Ana recollects the inspiring story of her professor's journey to becoming a female physicist,

> She told us that she was not strong in physics to begin with. But she kept going with it. She gave up quite a bit and was dedicated. Today, she does cool things and she loves what she does. She is a cool lady. I definitely look up to her.

This success story gave Ana the confidence to stand up for herself and create a space in the so called male dominated realm of physics.

As a little girl, her older sister was a major figure in Valeria's life. Her sister "worked hard at school, made good grades, and was extremely helpful and nice to others. So, people always liked her." Valeria aspired to be "like her sister one day." In high school, Valeria looked up to her dedicated and loving female physics teacher who believed that "any one could do physics if they were interested in it." She encouraged her students to share their opinions on physics and discussed with them their career options in physics. Valeria recalls, "She recognized that I was good at math. She encouraged me to focus on physics and may be going into engineering." She recalls doing "several engaging projects and labs" in high school that helped her to see the often abstract phenomena in physics, making it more tangible. Recalling several intimidating experiences when talking to male professors, Valeria suggests, "Teachers should be open to their students' questions without making assumptions about their knowledge."

On the contrary, both Lee and Ana had discouraging and disengaged male physics teachers in high school. Despite her love for physics which stemmed from various hand-on activities that she did with the "amazing middle-school science teachers" such as building rollercoasters and hot air balloons, she had second thoughts about a major in physics beyond high school. Ana strongly associates her hesitation to major in physics with her physics teacher, a "sad jaded old man," who often asked them to "think twice before making that choice." However, the irresistible "petawatt lasers," the opportunity to do research, and the "humbling experience" of coming close to the Milky Way, could not stop Ana from majoring in physics.

Lee's love for science started early on in middle school when she "noticed the little things swimming under a microscope" for the first time. This passion for "doing" science enhanced because of a highly dedicated and engaging chemistry teacher she had in high school. The experience of being a "cool scientist" doing "wet labs involving actual chemicals" furthered her interest in science and research. Lee with a glee narrates,

> She taught like a lot of my professors here do. She went up to the board and talked at us a little bit, and then we would start working on stuff. If we had a question we would have to go up to her and ask. She didn't hold our hand through it. She was just very affective at lecturing and very engaging. I just spent a lot of time in her class doing labs after school. She was very flexible with her hours and really made an effort for her students.

However, Lee's immense interest in philosophy encouraged her to choose physics over chemistry. But she, like Ana, had a disappointing high school physics teacher. Lee recalls,

> I did not have a great teacher for physics. He taught from a PowerPoint and didn't really elaborate much. He would just go over key concepts. The labs we were supposed to do to understand the concepts were not interesting. They were mostly simulations. My teacher didn't play as active role like my chemistry teacher. Maybe if he did, I would have been more confident to definitely physics. I was pretty uncertain, and I was really big on chemistry to begin with."

But her strong desire to study the physics of the universe, from her background in philosophy, along with the rare opportunity to do research in astronomy as a freshman, an added incentive, attracted her into the program. For Lee, it was the inspiration that she had gained from her peers who were majoring in physics, allowed her to choose physics over chemistry. Lee recalls,

> My peers and the people in my research stream that were doing cool things inspired me the most, not really the professors. I wanted to do cool stuff like them and be able to inspire others. So it was really like meeting new people that had interests similar to mine is what kept me in the program.

Today, the same inspiration continues from their end. Valeria, working as the outreach coordinator, says, “I usually tell girls that if they're interested in physics, they should have nothing to stop them from doing it.” Drawing from the positive interactions with her physics teacher, she says,

> When I teach, I will engage my students in the rewarding experience of solving and understanding complex problems. I will connect with my students at all levels, so that they can trust me not only with academics, but also with their personal struggles.

Lee, planning to work with at-risk populations, from her experiences with “often unapproachable” physics educators states,

> If I was a physics teacher, I would be more mindful about how I engage with physics and how I appear to be experiencing it. Young girls want role models that they know. Historical figures are great, but they're far removed from lives of people in the modern age. A known, tangible woman actively displaying interest in physics is more apt to help encourage more young women to pursue their interests in the field.

Lee, through the outreach programs (Figure 23), continues to solicit young girls into STEM fields.

Figure 23. Outreach activities with young girls.

Ana agrees with Lee when she shares, “I think that watching young, enthusiastic female share scientific information with them in an engaging way can be invaluable to young girls.” Therefore, it is certain that the positive role models that inspired them and that they, in turn, aspire to be encouraged the three young ladies in their pursuit of physics.

Discussion

The stories of these three female physics majors: Valeria, Ana, and Lee were unique in their own ways. It was a challenge finding similarities and differences between these three participants. I evaluated their stories with my peers, and wrote around the prompts for hours in search of answers to one major question: What did I learn from this study? That is when I was reminded of an old parable of a boy who struggled with school. He failed several of his classes. His friends bullied and ridiculed him. He was frustrated with school. One day, with tear-filled eyes, he tells his grandpa, “I just feel like quitting. School is not fun.” The grandpa, hugging the little boy, says, “I understand. Why don’t we do a little experiment at home today?”

“That sounds like fun,” says the little boy.

The grandpa placed three pots on the stove. He poured equal amounts of water in them. Once the water was hot, he added some carrots in one pot, few eggs in another and some coffee beans to the third. After few minutes, he dished out the carrots, the eggs, and coffee into three separate bowls. The little boy silently watched the entire process.

“What do you see?” asks the grandpa, turning to the boy.

“I see carrots, eggs, and coffee. Is this a trick question?” asks the little boy.

“Feel them,” says the grandpa.

The little boy touches the carrots and feels that they are soft and mushy. He breaks and senses the hard-boiled egg. He smells the aroma of the fresh coffee.

"What are you trying to say?" asks the little boy in confusion.

"The carrots, eggs, and coffee beans were exposed to the same adversity, hot water. However, they each reacted differently. The carrots, which were initially hard, turned soft and mushy, while the eggs hardened. But look at the coffee beans; they turned the hot water into coffee," he said with a smile.

I am not sure if the little boy understood what his grandpa implied, but I think this analogy is apt to interpret the experiences of these participants. The experiences are always neutral, but how you interpret the experiences determines your reaction toward it. Valeria chose to soften like a carrot, struggling with anxiety and depression; Lee chose to be an egg with a hardened heart, drifting away into the shell of an "introvert," while Ana, on the other hand, chose to be the coffee beans that changed the adversity itself, by challenging the stereotype of a physics major.

While Valeria and Lee initially had a negative attitude toward their experiences as female physics majors, Ana approached such experiences with a positive attitude. As a result, she never saw herself differently from her male counterparts. Ana commanded respect for who she was from the very beginning of her life as a physics major, while Valeria and Lee struggled with their dying existential selves. The constant encouragement and support of her dad and her teachers helped Ana develop a positive attitude toward life in general. She quickly understood the norms of existing social structures within the world of "weird competitive physics majors" and adapted to the change. Eventually, she became a part of this culture when she says, "It is not weird anymore." Her confidence grew with time to where she is now planning to change the circumstances itself; the culture of physics majors. Recall, she chose to challenge the societal assumptions of a physics major with her knowledge of physics, still keeping her Ana-ness alive. Sharing her experience when working as a tour guide at the observatory, Ana says,

> I feel like any doubts they had about my intelligence were put to rest as soon as I started talking about science. Many visitors complimented me on the depth of knowledge I had. They remarked on how surprised they were to see a physics major as outgoing as I was.

Valeria and Lee's intimidating childhood experiences did not allow them to adapt to the culture of physics majors easily. However, their desire to prove themselves as physics majors to their own selves and to society challenged them to change their circumstances, by carving new spaces comprised of people with similar interests. These new circumstances helped Valeria and Lee to thrive as physics majors. They learned that when they could not change the circumstances, they had to change themselves, and they did. Talking about her reaction to comments of a male TA, Lee says, "The comments were harsh. But, you know what, I needed a good grade. I took his criticism positively and redid my report. I got the best grade."

The self-efficacy of these female physics majors began to improve as they learned to interpret the experiences positively. Their success stories are testimonies that embracing a positive attitude toward one's experiences takes perseverance and hard work. They learned to expect difficulties and so were not afraid and defeated when faced with problems, but viewed them as part of the natural course of events. Valeria, Ana, and Lee agree that physics is difficult but talking about the support groups they created for themselves, they are confident that they can do this together. Lee shares, "I feel a lot better in my abilities to succeed because my friends in my study group know that I can succeed, and I know I can succeed. Those are the only opinions I consider and care about." They recognized that the harder they worked to sustain a positive interpretation, the more they appreciated physics and their role as female physics majors.

None of the three female physics majors chose their experiences of failure and defeat, but they definitely did choose how to respond to it. They realized they were not reacting to the situation of abandonment or failure itself, but to how they made meaning of those experiences. As a result, they understood the experience better. Lee, who once called her male peers “pretentious” now says, “ I now have guy friends that are totally cool, but it was like that freshman year, looking back, when everyone was trying to project that they know more than they did.” Lee’s opinion of her male peers, as dominating when describing her experiences of being “talked over” during conversations, is now understood by her as an equal struggle for everyone to fit into the existing social circles. Her attitude toward physics majors has changed as she approached the experience differently. Valeria, now is confident when interacting with her male counter-parts, and says, “I am the one that answers most of the questions.”

The life of these three physics majors is testimony to their potential to turn defeats into triumphs and to turn one’s predicament into an achievement. Valeria, Ana, and Lee are the role models for struggling female physics majors or for females hesitant to pursue physics, inhibited by the view of it as a male-only-domain. Lee says reassuringly, “I want to tell the world and other female students that physics is really hard. But it's not impossible. There is no math gene, and there is no intrinsic genius to physics. It's all hard work, every bit of it. And if you put in the work, you will see the results.”

Summary

In this chapter, I have presented the findings of the multiple case studies as three individual narratives: Metamorphosis - Valeria’s Comeback; Ana’s Magic - Stick With It; From Pencils to Pens - Lee’s Revelation. The narratives are composed from chronologically organized critical moments in the participants’ lives, which led to their interest in, and pursuit of, physics.

Three major themes that emerged from the cross-case analysis between the participants: (a) carving new spaces, (b) authoring an empowered self, and (c) show me you care and so will I, are also represented in this chapter. The discussion completes the chapter by securing all lose ends in the co-constructed meaning making process between my participants and me.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

Every story must have an end. It is now time for me to conclude this journey by answering the most important question for a researcher: So what? Recall, the purpose of this study was to explore how the educational experiences of female undergraduate physics majors contributed to their current dispositions toward, interest in, and pursuit of physics at a large southern research university. The specific research questions that guided the study were:

1. What are the critical moments in all of the educational experiences of female undergraduate physics majors that contributed to their interest in and pursuit of physics?
2. What college experiences of the female undergraduate physics majors contributed to their current dispositions to physics?

As a physics educator, I have constantly aspired to encourage more students to pursue science, especially physics, beyond high school. In this process, I always wondered, what was it that attracted me to this field? Was it my parents who constantly supported me to follow my dreams? Was it the scientific environment that I grew up in? Was it that first failing grade of 15 that I made on my high school physics test? Or was it that 97, I scored on my Mechanics test? I never could explicitly say which one of these experiences contributed to my pursuit of physics. There is an element of choice attributed to human behavior which is defined by society and cultural norms. Through these personal choices and interpretations, people formulate new meanings and decide upon future actions (Handberg, Thorne, Midtgaard, Nielsen, & Lomborg, 2014). The unique stories of my participants helped me recognize that it is not one, but an amalgam of many experiences that motivated me to pursue physics. In the end, I had a choice to make that dictated my future. Physics was defined and redefined as I encountered it in a new situation. The fresh interpretations of new interactions generated new personal meanings each time. It is through this cyclical process, I discovered my *self* as a physics major (Blumer, 1969; Carlson, 2013; Milliken & Schreiber, 2012). The interactions with and interpretations of my participants' experiences helped me to revive my role as a vested science educator.

In this chapter, I conclude the study by answering the research questions and connecting the findings of the study with the theoretical framework of SCCT. I suggest possible implications for the major themes presented in Chapter IV, for the science in STEM education, and also provide suggestions for further research.

Conclusions

Close examination of the learning experiences of the participants, analytical findings, and conclusions support the framework of SCCT (Lent et al., 2002). SCCT (Lent et al., 2002) provides a framework for understanding and explaining the ways in which the participants developed dispositions toward, interest in, and pursuit of, physics. The SCCT model (Figure 3) suggests that an individual's educational interest and pursuit depend on four interrelated variables: personal factors, environmental factors, self-efficacy, and outcome expectations (DiBenedetto & Bembenutty, 2013; Zhu, 2007). Self-efficacy, a person's belief in his or her ability to perform a task, is constructed through the integration and interpretation of four major aspects: experience of success (mastery experience); learning from watching successful people (vicarious experience); feedback received from others (social persuasion); and their own feelings involved with pursuing a task (physiological arousal) (DiBenedetto and Bembenutty 2013; Zhu, 2007). People constantly evaluate their choices against outcomes in the form of other people's behavior toward them (Bandura, 1986). Learning experiences constituted by different personal and environmental factors contributed to the participants' beliefs of self-efficacy and outcome expectations. These developed self-efficacy beliefs and outcome expectations played a significant role in enduring interest and encouraging their choice of physics as an undergraduate major.

Research Question 1

The first research question sought to find the critical moments in all of the educational experiences of female undergraduate physics majors that contributed to their interest in and pursuit of physics. Granted, all four types of learning experiences mentioned above influenced their overall dispositions, interest in and pursuit of physics, the direct experiences of learning science at a young age and social persuasions in particular were found to inform my participants' interest in and pursuit of physics. Ana and Lee, as young girls developed a passion for learning science because of the experiences presented to them, both at home and school. They could recall several critical moments in their K-12 experiences when they were actively engaged in learning science through hands-on activities and projects. These positive learning environments successfully connected science with real life, making it more authentic and meaningful to them, encouraging them to see it a possible career choice. Ana and Lee's interactions with science dated back to early pre-school years when they played with "skeleton toys, LEGOs and Bionicles." Lee learned to appreciate the idea of doing research by performing "cool" experiments such as "testing pH levels of water samples collected from a neighborhood lake and by "making aspirin" in her high school chemistry class. Lee says, "We took couple samples of water and looked at it under a microscope. There were these little things swimming around. To me, that was so cool." Lee, because of her immense interest for reading philosophical books, learned to appreciate physics for "logic and a fundamental understanding of how the world worked."

Ana enjoyed the creative aspects of science by building rollercoasters and hot air balloons in her middle school science classes. She states, "I do physics because I enjoy doing it." Both Ana and Lee enjoyed the prestige associated with being a "cool scientist," building confidence in their abilities to pursue it. Ana's and Lee's interest in physics can be directly attributed to their experiences of actively interacting with science during their early childhood and adolescent years.

On the contrary, Valeria, growing up in Mexico, was disengaged from science due to a lack of encouraging learning experiences. She explains, "If I had stayed in Mexico and had gone to college, I would have done art history and Spanish literature, or economics." It was not until she moved to the United States; she was authentically engaged in doing "a lot of labs and engineering projects." Valeria started encountering science outside a traditional classroom by participating in a science decathlon and science UIL activities. As a result, she began to appreciate the nature of science, especially physics. Citing an example for how much she enjoyed doing physics, Valeria says, "It would take 12-16 hours to do each of the problem sets in physics and I didn't mind spending all that time, because I really enjoy it." Valeria's strong math skills facilitated her success in physics. These experience of continues success in physics improved her self-efficacy. As a result, she developed an interest for the subject which later informed her pursuit of physics. It was interesting to note that all three participants addressed learning physics as "doing physics," meaning, the participants perceived physics as being tangible and hands-on. This finding largely differed from the ideas presented in earlier studies in which females found physics to be more abstract and not connected to real life, thereby losing interest in it (Allaire-Duquette, Charland, & Riopel, 2014; Semela, 2010; Zhu, 2007). The positive perceptions of my female participants can be strongly attributed to the pedagogical practices of their science teachers.

Social persuasions in the form of feedback they received from others such as family members, teachers and peers influenced the self-efficacy of the participants which in turn governed their interest in and pursuit of physics. Ana, as a young girl, was constantly supported and encouraged by her parents, especially her dad, to pursue science. When she had difficulties learning math, her father made worksheets for her to practice, encouraging her to persevere in spite of setbacks. The high school chemistry teacher's commitment to science and her strong advocacy to stick with it, encouraged Ana to pursue science beyond high school. Lee who was identified gifted early on "was liked by her teachers." However, growing up, her "parents played a pretty passive role in the development of her interest for science." The experiences provided by her "dedicated" high school chemistry teacher who always made time to answer all of Lee's questions, motivated her to pursue science in college.

The encouraging feedback of chemistry teachers strengthened the participants' interest in science, while the discouraging comments of their high school physics teachers forced both Ana and Lee to second guess their choice of majoring in physics. However, the positive feedback received from their peers who were also planning to major in physics and the readily available opportunity to do authentic research enabled these females to rethink their choices, thus majoring in physics. Lee says, "I declared to become a physics major after I met other people that wanted to do physics and already had ideas of where they were going with it. Those were more influential to me than the professors themselves."

Quite the opposite, Valeria encountered a caring high school physics teacher who believed that physics is for anyone interested; she made a choice to major in physics. Valeria narrates, “She would be very persistent and would always expect an answer. She would never let me be quiet. I always had to give some input.” Valeria’s self-efficacy grew with the constant positive feedback that she received from her physics. She enjoyed doing physics in her high school physics class because the outcome expectations were positive. Valeria chose to pursue physics because of the encouraging words of her high school physics teacher. She says, “My physics teacher was the first one to talk to me about college.” These experiences of social persuasion strongly influenced the participants’ self-efficacy, motivating them to major in physics.

These findings reinforced the quantitative outcomes of Hazari et al.’s (2010) research by showing that the early childhood and adolescent experiences of actively engaging in learning science positively impacted their competency beliefs making the participants more self-efficacious to pursue physics. Valeria, Ana, and Lee developed an interest for physics because of highly encouraging teachers and from learning science through real-life applications and active discussions in class.

Research Question 2

The second research question investigated the college experiences of the female undergraduate physics majors which contributed to their current dispositions to physics. While the mastery experiences and social persuasions from family members and teachers in the K-12 years contributed to their initial dispositions toward physics, current dispositions were mostly informed by vicarious learning experiences. Although, social persuasion continued to greatly impact the participants' current dispositions toward physics, it is interesting to notice the shift in these verbal persuasions from family members to peers.

Vicarious learning is defined as learning from seeing others successfully perform a similar task (Bandura, 1986; Zhu, 2007). The current dispositions of the three participants toward physics were strongly influenced by the vicarious learning experiences of their role models who were often their friends and professors. Valeria stated that when she "meets people who can solve complicated problems and are humble to talk" to her, she "feels compelled to be like them one day." Talking about her physics professor she says,

> I like her research topic and that is why I am doing research with her. What I like about her is that she is cozy and tries to be as close to students as she can. She enjoys mentoring and I really value that. I can talk to her about issues about being a woman in physics. I enjoy being able to voice my opinion of the things.

Drawing on the mentoring experiences of her physics professor, Valeria now is proud of the research she does. Talking about the work she does, she explains,

> I write source files that simulate particle collisions by using probabilistic Monte Carlo methods. I make more files that do the data display and analysis. Sometimes the analysis is beyond of what I know, and then I talk to my professor. It's enjoyable because it doesn't feel so much like someone is telling you how to do something, but rather sharing a perspective of why things are happening and somehow I feel I am contributing to the field, as small as it can be.

Following in the footsteps of her physics professor, Valeria aspires to be a positive role model for other young girls in her family. Informed by her current disposition toward physics, she says, "I want to show my cousins everything." She also counsels several students in "their pursuit of personal growth" through service in the community, and in the development of leadership skills. She serves as an officer for Undergraduate Women in Physics where she "develops mentoring programs to encourage young girls interested in STEM fields."

The success stories shared by her physics professors had a major impact on Ana's current dispositions toward physics. With an excitement, she shares,

> It was just great in talking to my professor. He is such a great guy and what he says is just spouts of wisdom. He talked about his experiences that really inspired me. Another thing that helped me was listening to my female physics professor about her journey to becoming a physicist. After talking to her, I realized she was not great in physics to begin with. But she just kept on going with it. She stuck with it. Honestly, that was something I realized that you really have to stick with. I understood that if you really want to do physics you have to be very dedicated. She did give up quite a bit to be successful. She loves what she does and she is so happy. She's such a cool lady. She has done some cool things.

Watching some of the successful individuals in the field and listening to their experiences definitely had a profound impact on Ana's current dispositions toward physics. She, with so much more confidence, seeks out for opportunities to inspire young females to pursue physics by sharing her own experiences as a successful female physics major.

Lee, who initially gravitated toward physics because of her interest in philosophy, "now appreciates physics differently." Her current disposition toward physics is immensely influenced by the vicarious experiences shared by her friends. She explains, "I think semiconductors are cool now. They are the basis of all electronics. My friend, who was here, worked on lasers most of the time and it was really cool stuff." She attributes her success as a physics major to the success of her friends, supporting the need for vicarious experiences to encourage more females into the field (DiBenedetto & Bembenutty, 2013). Sharing one such vicarious experience, Lee says,

> I look up a lot to my friends and peers that I work with. They really strive to be the best at what they do and that really inspires me to be the best I can. I do want to be like them in the sense that I want to be really passionate about what I'm doing. I really want to put myself out there, and like "go get 'em" attitude like my friend. She's in public health, and she started this organization called Girl Advocates, and she worked so hard in getting outreach stuff coordinated and going and doing workshops for young girls and stuff. She won Best New Organization of the Year by the university. She's just goin' and goin' and goin', and like that's so cool to see. Even though she does stuff that I'm not super interested in like public health related stuff, I really want to have her work ethic. I really want to have her attitude.

Lee currently is serving as the president of a student run organization at her university, where she provides resources to other undergraduate women in physics majors and does outreach activities for young girls to motivate them into STEM fields.

Interestingly, Lee turns to her favorite characters in the cartoon books for positive energy to motivate herself as physics major. She connects strongly with “Dr. Manhattan” from the book *Watchman.* Her interest in research stems partly from her admiration for “cool Dr. Manhattan” and the research done by him in the story. She had mentioned that she always carries the book with her to constantly remind her of why she chose to become a physics major. Another motivating force for Lee is Wonder Woman. She says, “If I'm in a stressful situation, sometimes I think, "WWWW - What Would Wonder Woman Do?” Lee shares her experiences of success with the world through her online blog, setting herself up as an example for others to see and learn.

Social persuasion, especially from peers, was another important form of learning experience which influenced the participants' current dispositions. It is important to note that Valeria had never experienced academic failure as a physics major. However, she defined her success as being accepted by her peers. She says, "I always made good grades, mostly A's. But when I was not appreciated, I felt lonely and depressed," she says. Valeria gained her self-efficacy when she was acknowledged as an "intelligent and humble person" by her peers. For Valeria, the social persuasions of her peers assured her of her social acceptance into the mostly male-dominated field of physics. Sadly, she was under-minded by her peers, leading to extreme physiological arousal that forced her to doubt her abilities as a female physics major. As a result, she struggled with low self-efficacy and almost wanted to exit the physics pipeline, which probably is a common experience for most female STEM majors. However, her experiences of success (mastery experiences) continued to propel her forward. Valeria shares,

> I struggle a lot with confidence. But when I got to this really hard class, which is waves and optics, I was one of the people that knew the most. In study groups, people would usually argue and they always wanted to be right. But most of the times, I was right. So, I felt like I was gaining confidence. One of my goals was to feel better with myself and be like, you can actually do this. They're not any smarter than you are. It is nice to know that you working harder and getting there.

The high outcome expectations that she had set for herself, encouraged Valeria in her pursuit of physics. The experiences of success boosted her self-efficacy, allowing her to regulate her modes of thinking. She adjusted her behavior by mastering the skills to negotiate and network with others in collaborative environments, thus gaining confidence to alter her environments. Valeria, who had to adopt "dumb" to be accepted in the social circle of physics majors now says, "They listen and accept what I say because I am more knowledgeable about the subject." She now enjoys doing physics and assumes it as a potential career option in the future. Therefore, in case of Valeria, mastery experiences leading to social persuasions strongly influenced her self-efficacy, thereby determining her current dispositions toward physics.

Unlike Valeria, who had stronger academic skills necessary to pursue physics, Ana lacked the required math skills. However, the social persuasion from peers and professors heightened her needed self-efficacy to succeed as a physics major. Talking about the professor that she dearly admired, Ana says,

> One of the main things that he always tells me is that if you are good at one thing, then you are probably good at something else. He also says that the best part about doing science is that you are finding something that no one else discovered before and made a contribution to the scientific community and that's awesome. I thought that that idea was really great.

Several such words of wisdom from her professors and the unconditional support of her peers in her study group formulated the social persuasions needed to boost her self-efficacy to persevere as physics major. As a result, she did not view the absence of required skills as a barrier; instead she assumed personal responsibility to master them as a means to attain her outcome expectation. She shares,

> I was taking a calculus sequence which combined the first three semesters of calculus into two semesters so that I could stay on track with my degree. It was intended for people who had taken calculus already and were able to fly through the material and I

was not one of them. Not to mention, I had never taken any calculus coming into college which really set me back my first semester. I struggled a lot with that class, which was discouraging because so many people were always laughing at how easy it was. I ended up barely passing the first semester, but that turned out to be a really good motivator. The second semester, I was able to pull myself together. I was able to find people who were like me, and we formed a really tight knit friend group. We were all physics and astronomy double majors, so we all had similar interests that we could go on about for hours, which really helped me feel comfortable as a physics/astronomy major. I started studying like crazy for calculus and passed that class with an A, which helped my self-esteem a lot. It helped me realize that I am a smart person; I just need to work hard for it to show.

The success that resulted from her hard work improved her self-efficacy which in turn provided the mastery experiences needed for Ana to continue her pursuit in physics. Ana's increased levels of self-efficacy allowed her to set high outcome expectations, standing up for herself by breaking the gender and cultural stereotype of a physicist.

Lee, who was identified intellectually gifted as a young girl had high self-efficacy shaped from the experiences of success, and social persuasions. However, verbal persuasions were completely missing from her experiences in the first year of college. She was often silenced by "pretentious" male-counterparts in the social circles of physics majors. The "harsh comments" of the male teaching assistant questioned her cognitive abilities. To worsen the situation, she failed a physics course for the first time. As an intellectually gifted student, she attributed the failure directly to her intellect. Like Valeria, Lee experienced increased physiological arousal in the form of depression. Consequently, Lee's self-efficacy began to suffer. She doubted her choice to major in physics. However, the verbal persuasion, mainly from her peers, cheered Lee in her pursuit of physics. Lee describes the experience,

> Waves and Optics, it was the first physics class that I took that was super difficult, and I didn't pass the course. I've always been a high achieving student. It just really, really bothered me. I began to think that physics was very difficult. I was so depressed and wanted to withdraw from the university. At one point I thought, "Why can't I just do math? Because I like it better, and it's, in my opinion, easy to do, and I don't have to deal with all the ugly pendulum systems." I was talking to my close physics friends, who are passionate about the subject, they said, "No Lee, you don't need to do that. You can totally do this and physics is what you like to do." They were just super supportive, and reminded me of why I liked physics in the first place. Physics is really hard, but it's easier when you have people that realize, "Hey, it's hard. But you work through it together." So, we stuck together and worked hard the following semester. I made a B+."

The experience of success elevated Lee's physics self-efficacy, resulting in her positive dispositions toward physics. She now tutors struggling students in the areas of science and mathematics in hopes of encouraging them to pursue STEM fields in the future. Based on the experiences shared by Ana and Lee, it can be concluded that in the absence of mastery experiences required for improving the self-efficacy, strong verbal persuasions can heighten their confidence, especially in females, motivating them to pursue STEM majors such as physics. The strong impact of different sources of self-efficacy on the participants' dispositions, interest in, and pursuit of physics support similar findings of the quantitative study conducted by Mills (2009).

In general, the findings of this study provide much needed qualitative evidence to support the pathways (Figure 3) presented in SCCT (Lent et al. 2002). In my study, the participants' self-efficacy beliefs and outcome expectations informed their current dispositions toward physics. These dispositions in turn contributed to their physics self-efficacy and future outcome expectations. Therefore, the relationship between the constructs of self-efficacy, personal dispositions toward the major, and the outcome expectations in the framework of SCCT (Lent et al., 2002) can be viewed as a cyclical process. Upon examining the learning experiences of the participants, the relationship between the constructs of personal and environmental factors, self-efficacy, and outcome expectations clearly support the framework of SCCT (Ali & Menke, 2014; Atadero et al., 2015; DiBenedetto & Bembenutty, 2013; Lee et al., 2015; Lent et al., 2003; Mills, 2009; Scheuermann et al., 2014; Thompson & Dahling, 2012).

The personal factors of the participants' gender, cognitive abilities, and predispositions toward science, accompanied by environmental factors such as the family, school, and the societal stereotypes defined their self-efficacy beliefs and outcome expectations. These beliefs about their self-efficacy and outcome expectations informed the participants' dispositions toward, interest in, and choice to pursue physics as an undergraduate major.

The findings of this qualitative study are consistent with that of DiBenedetto's and Bembenutty's (2013) quantitative results. To begin with, the participants, to some extent had an understanding of the nature of physics and the necessary skills needed to pursue the subject. These females were informed of their gender, confidence levels, and their career goals. As a result, they entered the field of physics with personal outcome expectations in place. However, these expectations were heavily influenced by their childhood and adolescent experiences of their social positions assigned by family members, teachers and peers. Common aspects among the three participants are that they had high outcome expectations for themselves, either in the form of performance or social status, and they did not hesitate to solicit help from their peers when barriers inhibited them from reaching their goals. These finding are in accordance with observations made by Karabenick (2011) that when faced with academic challenges, high achieving students seek help to attain the objective.

In general, it was observed that the learning experiences resulting from gender and cultural stereotypes accounted for participants' poor predispositions toward physics, hindering their persistence as physics majors. However, the experiences in which the family members and teachers presented science as a vibrant field to the participants had a profound impact on their interest in and pursuit of physics. As noticed by DiBenedetto and Bembenutty (2013), the vicarious experiences and verbal persuasions provided by peers and teachers enhanced self-efficacy beliefs and fostered grit in these females to pursue physics. The direct experiences of actively collaborating and contributing knowledge to the field encouraged a strong sense of social status in each of the participants.

While the findings of my study partly supported the findings of Gonsalves (2014) qualitative inquiry involving physics doctoral students, they also differed in certain ways. My participants, similar to Gonsalves's, felt the need for recognition in their social circles of physics majors. While Valeria felt compelled to reproduce the dominant discourse of the gender norms, Ana, clearly refused to surrender her Ana-ness for the stereotypical behavior of a "serious-looking old white guy." It is essential to note that all three participants carefully reflected on their actions at every critical point of their journey, thereby re-directing their lives, making new informed choices. When executing the plans for success, they changed their circumstances by regulating their paths of execution. As part of the regulation process, the participants carved new spaces in which they interacted with physics differently, resulting in improved self-efficacy. Through their authentic research work, not bounded by time and with no fear of failure, they recognized science as a vibrant field. They created support groups in which learning science was not competitive, but was collaborative in nature. Success and failure no longer belonged to any one person, but was shared equally by all members of the group. As a result, their perspective of failure changed. The participants became empowered and no longer viewed themselves as being different from their male counterparts. They were now part of the social circle of physicists.

Implications for Science in STEM Education

As much as I would like to explicitly discuss what the findings mean for each specific group of stakeholders, it makes more sense to address the implications of this study for the science education community at large. However, I invite all potential stakeholders of education such as educators, administrators, teacher educators, parents, and certainly female students, to think about these implications seriously, as they make major decisions at their own individual level.

Science as a Vibrant Field

Exceptional educators present science as a dynamic process of inquiry rather than as a body of organized facts. In present day schools, science, for the most part is taught as an abstract topic devoid of insights into human passion (Thornburg, 2009). As the educational level of students upsurges, particularly in sciences such as physics, the instructional material seemingly becomes more abstract and disconnected from everyday experiences. In a rush to present more material, teachers primarily resort to lectures, worksheets, and tests, resulting in an environment where students develop negative attitudes toward science. It is important for children to actively engage science in order to perceive it as an integral part of everyday life. Therefore, it is important for teachers to present science as a vibrant field, explaining how and why scientists spend much of their time exploring questions which might not yield a definite answer in their lifetime. When science is presented as a process of inquiry, students transform into real scientists, discovering answers to their own questions. Ana explains,

> This semester, I am taking astrophysics. It is an incredibly advanced and really hard class. But it is my favorite class. The homework that he gives us is very interesting, because you actually have to think about what is happening. When I was taking the introductory physics classes, it was like do this one problem the way we showed in class. It was basic, easy, and dumb. But in this class, I feel like I am really doing science and even when I get a step closer to the answer, it just makes me proud. I am actually figuring this stuff out. I remember this one problem that I thought was so cool. When a neutron star magically appeared right next to the earth, how thin of a shell would the earth form around the neutron star? I thought it was a crazy question. But solving questions like this makes you feel that you are outstanding and crazy. Honestly, answering questions like this actually made me realize that I am a physics major. This is really awesome. I get those moments a lot in this class.

It is evident from Ana's experience that when problems are presented in a form, where students have to delve deep for conceptual understanding, rather than a simple plug and chug, they enjoy the essence of doing science. Valeria recalls such understandings as, "The mind-blowing facts that you encounter every now and then are realizations of why things happen." Lee describes her contrasting learning experiences in math and physics class,

> In my physics classes, we get a lecture. This semester the lectures were basically book chapters on a PowerPoint. They were not that great. I didn't go to class too much,

because I could read the book and get the same information. Then, we would get problem sets that were from the book, and that was really it, and then the exams. But this past math class, I had this semester, was taught in a way like we did problem sets at home and then we came in and we discussed it for the entire class period about what methods work and why. It just flowed nicely. Apparently, that style is called inquiry based learning, and it's a lot of extra work. I spent more time doing math this semester than doing physics. I learned so much more. I wish some physics classes were taught that way, because I feel I would be more engaged with the material.

Lee emphasizes the need for inquiry as a method of physics instruction.

Inquiry is at the heart of science teaching and learning (NSTA, 2004; Windschitl, 2008). However, in reality, successful teaching is a complex and challenging process and it is even more challenging to teach good scientific inquiry. Scientific inquiry is a multifaceted process through which students develop a deeper understanding of scientific concepts, and experience the ways in which scientists study the natural world (NSTA, 2004; Windschitl, 2008). The activity involves the steps of scientific method: making observations, asking questions, reviewing the literature to see what is already known, designing an investigation, reviewing what is known in the light of experimental evidence, using appropriate tools to collect data, analyzing and interpreting the data, proposing explanations, and communicating the results effectively (Chiappetta, 2008).

During the process of inquiry, students' interactions with science extend beyond the four walls of classrooms, into the community, offering them future choices. Through scientific inquiry, students construct their own scientific understandings of the phenomenon in the broader perspective of real life, thus appreciating science as more relevant and interesting subject to pursue beyond high school. The process of inquiry might often involve failure. However, an effective science educator assumes the role of a facilitator, encouraging the students to learn through the process and to be successful at the end (Chiappetta & Koballa, 2014). Lee shares one such scenario from her high school chemistry class,

> I remember, after my teacher got done talking to us, we were sitting in our seats talking to one another. I asked my friend, "Have you done this problem?" She said, "No, I don't know how to do this." I said, "I don't either." Instead of having to go to the teacher, she came around and stopped at our desk. She asked, "What's up?" Pointing to the problem, I said, "Yeah, I just don't get what's going on here." She immediately said, "Oh, okay. Let's talk about it." So, I didn't have to take that step to go talk to her and by doing so, she made me want to go back to talk to her later when I needed help on something. I think a lot of teachers know that kids don't really approach them when they're stuck on a problem, especially in the [IB] program wherein we're supposed to know everything. She probably understands the pressure and stress we experience and that we don't want to appear like we don't know something.

Exceptional teachers understand the individual needs of their students, and appreciate the differences among them.

Despite the strong advocacy for scientific inquiry in STEM, students in K-12 science classes are deprived of opportunities for authentic research. Science teachers, forced by state mandates, spend 40% of their instructional time doing hands-on activities and labs. Sadly, most of these activities are confined to only the hands, and do not stimulate the minds of students (Lin & Tsai, 2013). The purpose of scientific exploration is defeated when teachers limit their instruction to structured lab activities, where procedures are dictated to students. Scientific inquiry demands a major paradigm shift in how teachers and students view science. Students will be alienated from the original premise of scientific inquiry, unless teachers are trained to effectively engage them with the process. While some of the deficit in good science instruction can be attributed to lack of intrinsic motivation from the low self-efficacy of science teachers, there is a dire need for professional development opportunities for teachers in the area of scientific inquiry.

Teachers must also be trained for effective integration of technology into the process of scientific inquiry without compromising the fun of doing actual experiments, for online simulations. Ana recollects her engaging experiences of building rollercoasters and hot air balloons in middle school science classes, while Lee was unhappy with simulated physics labs. Lee perceived her chemistry teacher, who did several wet labs, as “engaging and dedicated,” while she referred to her physics teacher as “sliding by, doing the minimum.” The low self-efficacy of students in science which in turn hinders their choice of STEM majors can also be associated with the shortage of qualified teachers. Alarmingly, 61% of high school teachers teaching chemistry and 67% teaching physics have no major or certification in the area taught (Thornburg, 2009). Low entry and retention of females in the areas of science such as chemistry and physics impacts the pool of qualified teachers. This unequal participation of females in STEM fields can be attributed to the paucity of female role models mainly in the form of high school teachers and college professors (Riegle-Crumb & Moore, 2014; Sonnert & Fox, 2012). Bottia et al. (2015) noticed the proportion of female science teachers at a school had a significant impact on female students’ likelihood of declaring and graduating with a STEM major.

The experiences of participants in the study indicate that the K-16 female science educators had a profound impact on their interest and pursuit of physics, supporting the finding by Bottia et al. (2015). Therefore, I recommend university administrators plan and develop financial resources, in the form of grants and scholarships, with a goal to recruit and retain female students in STEM majors such as physics in order to increase the pool of qualified science teachers. It is also essential for both K-12 administrators and institutions of higher education to seriously consider the need for female educators in STEM fields when recruiting for these teaching positions. It is important for institutions of higher education to provide incentives for female professors, specifically in the fields of STEM, in the form of research opportunities and remuneration, to recruit and retain them in the field. I specially urge the teacher education programs to find innovative pedagogical practices to improve the low science self-efficacy beliefs of pre and in-service teachers. Poor attitudes and low self-efficacy beliefs of teachers can profoundly impact the attitudes of students, particularly females, driving them away from their interests and choices to pursue sciences such as physics (Kazempour, 2014).

Since, students' success in science is heavily influenced by their attitudes toward it (Lin & Tsai, 2013), K-16 science educators must actively plan, organize, and implement instructional activities that develop positive attitudes in students. It is important to emphasize science in the elementary school curriculum allotting more time for students to independently explore nature through hands-on and minds-on activities. The findings of my study indicate that self-efficacy beliefs of female students are largely influenced by learning experiences in their early childhood years. This finding largely support recommendations made by NSTA in their position statement (NSTA, 2002).

I suggest school districts develop partnerships with institutions of higher education and local businesses to provide K-12 students with opportunities to interact with experts in STEM fields who are currently conducting authentic research. Meeting and observing some of these accomplished scientists in the field, can provide students, particularly females, with firsthand experience of what science really is. Listening to the stories of their journey to becoming scientists can not only help female students appreciate the work they do, but will also motivate them to think of science as a possible career choice. Such interactions with successful role-models can reassure young girls to resist gender related societal stereotypes with STEM fields. Thus providing them with the vicarious experiences needed to improve their self-efficacy, and increasing their chances to pursue a STEM major beyond high school.

It was observed that the participants' dispositions, interest in and pursuit of were heavily influenced by the vicarious experiences of watching and doing authentic research in the field. Therefore, institutions of higher education must provide exclusive research opportunities for females in STEM majors to engage in authentic research under the mentorship of experienced faculty. These opportunities might increase the self-efficacy of female students, motivating them to choose majors such as physics because they defy prevailing stereotypes (Bella & Crisp, 2015). Such promotion-focused approaches might also encourage the male-dominated physics community to be more accepting of women in the field, forcing everyone to revise prevalent gender stereotypes (Bella & Crisp, 2015; Gonsalves, 2014; Götschel, 2014).

Failure as an Opportunity to Succeed

The words from the old proverb, "A winner will only have a past to cherish, but a loser will have a future to strive for," have had a strong impact on my understanding of success and failure. But the experiences of my participants have added new dimensions to the relationship between success and failure. I learned that success and failure, encouragement and criticism, are like a two sided coin, co-existing in life not knowing what will be revealed, until a critical moment presents itself. How a learning experience becomes a critical moment determines whether the person experiencing it perceives it as success or failure. Bandura (2001) says, when people attribute failure to their personal deficiencies, they work hard to reach their goal, which was the case with Ana. She never felt *othered* as a female physics major. As a result, she perceived the academic challenges that she encountered as "little hiccups," moving forward, surpassing them with confidence. She attributed her poor performance to her lack of background in calculus, rather than to physics itself. Hence, she worked extra hard to become a successful physics major. On the contrary, Valeria who felt *othered* and disrespected in social circles, became hostile to these environments. She says, "Grades no longer mattered. I did not work hard." She was always an overachiever, but perceived herself to be a failure, resulting in depression and anxiety.

Despite the contrasting stories of how these participants made sense of failure, they show that perseverance amidst setbacks is one of the most significant traits of success. For example, in retrospect I believe that I probably learned more from failing a test with a score of 15 than from making a 97 on a subsequent test. Because it is through that process of failing that a person evolves, learning his or her strengths, and fostering grit. Grit is often defined as one's ability to strenuously work through challenges, maintaining effort and interest over long periods of time, despite the adversities and failures he or she faces in life (Duckworth & Eskreis-Winkler, 2013). In a seemingly unpredictable world it is important for us, as educators, to prepare students to engage the unknown. Students must recognize that they won't always succeed and realize that a good failure is an opportunity to learn and strengthen their knowledge and skills (Hoerr, 2016). Stating her opinion about failure, Lee says,

> Because I failed a class, I thought it was the end of my career in physics. But I realized it wasn't. Now you know what, no matter what my grades, I'm still here, and I can do

> physics. Physics is very much about making mistakes, and I made a lot of them. I think, now I make mistakes on purpose to help me move forward with thinking about a problem.

Accomplished individuals often view life as a marathon and not a sprint, plodding on toward the goal despite the slow and uneven the progress (Duckworth & Eskreis-Winkler, 2013).

When we look at the increasing number of undergraduate students attempting suicide, it makes us question our very existence as educators: Am I really preparing the students for life beyond the four walls of my classroom? If so, why are they helplessly and hopelessly attempting to end their lives? The powerful narratives of these participants forced me to reflect on my role as an educator in fostering one of the most important elements for success in life, grit. Duckworth, Peterson, Mathews, & Kelly (2007) found that individuals with less grit are more easily discouraged and frequently distracted by new passions. Since, a person's present actions are motivated by his or her future goals (Bandura, 2001), reminding the students of that final goal might motivate them to move forward despite setbacks. Even though the mission of present day schools is to prepare students for life beyond school, Tough (2012), identified that opportunities for the students to fail and develop grit simply do not exist in modern education, especially in United States.

Agency, as defined by Bandura (2001), is not limited to an individual's ability to make choices and plan future actions, but also in the ability to regulate execution of the plans (Bandura, 2001; DiBenedetto & Bembenutty, 2013), which requires grit. Students with higher levels of personal agency exercised greater amounts of effort to obtain their goals (DiBenedetto & Bembenutty, 2013). It is therefore, the responsibility of leaders in education to encourage teachers to start the dialogue of fostering grit in their classrooms. Hoerr, in his book, *Fostering*

Grit: How Do I Prepare My Students for the Real World? (2013), identifies six steps for teaching grit: (a) establishing the environment; (b) setting expectations; (c) emphasizing the vocabulary associated with grit such as resilience, tenacity, and perseverance; (d) creating frustration; (e) closely monitoring the response; and (f) reflecting on and learning from the experience. In cross-sectional analyses, Duckworth & Eskreis-Winkler (2013) observed that in individuals, grit increases throughout adulthood. Although they attributed this increase in grit to people having a growing appreciation of the efficacy of effort as they age, they found that grit is fostered through deliberate practice. Because, often the success from overcoming the challenges supports a resilient sense of self-efficacy in individuals more than an easily won success (Bella & Crisp, 2015; Britner & Pajaras, 2006).

Holmes, Day, Park, Bonn and Roll (2014), in their study with undergraduate physics students, implemented an activity called Invention activity. Invention activity is a productive failure activity in which students are expected to generate solutions to a novel problem prior to receiving instruction on the concept. As students struggle through the process of generating solutions, they reflect on and evaluate the steps of their failure to repair the process. The repair process addresses the key mechanism of attempting to overcome the failure rather than simply the act of failing itself. Holmes et al. (2014) found those students who were exposed to the invention activity before instruction outperformed the other group that had direct instruction to start with. However, they observed that not all failures were equally productive and that some manner of support, in the form of scaffolding or as prompts to reflect on the reasoning used to solve a problem, must be provided during the process for students to learn from their failed attempts (Holmes et al., 2014). Similar inquiry methods can be used by science teachers to help students recognize that every problem has a solution and that failure is a midpoint in the path to reach the solution. But such deliberate failure activities require efficient planning on the part of educators. The goals of such activity must be clearly communicated to the students and parents.

Hoerr (2016) emphasized that by honoring effort, educators can help develop grit in their students. As important as it is for us, as educators, to provide experiences that create frustration in students, it is our responsibility to communicate to the students that we are with them, walking beside them throughout the process (Hoerr, 2016). It is through this support and close monitoring of how students respond to these frustrations, that educators can successfully prepare their students for life after school (Hoerr, 2016). Ana's chemistry teacher emphasized the value of grit to her students through her magic slogan of "stick with it." Sharing the experience on the first day of AP chemistry class, Ana says,

> It was the first day of AP chemistry class. Half of the people are thinking "I am probably going to end up dropping this class before the end of the semester." That is when she gave us the speech on need to stick with it. She said, "If you want to do something, you just can't give up on it because it's hard. If you want to be successful you have to really work on it. No matter how hard things get, you need to stick with it." That stuck with me. It is my inspiration. When I am upset with everything and I want to throw everything in the middle of the street, I tell myself, no. I just have to stick with it. You just cannot breeze away through life. Things get hard, but you have to try and work hard if you want to be successful.

These powerful words of her teacher fostered the much needed grit in Ana, to pursue physics.

In an educational world, where success is defined only in terms of standardized test scores, I call upon all individuals invested in a child, to change paradigms by placing the child's heart at the core of education. I urge educators in particular to take on the challenge of developing strong individuals who can thrive, not just in our class, but through the inevitable adversities of human life, giving them the hope to follow their dreams. As educators risk their positions by exposing their students to deliberate failure, administrative leaders must encourage and support the venture with one common goal in mind, to foster grit as an important life skill necessary for students' success beyond school. Both parents and teachers must share their personal stories of success and failure with children from a young age, for them to see that failure is only a short pause, not an end in the journey of life. Most importantly, it is essential to stress how one can overcome failure and scout forward, learning from his or her mistakes. These strong examples set by closely related individuals in their lives can help build confidence in young children, especially females.

Collaboration, not Competition

Humans are social beings. Social interactions play a major role in how we make meaning of an experience. Social persuasion is a major aspect in developing self-efficacy, especially for females. However, research on college students pursuing STEM majors consistently finds that females often feel more isolated than males, underscoring the need for more collaboration to improve their self-efficacy. Excessive competition prevails in STEM fields, propelling women out of majors such as physics (Chesler & Chesler, 2002). The participants in this study experienced serious competition as physics majors. Explaining the environment in one of her physics class, Lee says,

> It was a more competitive environment. People in the class were just driving really hard to make the best grade in the class and beat everyone else. The material, looking back on

> it, was fairly simple, but I wasn't used to the environment. The professor was intimidating and I didn't want to embarrass myself.

Ana, who is highly sociable, expresses a similar concern of heavy competition among physics majors.

> It is a problem with physics majors in general. It is really competitive. I found it always pretty easy to interact with guys. However, it is the change in the whole physics atmosphere how all of a sudden everyone is now competitive and I am not used to it.

Unable to withstand the severe competition, these women were forced to question and doubt their space as physics majors. They were almost ready to exit the physics pipeline when they recognized the need for collaboration. In a collaborative activity, a group of people with common goal build shared practices and knowledge through social interactions (Li & Demaree, 2013). They designed a support system, comprised of people with a common goal to thrive and succeed as physics majors. The support system included study groups and student run organizations such as Undergraduate Women in Physics. Ana and Lee attribute their retention in a highly demanding major such as physics, to the support they received from the collaborative groups.

Classroom practices strongly influence students' self-efficacy. The positive physical states of students in collaborative classrooms can bolster confidence in female students. Gender differences in STEM majors can be attributed to difference in the learning styles. While males preferred abstract modes of learning concepts, girls attended to collaborative activities (DiBenedetto & Bembenutty, 2013; Zhu, 2007). However, with most instructional practices favoring males, females find sciences such as physics uninteresting and not relevant to real life.

As a result, they employ rote methods of learning, hindering the development of their ability to reason (Zhu, 2007).

Interactive engagement techniques have a significant impact on students' learning gains, positively influencing their self-efficacy (Kost-Smith, Pollock, & Finkelstein, 2010). It is through collaboration, students become agents of learning, taking ownership of their knowledge and contributing to the learning community. It is therefore important for science teachers to provide students, particularly females, with ample opportunities for discussion and debate. By actively participating in these collaborative classroom practices, students develop a strong voice and self-identity, making learning a more engaging and meaningful process (Li & Demaree, 2013). Teachers must plan for collaborative activities that can encourage female students to interact with male peers, challenging them to actively engage with the content.

Problem-solving, as a collaborative activity will no longer remain a daunting task for physics majors (Chen, 2002). During classroom interactions, students, like experts, will be forced to think deeply about the problem without limiting solutions to answer-driven recipe techniques (Lin & Tsai, 2013; Wieman & Perkins, 2005). Collaboration can compel students to think of problem-solving as a constructive meaning-making process that requires organizing knowledge base and reasoning, taking it to higher levels of Bloom's taxonomy. Using collaborative activities, teachers can communicate high expectations for female students which in turn can enhance their self-efficacy. Collaborative environments can encourage female students to self-regulate the process of problem-solving by utilizing the help-seeking strategy. In this self-regulatory strategy, females can be encouraged to seek help from others to facilitate the learning process when they encounter obstacles (DiBenedetto & Bembenutty, 2013). As a result, female students can gain confidence in their abilities to pursue STEM majors.

Talking about the collaborative environment established by her physics professor, Valeria says,

> I like the community my professor has built among her research group because it is always about learning more and improving one’s knowledge. I like that we can collaborate together. You have to work together to come up with good results that are not only true to you. I usually learn a lot from talking to other physics majors and postdocs. It's enjoyable because it doesn't feel like someone is telling you how to do something, but rather sharing a perspective of why things are happening and somehow I am contributing to the field as small as it can be.

Lee, like Valeria, favors collaboration over competition when she shares,

> I think the biggest challenge was just convincing myself that physics was something I was capable of doing. I wasn't used to doing poorly at anything. So, I thought it was something intrinsically wrong with me, and that I just didn't have the aptitude for physics. This was exacerbated by not feeling like I had much of a voice and not knowing many other women in physics. I felt a little isolated for a while. In some study groups, I felt like everyone knew so much more than me. So, I stayed silent a lot and didn't really learn anything. Over time, these things seemed to work themselves out: I met other women in physics, I found people that valued my opinion on problems in study groups, so I now have a supportive and encouraging group of people to turn to. Now, I found a good study group who made me feel like I had good ideas to contribute. I learn better when I can talk about stuff, and so having a study group that discusses problems as we're working on them was really important.

In these collaborative groups, not only did the participants learn physics, but they built a stronger self-image, informing their interest in and pursuit of physics. They established a mentoring community with people of varying strengths. These differences were appreciated and a trusted relationship was established between the members of the group.

In the real world, no problems are solved in isolation. Therefore, there is no reason that teachers should expect students to complete worksheets in isolation. Learning science becomes more vibrant with collaboration. Supporting the process of collaboration in discovery learning activities can have a positive impact on students' learning (Holmes et al., 2014). Project-based learning can foster collaboration over competition (Donnelly & Fitzmaurice, 2005). When doing a project, whether it is small such as solving a simple physics problem or as big as an investigative research project, each group member is forced to contribute his or her share of knowledge. Donnelly & Fitzmaurice (2005) suggested that project-based learning activities can also encourage students to interact with each other using the language of the discipline, increasing their self-efficacy in the subject under study. They will learn to take responsibility for their learning and their success. However, success and failure will become a collective responsibility of the team. Such collaborative activities could help students to understand how scientists actually conduct their work in the field and appreciate the importance of teamwork for success in an endeavor. Working as a team, they can potentially become positive role models for each other, learning from one another's personal experiences. It is essential for science teachers to foster a collaborative, safe classroom environment in which students can creatively explore nature with no uncertainties attached. In this age of technology, it might be important for educators to create Facebook pages, class blogs and twitter accounts for students to efficiently collaborate with people all over the globe, sharing ideas and establishing new relationships.

Encouraging activities such as peer tutoring and science clubs can bring together students of similar interests to strive for a common goal. This can encourage female students to see science as a field of collaboration over competition in which they can be helpful members in the community, thus enabling them to pursue fields such as physics.

To recruit and retain more female students, mainly in fields such as physics, universities must help establish organizations such as Undergraduate Women in Physics. I ask the leaders of these organizations to promote and publicize the experiences of successful females in STEM majors because emphasis on positive outcomes can nurture the confidence and inner drive to excel for other females (Bella & Crisp, 2015). The student-run organization started as a small club at their college by a few females such as Lee. Today it provides support to several others. As the president of this organization Lee proudly says,

> It was just a group of female physics majors that got together occasionally to just kind of chat. Primarily, we provide resources to other undergrad female physics majors and do a lot of STEM outreach to middle and elementary schools. We provide information about conferences for members to establish strong network system. We host different guest speakers, not just people doing physics research. We had a gender studies professor come and talk to us about some of the issues facing women in STEM. Using the contacts from the conferences, I organized this for months, and we had a career toolbox workshop. We felt like the university wasn't giving the tools necessary for people going into industry. So we had this big career toolbox workshop, and it was really successful. We had a panel of industry people who did physics as their background. We wanted to promote to all our female members that, hey, there's other stuff you can do if you feel like grad school is not for you. Like I don't want any of the members of our group to feel like

> they don't have any prospects because they have bad grades are they can't do anything with physics major other than teaching.

These collaborative groups can help female students learn the art of negotiation, thus, breaking down gender and societal stereotypes. As a result, all students can have equal access to viable STEM career options. The findings of my study indicated that although K-12 experiences of actively interacting with science had a detrimental impact on the participants' interest for physics, their vicarious experiences and the verbal persuasions of their peers had a profound influence on their persistence in the major. Therefore, it is important for educational institutions to find innovative means to network female undergraduate and graduate students in different STEM majors, especially science and engineering, for them to share and learn from each other's experiences. These collaborative groups or organizations can serve as informal peer mentoring models in which female students, through their experiences can motivate and support each other, empowering them in their pursuit of STEM majors such as physics.

Recommendations for Further Research

Physics, which once was an option for high school students, is now a graduation requirement. This standard has placed an immense responsibility on high school physics teachers to design ways to actively engage students with physics, overcoming intimidation and societal stereotypes. As challenging as the process is, I see it as a venue to encourage more students to become STEM majors. My constant struggle to help students appreciate physics informs much of my research interest. With my primary goal to improve science education, I try to find resources that can help enlighten the instructional practices of science educators. This study would benefit from examining the data using feminism as the theoretical framework, while the following studies might assist in understanding the learning needs of students and expectations of science educators.

1. A cross-case analysis of the experiences of male and female students that inform their current dispositions toward high school physics.
2. A cross-case analysis of the experiences of male and female students that inform their interests in problem-solving in physics.
3. A case study of the experiences of physics majors prompting their current dispositions toward problem-solving in physics.
4. A case study of the experiences of female physics majors in classes nurturing collaborative practices.
5. A cross-case analysis of the experiences of male and female students when using project-based learning in physics.
6. A cross-case analysis of the experiences of male and female students when using the process of scientific inquiry in their science classes.
7. An ethnographic case study of the experiences of high school physics teachers and their current dispositions toward teaching physics.
8. A cross-case analysis of the experiences of female and male educators teaching undergraduate physics courses.
9. A case study of the experiences of student teachers informing their current dispositions toward the process of scientific inquiry.
10. A case study of the experiences of student teachers influencing their choice to teach physical sciences.
11. A phenomenological case study of the experiences of female students involved in STEM research.
12. An ethnographic case study of the experiences of females with STEM careers.

Closing Thoughts

The experiences of these participants support the theoretical underpinnings of SCCT, supporting its premise that personal and environmental factors played a major role in shaping these females' self-efficacy, informing their interest in and pursuit of physics as an undergraduate major. Since children spend most of their active time at school, we as educators can exert a profound impact on their belief systems. I urge educational stakeholders to closely inspect their own belief systems because we have a huge responsibility and challenge ahead of us: to retain America as a global leader. This colossal responsibility demands creativity among scientifically cognizant citizens. Females, with their high emotional intelligence, view problems differently from men. It is this diversity in thought that needs to be tapped for solving present day issues.

Through this study, I attempted to create a personal space for all the members of the science community to reflect, as we each connect with the participants' experiences when we determine our future actions. As I salute parents and teachers who challenge young girls to push the limits beyond the existing societal stereotypes, I urge others to hearten imagination in their children. I am blessed with parents who constantly inspired me to dream big. With big dreams comes the motivation to change them into reality.

This study is a celebration of success for those females who dare to change their dream into a reality, pushing past major impediments. The experiences of these exceptional females reassure those who are currently pursuing STEM fields and those who are planning for similar pursuits in the future that there is a solution to every problem. To find the solution, one must change existing circumstances or change themselves as needed to shift the paradigms of STEM education. As a final thought, I leave you with a question which a good friend once asked me: If we don't, then who will?

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APPENDIX A

IRB Approval Letter

OFFICE OF RESEARCH COMPLIANCE
Division of Research, Commercialization and Outreach

6300 OCEAN DRIVE, UNIT 5844
CORPUS CHRISTI, TEXAS 78412
O 361.825.2497 • F 361.825.2755

Human Subjects Protection Program	Institutional Review Board
APPROVAL DATE:	May 1, 2015
TO:	Ms. Vani Savithri Jaladanki
CC:	Dr. Bryant Griffith; Dr. Tonya Jeffery; Dr. Elsa Gonzalez
FROM:	Office of Research Compliance Institutional Review Board
SUBJECT:	Initial Approval

Protocol Number:	61-15
Title:	In the Foot Steps of Madame Curie… Stories of Female Undergraduate Physics Majors
Review Category:	Expedited
Expiration Date:	May 1, 2016

Approval determination was based on the following Code of Federal Regulations:

Eligible for Expedited Approval (45 CFR 46.110): Identification of the subjects or their responses (or the remaining procedures involving identification of subjects or their responses) will NOT reasonably place them at risk of criminal or civil liability or be damaging to the their financial standing, employability, insurability, reputation, or be stigmatizing, unless reasonable and appropriate protections will be implemented so that risks related to invasion of privacy and breach of confidentiality are no greater than minimal.

Criteria for Approval has been met (45 CFR 46.111) - The criteria for approval listed in 45 CFR 46.111 have been met (or if previously met, have not changed).

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

Provisions:	
Comments:	The TAMUCC Human Subjects Protections Program has implemented a post-approval monitoring program. All protocols are subject to selection for post-approval monitoring.

This research project has been approved. As principal investigator, you assume the following responsibilities:

1. Informed Consent: Information must be presented to enable persons to voluntarily decide whether or not to participate in the research project unless otherwise waived.
2. Amendments: Changes to the protocol must be requested by submitting an Amendment Application to the Research Compliance Office for review. The Amendment must be approved by the IRB before being implemented.
3. Continuing Review: The protocol must be renewed each year in order to continue with the research project. A Continuing Review Application, along with required documents must be submitted 45 days

before the end of the approval period, to the Research Compliance Office. Failure to do so may result in processing delays and/or non-renewal.

4. Completion Report: Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the Research Compliance Office.
5. Records Retention: All research related records must be retained for three years beyond the completion date of the study in a secure location. At a minimum these documents include: the research protocol, all questionnaires, survey instruments, interview questions and/or data collection instruments associated with this research protocol, recruiting or advertising materials, any consent forms or information sheets given to participants, all correspondence to or from the IRB or Office of Research Compliance, and any other pertinent documents.
6. Adverse Events: Adverse events must be reported to the Research Compliance Office immediately.
7. Post-approval monitoring: Requested materials for post-approval monitoring must be provided by dates requested.

APPENDIX B

Consent Form

In the Foot Steps of Madame Curie: A Cross-Case Study of Female Undergraduate Physics Majors

Introduction

The purpose of this form is to provide you information that may affect your decision as to whether or not to participate in this research study. If you decide to participate in this study, there is a one-page consent form at the end of the study that you can sign to record your consent.

You have been asked to participate in a research project where the researcher would be exploring how the educational experiences of female undergraduate physics majors contributed to their current dispositions toward, interest in, and pursuit of physics as an undergraduate major at a large southern research university. The findings of the study could potentially inform physics educators as to how they can motivate and enable female students to engage meaningfully with the subject and possibly pursue physics as a career choice. You were selected to be a possible participant because you are at least 18 years old undergraduate female physics major in the junior or senior year of the undergraduate program and is willing to take part in the study.

What will I be asked to do?

If you agree to participate in this study, you will be asked to engage in interviews, share photographs of learning environments that are significant to you, artifacts and documents such as journals, transcripts, and merit certificates that can help in providing a rich description of your educational experiences that contributed to your current dispositions toward, interest in, and pursuit of physics as an undergraduate major. This study will take at least 6 months. Over the course of the these months, I will interview you for approximately an hour on at least three separate occasions, and follow up with you to review data, to check for accuracy of transcription, verification of meanings made, and verification of findings.

Your conversations with me will be audio recorded, if unwilling, cannot take part in the study. They will be transcribed later and analyzed. Documents, photographs, and other artifacts provided by you will be analyzed for themes and patterns of how your educational experiences contributed to your current dispositions toward, interest in, and pursuit of physics as an undergraduate physics major.

What are the risks involved in this study?

There is minimal risk for participating in this study. Confidentiality of the participants and the data collected during and after the study will be maintained as outlined below:

1.) Using a pseudonym for the participants' names

2.) Removing or encrypting any identifiable information

3.) Not sharing any identifiable information with any persons outside this study

4.) Ensuring privacy during interviews

5) No findings will be reported without the participants' consent

6.) Storing data in ways that grant access solely to the researcher

7.) Electronic files will be stored on the researcher’s password protected computer

8.) The researcher is the only person privy to the password

9.) Audio recorder and hard copies of transcripts will be stored in a locked cabinet

At any point you can exit the study without penalty if you feel uncomfortable.

What are the possible benefits of this study?

There is no direct benefit for you to participate in this study. However, gaining an in-depth understanding of your experiences could potentially inform physics educators as to how they can motivate and enable female students to engage meaningfully with the subject and possibly pursue physics as a career choice.

Do I have to participate?

Your participation is voluntary. You can exit the study at any time without any penalty or prejudice.

Who will know about my participation in this research study?

The records of this study will be kept confidential. No identifiers linking you to this study will be included in any sort of report that might be published or presented. Your confidentiality will be fully assured. No findings will ever be reported without your explicit consent. Research records will be stored securely and only my methodologist, Dr. Gonzalez, and my advisors Dr. Griffith and Dr. Jeffery will have access to the records.

Whom do I contact with questions about the research?

If you have questions regarding this study, you may contact Vani Jaladanki at 361-229-3825, or at vjaladanki@islander.tamucc.edu , Dr. Elsa Gonzalez at 361-825-2438 or at elsa.gonzalez@tamucc.edu, Dr. Bryant Griffith at 361-825-2446 or at bryant.griffith@tamucc.edu, or Dr. Tonya Jeffery at 361-325-2453 or at tonya.jeffery@tamucc.edu .

Whom do I contact about my rights as a research participant?

This research study has been reviewed by the Research Compliance Office and/or the Institutional Review Board at Texas A&M University-Corpus Christi. For research-related problems or questions regarding your rights as a research participant, you can contact Erin Sherman, Research Compliance Officer, at (361) 825-2497 or erin.sherman@tamucc.edu

Signature
Please be sure you have read the above information, asked questions and received answers to your satisfaction. You will be given a copy of the consent form for your records. By signing this document, you consent to participate in this study. You also certify that you are 18 years of age or older by signing this form.

Signature of Participant: ________________________________ **Date:** ____________

Printed Name: ________________________________

Signature of Person Obtaining Consent: ____________________ **Date:** ____________

Printed Name: ________________________________