THE EXPERIENCES OF WOMEN IN POST GRADUATE PHYSICS AND ASTRONOMY PROGRAMS: THE ROLES OF SUPPORT, CAREER GOALS, AND GENDERED EXPERIENCES

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In physics and astronomy the low representation of women is obvious at every stage of the educational pathway from undergraduate students to full professors. These low numbers perpetuate themselves by failing to create new mentors to foster the next generation of women. Women and men also have different experiences as they traverse into physics and astronomy careers. Women often experience chilly climates, discrimination, and challenges coordinating the demands of young families with their careers. In the literature exploring this topic, little focus is put on the experiences of women graduate students in physics and no focus is put on women graduate students in astronomy. This research seeks to fill this gap by studying the educational experiences and academic choices of women in physics and astronomy. This project uses in-depth in-person interviews with women who are pursuing PhDs in astronomy, astrophysics, or physics and have passed their qualifying examinations. In all there are 21 participants from three institutions of higher education. Analysis of interviews uses a constant comparative method to apply action codes to participants' statements. These codes are then organized into themes to understand common experiences. Results indicate that peer support and mentoring by faculty or post doctorate associates are critical for these women's success in undergraduate and graduate education. Although they had mostly positive experiences, many of the women describe micro aggressions towards them because of their genders; in a few cases women experience overt sexual harassment and in one case physical danger. Largely, these women want to pursue non-academic or teaching-oriented academic professions so they will have the time to live lives that include more than just work and will have the opportunity to raise children if they desired.

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by

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"But friendship is precious, not only in the shade, but in the sunshine of life, and thanks to a benevolent arrangement the greater part of life is sunshine."
-Thomas Jefferson

It was not without friendship and support that I endured the PhD process. I owe a debt of gratitude to my best friends and dearest companions Amy and Sandy for always being there through success and defeat. I also recognize the immense importance of my colleague and close friend Melinda who was pivotal not only in the academic success of my dissertation, but making me realize I could change my career goal and pursue all new worlds at the intersection of gender and physics.

Professionally I would have never persisted without the help of my graduate mentor Charles, who gave me the practical tools necessary to pursue my scholastic interests and invited me into his professional community. It was by luck that I was assigned as his teaching assistant and within a year worked with him full time on a fellowship he helped me earn. Lastly, thanks to the one person who has always been there; my big sister Markina.

Ramón S. Barthelemy

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CHAPTER 1. THE PROBLEM

Introduction

"The primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering… 4 percent of the nation's workforce is composed of scientists and engineers; this group disproportionately creates jobs for the other 96 percent" (NRC, 2011, p. 4; NSF, 2012a, p. 2).

The turbulent economy and changing job sector demand that a more scientifically literate workforce and student body is developed. A recent study by the National Research Council suggests that future job creation will come from developments in science and technology (NRC, 2011). It has also been argued that by retooling the American work force towards STEM (Science Technology Engineering Mathematics) it may be possible to add $100 Trillion to the economy over the next 80 years (Hanushek & Woessmann, 2012). However, this change in the job market and demand for new STEM talent is coming at a time when the USA is beginning to lose its dominance within STEM (Broad, 2004; OECD, 2010). Major changes in STEM infrastructure need to be developed and implemented in order to recruit and retain more students.

Part of these infrastructure changes should include efforts to reach out to groups traditionally underrepresented in STEM. Such groups include women, and the field of physics is a great starting point for research due to its historical and current underrepresentation of women that exceeds most other STEM disciplines (AIP, 2013; Rossiter, 1982). Juxtaposed with the field of physics is astronomy, which is similar in content to physics but has significantly higher representation of women (AIP, 2013; Barthelemy, Van Dusen, & Henderson, Submitted).The low numbers of women in academic physics are obvious from the undergraduate through faculty levels. Currently, women comprise 22% of undergraduates, 18% of PhD graduates and 14% of faculty (AIP, 2013). Astronomy's representation of women is 35%, 40%, and 17% respectively (AIP, 2013) (Barthelemy, Van Dusen, & Henderson, 2013; Henderson, Barthelemy, Mestre, & Finkelstein, 2011). The representation of women in these fields is shown in Figure 1.

It should be noted that the numbers of women in these categories have been on the rise, but over the last half century physics has not seen the large increase in representation levels of women that has been seen in other science fields like biology or chemistry (NCES, 2012). The American Institute of Physics has done extensive work studying the issue of the low representation of women in physics. They have concluded that within the often used "pipeline" metaphor there is no leak from undergraduate to faculty levels (Blickenstaff, 2005; Ivie, 2011). This is not evident in Figure 1, but when controlling for PhD production of years past, there are equal numbers of women in physics faculty positions as there were graduates, as seen in Table 2 (adapted from Ivie , 2011). Equivalent data does not currently exist for astronomy.

The author of these claims, however, is quick to point out that an equal pipeline does not imply equity (Ivie, 2011). In fact, there is a 5% salary difference between men and women in physics, in men's favor (Ivie, 2011). Women's success, also, is in the face of well-documented bias within academia (Budden et al., 2008; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; Steinpreis, Anders, & Ritzke, 1999; Trix & Psenka, 2003; Wenneras & Wold, 1997). Most of these studies, however, heavily focus on academia as a whole and not specifically on physics.

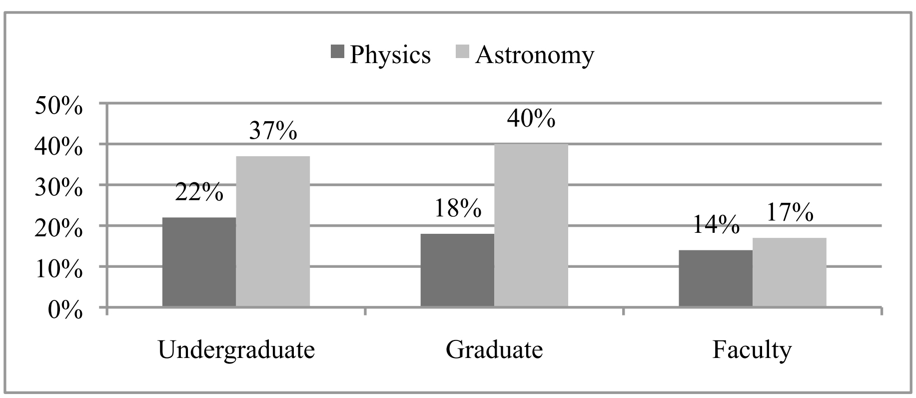

Figure 1 Women's representation in physics and astronomy. All data is from 2010 except for astronomy faculty, which is from 2006.

Table 1 Pipeline of Women in Physics Faculty Positions

	Dates of PhD	Average PhDs to Women	Women Faculty 2006
Full Professor	1969-1983	4%	6%
Assoc. Professor	1985-1993	10%	14%
Assit. Professor	1994-2000	13%	17%

Research Methods

This study seeks to understand the educational pathways and experiences of women in pursuit of a PhD in physics and astronomy. Feminist Standpoint theory (FST) will be used as the theoretical framework in this undertaking (Harding, 2001). FST looks at the development of scientific knowledge, life in social situations, and general experiences from the viewpoint of women as unique knowers who exist as a marginalized group. This is a particularly strong framework to investigate the lives of women in physics because so few women are in physics, and the literature shows women must often masculinize themselves to fit in and persist in the field (Gonsalves, 2012). This approach has also never been used in studying women in physics, and will give voice to women graduate students' experiences by recognizing their lives as unique compared to the whole of physics. This uniqueness will allow a secondary goal of the project to emerge, which is furthering the theoretical framework of FST.

Data was collected through face-to-face in-depth interviews with women graduate students at large US research universities. To participate a graduate student did not need to be a biological female, but only gender identify as a woman. Interviews were conversational in style, as the participant and interviewer seek meaning together (Reinharz & Davidman, 1992). Open-ended prompts were used to let the participants express their lived realities. Data analysis began with line-by-line coding and chunking text segments for themes, which were then cross compared amongst all the participants (Charmaz, 2005, 2006). A detailed treatment of the methods is provided in Chapter 3.

Research Questions

To address the problem of the low numbers of women in physics, interviews will be conducted with women in graduate physics and astronomy programs using open-ended prompts to explore their experiences. These interviews will be used to answer the following research questions about women's experiences as undergraduate students, graduate students, and their career goals. Additionally, their specifically gendered experiences will be gathered to understand what unique barriers women may perceive themselves to face in physics and astronomy.

I. *What experiences as undergraduate students helped these women persist in their field?*

II. *What experiences as graduate students helped these women persist in their field?*

III. *What are the participants' desired career pathways after graduate school, what shaped these goals?*

IV. *What are the distinctly gendered experiences that these women have had in physics and astronomy?*

Significance

Researching the educational pathways and persistence of women may lead to a better understanding of women's experiences in physics and astronomy, such as what drew them to the fields and what positive aspects helped them succeed. Understanding what drew women to physics and astronomy will help recruiters build outreach programs that can target women, who currently comprise 57% of undergraduate students (NCES, 2012). By documenting the helpful aspects of physics and astronomy educational pathways for women, department chairs and advisors could be better informed on how to set up their programs so that their female students will succeed. This may also result in creating an overall stronger community and department for all students. These results and methods may also help inform work to be done in other fields such as computer science and engineering, which also have low representations of women students.

This proposed research will help in these goals by thoroughly documenting women's experiences at the graduate level in physics and astronomy programs. As discussed, this is of particular importance because few other research projects have explored the graduate student stages of physics and astronomy. This documentation could be used to better inform graduate chairs on how to help their female students persist and inform them of their special concerns in graduate programs. Alongside this, the project will help strengthen a weak literature base on the educational pathways of women in physics and astronomy. Documentation of these pathways is needed to grasp the overall trajectories women are currently following and how they can be supported.

Lastly, by building research to help women into and through the field of physics, more women faculty may be produced who can act as role models and mentors for even more women students. This would not only increase the number of women entering physics, and thus the overall student numbers, but would also grant women access to the economic prosperity that often comes with work in STEM (Hazari, Sonnert, Sadler, & Shanahan, 2010). This goal has roots in social justice and seeks economic and academic equality for women students. Consequently, this project rises above merely adding greater numbers of students to physics, but also seeks to expand the overall equality and access of women to educational resources and prosperous futures.

The Researcher

This study addresses gender disparities in physics. My multidisciplinary background will support me in this interdisciplinary goal. It has been suggested that strong science may be derived from those who engage in many communities, and this assertion may hold true for social research as well (Fehr, 2011; Tuana, 1995). As a scholar, I have been a part of physics, gender, queer, and science education research communities. By participating in multiple research communities, I have gained a broader understanding of not only research methods, but the work that has been done across disciplinary lines. This gives me a stronger sensitivity to the experiences of women and the experiences that they may have had from interactions with many different persons and research initiatives.

My closeness to gender studies and the achievement of equality of women may cause potential biases in my analysis. As an advocate for equality my aim is to illuminate and describe the negative and discriminatory experiences of women. Due to this I will make sure to review all my conclusions in conjunction with an outside validator to ensure my bias is not revealing a reality that does not exist. In addition to this bias I may also not recognize specific women's experience due to my standpoint as a biological male and gender identifies man. To alleviate this concern the validator who will help me review the interviews and conclusions will be a woman who can use her standpoint to add to mine.

CHAPTER 2. REVIEW OF LITERATURE

Introduction

This chapter provides an overview of the existing research on women in physics. It focuses on three specific areas of research: (1) the low numbers of women in physics, (2) gender gap research and a move towards research from women's perspectives, and (3) women in undergraduate and graduate physics. These three areas were chosen because they illuminate the current state of research on women in physics, and in particular, a hole within this literature. Currently the bulk of research on women in physics focuses on descriptive statistics of their representation and how they do in comparison to men. The majority of this work has focused on the undergraduate level, with a few articles looking at issues of women in graduate physics.

This chapter is divided into four sections. Section (1) presents the basic statistics on women in physics at varying stages and juxtaposes them with astronomy when possible. Section (2) introduces readers to the research based on the widely used framing of the low representation of women in terms of a gender gap and argues that this framing fails to view women as a unique group within a male dominated culture. Section (3) outlines the relevant literature on women in undergraduate and graduate physics that is not based on the gender gap framework. Lastly, section (4) provides a synthesis and conclusions.

The main message resulting from this review is that: *The field of physics has a male-dominated culture where women are seen as outsiders. The field of astronomy requires preparation and graduate coursework similar to that of physics, yet manages to have a representation of women double that of physics. Few studies exist exploring and seeking to understand the lives of women graduate students in physics. No prior studies have sought to investigate the lives of graduate students (men or women) in the field of astronomy.*

What will be shown is that women are poorly represented in physics and most adapt to a male centric and male dominated culture. Within the literature a focus has been put on gender achievement differences of women and men in introductory physics courses as an explanation for women's underrepresentation. This mode of research should be exchanged for studies that look for understanding and meaning of women's experiences from their lives, while not comparing them to men. Such research has occurred at the undergraduate level and has been productive. This has been used as motivation for similar work at the graduate level, such as the research presented in this thesis.

Low Numbers of Women in Physics

The low numbers of women in physics are evident at every stage of the educational pathway. Currently women comprise only 22% of undergraduate physics majors, 18% of physics graduate students, and 15% of all faculty positions in physics (AIP, 2013). These poor showings of women in the field of physics are in spite of their overall dominance at the undergraduate level. Women currently comprise 57% of all undergraduate students and 38% of science and engineering undergraduate majors (NCES, 2012; NSF, 2012). Women have also made significant gains in graduate education and now receive 49% of all PhDs, and 36% of PhDs in science and engineering (Figure 2) (NSF, 2012). At the faculty level, women currently hold 35% of all positions within colleges and universities (NSF, 2012). Consequently, the role and positions of women in physics have severely lagged behind those of women academics overall.

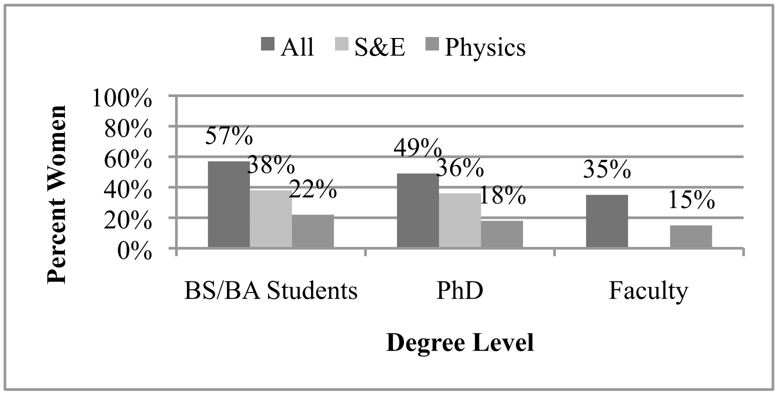

Figure 2 Women's representation in different roles in higher education institutions: BS/BA students, PhD students, and faculty. Each role is separated by discipline: all disciplines, science and engineering disciplines, and physics.

In addition to low numbers of women, those women who are in academic physics tend to be relegated to lower prestige positions. With respect to faculty, women have a higher representation at schools that only confer bachelor's degrees as the highest physics degree (17%) as compared to PhD granting institutions (12%) (AIP, 2013). These bachelors' institutions are generally seen as being less prestigious faculty positions than PhD granting research institutions. Even further, women have a much higher representation amongst instructors and adjunct faculty (21%) than in full-time tenure or tenure track positions (Figure 3).

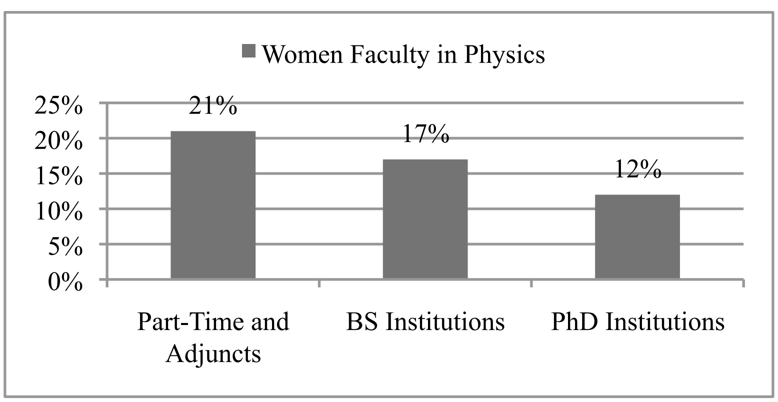

Figure 3 Women's representation in physics faculty positions

Within physics, however, there is an area which stand in stark contrast and has representations of women larger than the field overall. This field is astronomy.

Astronomy is very similar in content and educational requirements to physics overall, and astronomy is even frequently a part of the physics department. Yet, astronomy vs. physics manifest very different representations of women at all levels. Astronomy's representation of women is 35% at the undergraduate level, 40% at the graduate level, and 17% at the faculty level (AIP, 2013)(Figure 4).

It should be noted that astronomy is much smaller than physics overall. As reported by the American Institute of Physics, annually there are over 2,000 new first year students in physics and 200 in astronomy (AIP, 2013). Astronomy is much smaller than physics (by a factor of 10) but shows a much higher gender diversity. An important hole in the research that this study hopes to fill is that little to no prior research has discussed this difference or considered women in astronomy.

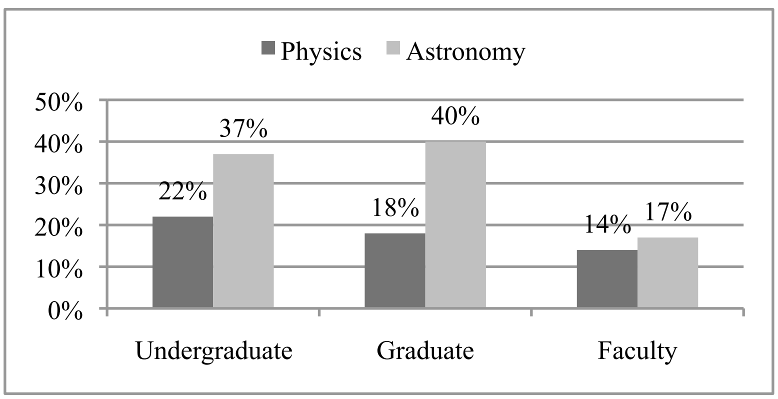

Figure 4 Representations of women in physics and astronomy

Summary

As demonstrated above, women are severely underrepresented in the field of physics, but have a higher representation in the smaller, but highly similar field of astronomy. The following section will review literature concerning women in physics. This review will begin by considering gender gap research, look at a strong example of exemplary work on women undergraduate students in physics, and then conclude by looking at the literature on women graduate students in physics.

Moving Away From the Gender Gap: A View From the Lives of Women

This section reviews research on the gender gap in physics. An important conclusion is that this widely used framing of the problem of women's underrepresentation only in terms of a gender gap is not productive. Future research should instead seek to explore the experiences of women in physics without a comparison to men. Research on women should be woman-centric and from the viewpoint of their lives.

The most common type of gender gap research in physics is grounded in the well-documented gender achievement differences in the introductory physics courses and attempts to understand and remedy them. Three such seminal pieces will be discussed here (Lorenzo, Crouch, & Mazur, 2006; Miyake et al., 2010; Pollock, Finkelstein, & Kost, 2007). Lorenzo, Crouch, and Mazur (2006) studied the gender gap in their introductory calculus-based physics courses. Between 1990 and 1997 Lorenzo et al. (2006) collected data on the achievement differences of men and women from over 1,000 students as measured by the Force Concept Inventory (FCI) and Mechanics Baseline Test (Hestenes, Wells, & Swackhamer, 1992). Within these years the course was taught in three different styles: traditional lectures, lecture with peer instruction, and peer instruction with tutorials. The researchers found that the gender differences in achievement on conceptual inventories (the gender gap) disappeared in the fully interactive (peer instruction with tutorials) courses.

Their work, however, was refuted by Pollock et al. (2007) who showed that the gender gap was not closed for students in a different large research intensive university in courses taught with interactive methods (Pollock et al., 2007). Their results, based on 3,000 students in introductory physics, found a gender gap still emerged in student learning. This gap was measured by difference in achievement on the FCI. The authors were quick to point out that this did not manifest itself in the overall course grade, as men did score higher on exams but women scored higher on homework. These same scholars, later, did remove the gender gap through psychological interventions as will be described below (Miyake et al., 2010).

Miyake et al. (2010) approached solving the gender gap differently than previous studies (Miyake et al., 2010). In a study of 399 undergraduate students the researchers assigned students randomly to a control and experimental groups. The experimental group had to complete an assignment where they wrote about their values twice in the semester. Each intervention took only 15-20 minutes. This is known as values affirmation and is a psychological intervention. The control group did not have to write about their values. It was found that in the experimental group that the gender achievement gap was closed and women's grades were raised from the C to the B range. A follow up study by the same group found that values affirmations was only sufficient to increase women's grades and did not reduce the gender gap on concept inventories (Kost-Smith et al., 2011).

What can be seen from these examples of gender gap research is that results are often contradictory and do little to offer best practices to support women. These modes of research are insufficient in increasing women's representation in physics and increasing their persistence and success.

Recently, calls for research have suggested that scholars need to look beyond gaps and move away from comparisons of men and women (Danielsson, 2010, 2012). Following these calls, I argue that the focus on "gaps" is based on multiple problematic ideas. Included in these is the idea that men are the standard in science and women should be compared to men and assumed to aspire to be like men. Gender gap research also does not take into consideration the unique circumstances in women's lives that may not affect men, such as the role of socialization, gender expectations on women, safety concerns (i.e. working late in the lab), and maternal responsibilities that dwarf the paternal. Rather, women's experiences should be viewed as unique and assessed independently of those of men.

An example of proactive efforts that took into account women's experiences are the diversity efforts put forth at the Massachusetts Institute of Technology in the departments of science (MIT) (MIT, 2011). Through discussions of the experiences of women faculty that involved faculty and administrators, an action plan was put in place in the late 90's to overcome the barriers women were experiencing. In one decade the university managed to raise the number of women faculty in science by

11%, remove barriers for junior women faculty to have children, fix pay inequities, and more. Though activities and results were not documented by rigorous research, this is an example of an effort to support women's experiences and success by understanding their problems from their perspectives. MIT attempted to change the culture at their university and there is evidence that these efforts were successful.

The Culture of Physics

Several researchers have studied the culture of science (e.g., Keller, 1985) or, more specifically the culture of physics (Danielsson, 2010, 2012; Gonsalves, 2011, 2012; Traweek, 1988). Sharon Traweek's (1988) book was a landmark study of the culture of physics. She embedded herself in high-energy physics labs world-wide and collected data through interviews and observations. She lived at the labs while collecting data and became a part of their culture, to gain a full understanding of their inner workings.

Her in-depth ethnography of high energy physicists found a community that was described by its inhabitants as being "a culture of no culture" (Traweek, 1988, p. 144). Her book highlighted the field of physics as valuing itself for extreme objectivity and rationality while not being concerned with issues of the outside world. Physicists in Traweek's (1988) work described the importance of objectivity and suggested that physics was genderless and unrelated to culture. Within their "no culture", though, there was intensive competition, aims for prestige, political games to gain experimental time, and no concern with lack of gender diversity. Clearly a culture did exist, and one which was filled with masculine ideals. Their ideal of objectivity, as well, seemed to be thrown aside in their political struggles as Traweek (1988) explained the crucial role of nepotism in selection of post doctorate scholars.

Gonsalves (2011) has supported Danielsson's (2010, 2012) claim that research needs to move beyond gender gaps by studying the symbolic masculinity in physics through interviews with 11 men and women graduate students in a physics over an eight month period. Symbolic masculinity in physics is the predisposition of the field to be portrayed as masculine and support masculine qualities such as extreme objectivity and competition. Gonsalves (2011) explained that “the symbolic masculinity of physics reifies an understanding of women as an always, already gendered category that is naturally situated in opposition to physics” (Gonsalves, 2011, p. 119). What this quote implies is that physics is described and understood to be a masculine field, but at the same time is viewed as being gender neutral by community members. Consequently, when women participate in physics their gender is immediately apparent and seen in contrast to what physics is and who should be doing physics.

She found that participants largely regarded physics as the pinnacle of science due to its difficulty and rigor. With this understanding, the participants saw physics to be gender neutral while simultaneously placing traditionally feminine characteristics as being incompatible with physics. For example, femininity, through the lens of one woman participant, was seen as illogical and silly. She specifically distanced herself from "girly" girls and the act of wearing high heels and dresses, which were things seen as being incompatible with physics. This reflection was part of an overall trend of women redefining their gender to distance themselves from traditional female characteristics in an effort to become a part of physics. What was fascinating in this analysis of discourse was that physics was seen as being genderless, but only as long as there was no femininity. Gendering of physics also emerged in the kinds of work that students did, with women performing work that did not require strength, but “delicate” hands. In the specific example referenced in her paper, a woman student discussed being the only lab member who reached into a detector and set up small experimental equipment. Further work by Gonsalves (2012) showed that these women became a part of the physics community by dressing masculine and hiding their femininity. They felt that to be physicists they had to separate themselves from the feminine. Men in these studies also followed these patterns.

This mode of research is being continued in other more modern work, such as Danielsson (2010) where processes of becoming a physicist and acting as a man and woman were considered together. For women to participate in physics they had to also be aware of their gender and perform as men.

Summary

As these studies have demonstrated, the culture of physics is an important issue to study in order to understand women's experiences. The picture of physics as a man-dominated masculine-centric culture, where women must masculinize and remove their femininity, suggests that women do truly have a unique standpoint and position within the field. Women who enter the field cannot act feminine, or their values and behaviors will conflict with those of physics.

Gapless Research: Women in Undergraduate and Graduate Physics

With an understanding of the need to move away from gender gap research and the necessity to understand women's unique position in physics, it is possible to begin exploring relevant literature in this pursuit. The following section will discuss studies concerning women in physics at the undergraduate and graduate level that is not focused on gender gaps. Within this literature it will be seen that significant work, by one team of researchers, has pursued the issues of women in undergraduate physics. However, little thorough research has been done to assess women's experiences in graduate physics. The work that has been done at the undergraduate level is a good starting point for considering projects at the graduate level

Undergraduate Research: Whitten et al. (2003, 2004, 2007)

There are few studies directly investigating the lives of women in physics without comparisons to men. The most prominent of these is a series of publications that focus directly on the lives and needs of women at undergraduate institutions. These are ethnographic studies conducted by Whitten et al. (2003, 2004, 2007). In these studies, Whitten et al. investigated the lives of women students at undergraduate institutions and identified common characteristics that support women. These investigations were done both at mixed gender schools (Whitten et al., 2004; Whitten et al., 2003) and all women's colleges (Whitten et al., 2007). The following paragraphs will describe the methods of the study followed by a summary and analysis of important findings from the (2003) and (2007) paper.

Whitten et al. (2003) was the flagship study and also provided results for the (2004) publication. This study sent teams of women physicists to nine undergraduate institutions to collect data over a two-day period at each school. Schools were chosen that only had undergraduate physics programs and had a participation of women in the physics major between 15% and 17%. Five schools were chosen that fit into this category, and 4 were chosen that ranked better on this measure. The team consisted of two faculty, and one recent physics undergraduate student. One senior faculty researcher and the recent undergraduate were present at each visit; the third faculty member of the data collection team rotated for each visit . Data collection included interviews with provosts and deans; focus groups with faculty and students; and analysis of curricula. The faculty researchers collected all of the faculty and administrator data while the bachelor's level physicist collected the student data. This was intentional, so the research participants would see the interviewers as peers.

Analysis of curricula was explicitly looking for innovative teaching strategies that may be attractive to students. In all nine schools only traditional curricula were found. An important model that evolved from the results was a model to encompass the necessary components to support undergraduate women in physics; the model of a loom. A second model also came out the (2007) publication, which used similar methodology to study all women's colleges. This was the pathways model, that suggested women's entrance into physics cannot be seen as a linear pipeline but rather as a set of varying pathways. The following two subsections will explore the model of the loom and the pathways model. A third concluding section will synthesize their meaning and use in future research.

These two models originate from woman-centric research that offers tangible results and best practices to support women students. Such research could easily be transported into studies on women graduate students in physics. Consequently the methods and results of Whitten and her colleagues will be used in the creation of the project proposed here.

The Loom Model

"Male students can survive cold climates better than women, but all students are benefited by "warming up" the department culture….We have adopted the metaphor of a loom to describe this culture"
(Whitten et al., 2003, p. 244)

Whitten and colleagues described the factors that built a female-friendly climate using the metaphor of a loom, which supports the faculty and department, as well as the students, in a way that encourages academic success. They chose the loom because in a loom each piece in the frame and thread in the warp and weft are necessary for its sound structure. They believed that there was no one "silver bullet" for women's success and that fostering a female friendly environment required constant work and to address many issues.

According to Whitten et al. (2003, p. 244). "Institutional and departmental structures form the framework of the loom, supporting faculty members and students in their work." Additionally, "The faculty members form the warp of the fabric, providing continuity and structure. The students provide the weft, interacting with faculty members and one another to create a strong fabric" (2003, p. 244). Whitten et al. (2003) used this metaphor to structure their results as well. In the next few sections the main components of the loom model will be outlined with key findings. The original model can be seen in figure 1 in the original publication (Whitten et al., 2003).

The Loom

The first part of the model is the loom itself, or the frame. Whitten et al. (2003) equated this part of the metaphor as relating to the faculty in the department. Their belief was that a female-friendly environment was started and supported primarily by the faculty. Aspects of this part of the model included both actions the faculty took for the students and also for themselves:

> *A successful institution provides support for its faculty members in both their personal and professional lives. Mentoring programs should be available to junior faculty members, and*

they should be provided with enough resources to begin productive research programs. Family-friendly policies on "women's issues" such as family leave, slowing the tenure clock for childbirth, support for two-career families, and the existence of an on- campus child care facility are all important for most women and for many junior male faculty members. (Whitten et al., 2003, p. 245)

First, the faculty need to create a positive environment for themselves. To Whitten et al. (2003) it was critical that departmental faculty supported one another beyond just their research and teaching, they concluded that they need to make sure the environment was friendly for their private lives as well. Particularly for familial responsibilities, this included family leave, childcare, and accommodating dual career spouses. The section concluded by warning that deans and administrators need to be particularly cautious about their expectations of junior faculty. For example, a major concern of the participants was that junior faculty were expected to come up with undergraduate student research projects, which was slowing down their productivity and potential success for tenure.

The Warp

The next metaphoric piece was the warp, which is the vertical threads in the loom. The warp, as with the loom itself, focused on faculty. This piece, however, concerned how the faculty created a culture for the students. In the description of the warp Whitten et al. (2003) recognized that women, generally, are socially reared to thrive in different cultures than men:

A warm and inclusive department culture benefits all students but has a differentially large impact on women. This is partly because women are socialized to value personal interactions and partly because women are more isolated in the largely male culture of physics. In a cold department, it is easier for male students to create a support structure of study groups, peer friendships, and so on (pg. 24).

Components of the warp included making introductory courses that were progressive and interesting, having readily available four year mentoring for all majors, spending money on students so they may do research and have experiences in physics (i.e. attend a conference), conducting outreach and recruiting, and ensure a female friendly atmosphere. Creating this female friendly atmosphere, what they sometimes labeled as culture, included many points. The article suggested things like a constant monitoring for sexist language, encouraging student-faculty research, and ensuring that female students felt physically safe coming to the department and working at night. Many of these concerns were issues specific to women that may not encumber or be considered by men. Another unique suggestion was that physics should be seen as a field with more diverse applications, such as the environment. This altruistic approach was said to be important for women and students of colors when they choose their majors (Seymour & Hewitt, 1997).

The Weft

The last part of the loom model is the weft, which is the horizontal threads that cross with the vertical to form the fabric held on and created by the structure of the loom; this metaphorical part is built by the students. Whitten at al. (2003) suggests that students do the bulk of the work creating the culture after the faculty provide a structure. For such a culture to work students need to mentor and support one another in a system where more senior students help the junior students. This might include, for example, students staffing tutor labs and running physics clubs. Whitten et al. (2003) argues that this both helps students take on leadership roles and reduces the burden on faculty.

The Loom Reconsidered

The loom model suggested by Whitten et al. (2003) describes a possible culture in physics departments that supports all students but takes into consideration the special concerns of women. The culture that is proposed by the loom stands in stark contrast to the cultures discussed by Traweek (1988), Gonsalves (2011), and Danielsson (2010). Whitten is arguing for a female-friendly culture that encompasses values important to women and that would also help men, such as peer support and viewing physics more broadly. This model starts with faculty (the loom frame and warp) and is synched together by the students (the weft). Whitten and her colleagues have shown that it is possible to create female-friendly culture, and in doing so also support male students.

The loom model addressed building a culture that was accepting and supportive of women, but did not address how women choose physics in the first place. In a follow up study of physics departments at all women's college Whitten et al. (2007) considered this issue, and came up with a model of women's entrance and persistence into physics.

The Pathways Model

This section will outline the pathways model suggested by Whitten et al. (2007) juxtaposed with supporting literature. The pathway model by Whitten et. al. (2007) argued that women's academic trajectories cannot be modeled, as is commonly done, by a linear pipeline (Whitten et al., 2007). She suggests that such a linear pipeline does not accommodate students from nontraditional backgrounds. The pipeline infers that students choose physics as a major straight from high school and eventually become faculty. This linear model argues that women "leak" from the pipeline and these leaks need to be plugged in order to raise the number of women in physics (Blickenstaff, 2005; Whitten et al., 2007). For instance, women comprise 47% of high-school physics students but only 22% of undergraduate majors (AIP, 2013). Thus, the problem of low representation of women is often framed as the problem of retaining more of the initial 47% of women. Whitten et. al. (2007) argued that the pipeline needs to be re-envisioned as a series of pathways where students can enter from a variety of directions. Such students could include undeclared majors or older students coming back to school.

The pipeline model falls apart for women because it does not represent how they enter the field. The pipeline model assumes that students enter into a STEM major and leak out before graduation. However, in a survey of 10,000 undergraduate students it was found that only 32% of women who ended with a STEM degree began college with that major in comparison to 53% of men (Xie & Shauman, 2003). In contrast, 54% of women who ended with a STEM degree switched in from a non-STEM major as compared to 32% of men (Xie & Shauman, 2003). A majority of women are switching into STEM during college and not choosing it at the end of high school. Consequently, the pipeline model is clearly missing important aspects of the situation and only works for about 1/3 of women in STEM.

In physics, no pipeline leak is apparent. When controlling for historical output of PhDs in physics, no leak between graduate women numbers and faculty numbers is apparent (Ivie, 2011; NAP, 2008). And the "leak" between undergraduate and graduate degrees is also rather small (about 2-4% depending on the source of numbers) (Ivie, 2011; NSF, 2012). This further supports Whitten et al.'s (2007) idea that the pipeline model is not able to explain the low representation of women in physics and, thus, cannot be expected to help solve this problem.

Whitten Revisited

Whitten and her colleagues approached studying women in physics differently than had been done previously. They collected broad data at undergraduate institutions without any comparisons to men in order to understand women's experiences, and how physics can be reconceptualized to include and support women. Their data was woman-centric, although it did include views, ideas, and data from men in the departments. An interesting claim in Whitten et al. (2003) was that departments did not actually need women faculty, what they needed was a reformed departmental culture. It was argued that women faculty help, but are not a fix. Culture is what matters. And this culture is built first by faculty and then instituted and supported by the students.

Whitten's work ends with undergraduate students and did not included graduate education. Her methods and approach, however, appear to be applicable in explorations of women's graduate experiences in physics. In addition to the culturally-framed work by Gonsalves and Danielsson described earlier, a few other articles do exist that look at the lives of women in graduate physics. Three such articles could be located in the literature in the last three decades (Curtin, Blake, & Cassagnau, 1997; Dabney & Tai, 2013; Hollenshead, Younce, & Wenzel, 1994). The next section will relate these three articles to the work pursued by Whitten and her colleagues. It will be concluded that work at graduate level should include an approach similar to Whitten and her colleagues.

Women Graduate Students in Physics

As demonstrated above much work focusing on women in physics has addressed undergraduate students. Fewer research articles have specifically addressed women graduate students in physics. Of the five such articles that I was able to identify, two (Danielsson, 2010; Gonsalves, 2012) have been discussed previously. These two articles were focused on the culture of physics in general, of which graduate students were a part, and found that women persisted in a male dominated culture. This section of the literature review will focus specifically on the other three articles concerning women in graduate physics to summarize and synthesize their results. An important finding of these articles is that women experience chilly climates and face issues of discouragement and uncertain career paths due to concerns over work-life balance.

Hollenshead et al. (1994) studied the lives of women graduate students in physics and mathematics through the use of two focus group interviews. There were 23 total participants broken into two focus groups based on who had (N=12) and had not (N=11) passed their qualifying examination. Themes were presented that were openly discussed in the focus group, which included: encouragement, competition, and sexist attitudes. Within the participants it was seen that encouragement was key to their success, often to overcome sexist attitudes and advice that suggested they were not cut out for the rigors of physics.

This included an episode where a woman, as an undergraduate, was told she wasn't good enough for graduate school and shouldn't apply to top schools. With the support of her father, who had experience in academia, she still applied and got into the program she was told she could never get into or succeed in. Support was also important from faculty, which included both men and women role models. The most interesting result, however, was the difference between the focus group who had passed their qualifying exam and the group who did not.

Hollenshead et al. (1994) reported that the group who had not passed their qualifying exams was very open about their sexist experiences, challenges they faced, and the barriers in their lives. However, the group who had passed their qualifying exams was more quiet, reserved, and closed off about their experiences. Hollenshead et al. (1994) labeled these students as *survivors*. She explained them to be students who had made it through and suggested the students who have survived are inherently different than those who do not. The survivors were more reserved and didn't speak freely of their issues, they had developed methods to succeed and cope. Part of these methods was silence and blending in. This can be seen as similar to the women in Gonsalves (2011) and Danielsson (2010) who found ways to adapt to the culture of physics. These women had the characteristics necessary to persist.

Curtin et al. (1997) conducted interviews with women and men graduate students at 17 departments that had graduate programs in physics. Departments were self-selected after being invited to participate. Two departments, however, asked the team to visit due to a perceived need. No specifics were given on the number of graduate students interviewed. This study, actually, was the predecessor to the work pursued by Whitten and her colleagues above.

Interview excerpts revealed that women experienced sexist language, discriminatory action against them, and lamented about the lack of women faculty. Responses to a climate survey indicated that women, more often than men, suffered from discouragement from the departmental climate and concerns about long term employment after completing their degree. Women also reported less collegial interactions with their advisors than men. The authors concluded by saying that men's and women's experiences were similar, but women's were statistically significantly more negative. The results were combined together to form 10 best practices for supporting women in graduate physics. Some suggestions included hiring more women faculty and accommodating students with children.

The last study to be considered is much more recent and focused on a secondary analysis interviews with eight women graduate students in physics, as well as two faculty members and a post doctorate fellow (Dabney & Tai, 2013). Interviews were analyzed from a larger project investigating the transition of graduate students to becoming independent researchers. In all, 11 interviews were conducted. To analyze the data the authors created a code list from the literature. Each interview was analyzed with codes being applied, as well as developing emergent codes that were also then applied.

Dabney and Tai (2013) focused on very different ideas than Hollenshead et al. (1994) and Curtin et al. (1997). They reported, primarily, on the career concerns of women participants and the role of work life balance predictions in their career goals. It was found that women in physics felt isolated from their families and that they could not continue working the way they were in graduate school indefinitely. A few specifically reported wanting to seek jobs at teaching intensive universities to avoid their current lives.

Similar findings to these were found in another field, chemistry. In a qualitative study of women graduate students in chemistry Grunert and Bodner (2011) found that women chemists did not want to pursue careers at research intensive universities as they perceived the need to work 80 hours a week. Their life goals were not well suited for this lifestyle and they were making predetermined career goals around this perception. If women in physics are also making decisions such as this, it may explain their higher overall representation in part-time and bachelor's level institutions as reported earlier (Figure 4).

What is clear from addressing these three studies is that women are facing barriers in physics. Hollenshead et al. (1994) and Curtin et al. (1994) found similar themes of discouragement and sexist attitudes. Dabney et al. (2013) showed that women were uncertain about the demands of their future careers. This study was also limited in that it was a secondary analysis, so ideas of encouragement and sexism may not have been discussed. These studies cumulatively demonstrate a culture of physics as masculine and not compatible with women's values and characteristics. These studies, however, are also dated. Some of this research is nearly twenty years old and may not reflect current situations. A significant critique of these projects, as well, is that they did not produce theory or workable models such as those from Whitten and her colleagues. Future work should seek to do more than just explain the experiences of women, they should seek to generate meaningful understandings of women's experiences and develop theoretical models as did Whitten et al. (2003, 2004, 2007).

Conclusion

This chapter explored the educational experiences of women in physics. At the undergraduate level, by moving away from assessing gaps in learning, research has better revealed women's experiences and developed models and ideas to make departments more female friendly. This was clearly on display in the work by Whitten et al. (2003, 2004, 2007). By producing two useful models Whitten and her colleagues have generated research that suggests how to support women into and through physics. They also managed to show aspects of a new kind of physics culture that would promote women's success by changing the current male-centered attitudes, beliefs, and institutionalized structures.

The level of breadth and sophistication of the work at the graduate level leaves much to be desired or is outdated. The themes, however, did reveal the same culture found by Gonsalves (2011) and Danielsson (2010) of male dominance and sexist attitudes. Future research in the area of women graduate students in physics may want to attempt to recreate the work by Whitten and her colleagues and see if the support elements at the undergraduate level are also apparent or relevant for women in graduate programs.

The result by Dabney and Tai (2013) that women do not see the traditional career model in physics as being what suits their ideas of a good career path may be remedied by applying Whitten et al.'s (2007) pathways model. It may be that women's eventual careers should be modeled as their entrance into physics, as a series of pathways to varying and unique careers that fit their life circumstances. For example, a woman physics PhD may decide she wants to work at a community college teaching physics so she is not required at the lab during evenings.

What is clear from all of this is that work at the graduate level is needed. Such work should utilize existent frameworks to explore issues of women in physics, particularly the pathways model from Whitten et al. (2007) and the model of the loom (Whitten et al., 2003). Considering that results from both Curtin et al. (1997) and Whitten et al. (2003) suggest the need for women faculty, it may be that culture in departments change when women are present, active community members, and visible to students. This claim further suggests that a study of women graduate students in physics may benefit from a comparison to women graduate students in astronomy. Such a study would compare similar fields that have similar scholastic requirements yet very different representations of women to reveal experiential and cultural differences. Chapter 3 describes such a project.

CHAPTER 3. METHODOLOGY

Overview of Research Goals

The goal of this research is to understand women's experiences as undergraduate and graduate students in physics and astronomy. Through in-depth interviews this research collects the lived experiences of women in these two fields in order to answer four research questions that highlight four important areas of a woman's educational experience: (1) their undergraduate experiences, (2) their graduate experiences, (3) their career goals, and (4) their unique gendered experiences in the field.

I. *What experiences as an undergraduate student helped these women persist in their field?*
II. *What experiences as a graduate student helped these women persist in their field?*
III. *What are these participants' desired career pathway after graduate school, and what shaped these goals?*
IV. *What are the distinctly gendered experiences that these women have had in physics and astronomy?*

These four questions are tied directly to the literature discussed in Chapter 2. The first question will help confirm, augment, or correct Whitten's findings in her study of physics undergraduates. The second question will extrapolate the little work that was found addressing women in graduate physics programs. The third question will show if these career concerns reported in the literature are important to these women. Lastly, the fourth question will help to document components of a graduate experience that are distinctly gendered and may impact a woman's career. This has not been explored at all in the literature, and would add a missing piece.

Research Methodology

This section outlines the theoretical framework and research methods employed in this project. By using a Feminist Stand Point Theory lens, this project recognizes women as providing a unique perspective on the field and culture of physics because women must navigate multiple identities (Harding, 1991, 2001, 2009). These identities could include, for example, being a woman, being a physicist, being from a marginalized group, and being a mother. To collect these experiences, in-depth in-person interviews were conducted with women PhD students in physics and astronomy. These interviews were analyzed through qualitative coding to answer the four research questions.

The research methodology will be discussed in six sub-sections. The first sub-section describes the theoretical framework and its implications for the study. The second gives an overview of the research design and chosen methodology. The third explains the process of selecting study participants. The fourth outlines data collection, which was done in the form of in-depth interviews. The fifth explains the method of analysis, which includes coding, biographical narratives, and theme construction with the help of a validator. Lastly, the sixth section addresses the role of the researcher and validator in the research process.

Theoretical Framework

As was demonstrated in the literature review, women hold a unique position in physics. Their experience of the physics educational pathway is different from their male peers, in that they are outsiders within (Harding, 2001). They represent an identity and social category that is scantly present within physics, and they are often required to hide or change their behaviors in order to assimilate with the culture of the department (Gonsalves, 2012). In light of this, it is necessary to choose a framework that can accommodate women's unique standing in physics. The framework chosen to do this is Feminist Stand Point Theory (FST) (Anderson, 2012; Brooks, 2007; Harding, 2001, 2009).

FST takes into account women's social location and recognizes this position as one of epistemic privilege. The following paragraphs will describe FST and explain why it is an appropriate theoretical framework to use in this project. It will be shown that FST works to reveal women's experiences from their point of views, and this tactic in the study of physicists will help to unveil new knowledge about women's experiences that are not juxtaposed to men.

FST recognizes the "differences between women's and men's situations which give a scientific advantage to those who can make use of the differences" (Harding, 2001, p. 145). In other words, women have a historically contextualized viewpoint in which they see the world from. Their systematic oppression across time and culture creates a unique modern context for their exploration of a male dominated field such as physics. If research can leverage this knowledge of women's unique viewpoint, they may be able to generate important knowledge about women's experiences. FST argues that data collection should begin from the lives of women, as they have an epistemic privilege. This privilege comes from their social location of being outside the dominant group, and outside of those in positions of power (Harding, 2001). In other words, women in physics experience their educational path as both women and physicists, while men only experience it as physicists. This gives women two viewpoints from which to assess their experience.

This relates back to the previous discussion of the male-dominated culture of physics. Because women must persist in a culture that men created and largely control, they navigate the setting as both physicists and women. This gives women who are aware of their standpoint the ability to see cultural aspects that men may not. They may be aware of issues that men are not because men do not have to acknowledge these issues to function efficiently. This may include issues like not being seen as competent, facing sexual harassment from peers, and the challenges of child rearing as a mother in physics.

This stance in standpoint theory is directly related to Marxist philosophy, which understands the view of the proletariat to hold greater truth than the view of the bourgeoisie (Anderson, 2012). This analogy, however, is dangerous, because it comes with a binary baggage. It assumes that men and women are cleanly divided into two groups, but women can hold multiple identities that intersect and interact to create a wide array of social locations in which they may exist (Collins, 1990). Such interactions may include women of color, lesbians, women with disabilities, or women from a low socio-economic status. Because of this, it is important to conduct research that involves women with intersecting identities, while understanding there may exist many differences within any one group of women. This viewpoint sees women as a heterogeneous mix of lived realities. FST collects data from women and creates models of understanding from their lives in recognition of their unique social location.

In physics, using FST means recognizing that women are outsiders. Women are a social class of people who did not participate in the construction of physics and the pathways to become a physicist. Their knowledge and voices are not heard, largely, in the physics community. This can be seen in studies of physicists where mostly men are the participants who describe their (men's) culture and their (men's) experience, partially because women are physically not there (Hermanowicz, 2009; Traweek, 1988). FST seeks to give voice to marginalized persons, and women in physics are both scarce and marginalized. Consequently, FST can help in the goals of recognizing women's position and collecting data from their viewpoint and lives.

Although FST suggests women have epistemic privilege, it is also argues that research should come from the lives of women even if the researcher is not coming from that social location (Harding, 1991). In this, the role of a male doing feminist work is mitigated. This is particularly true for this project as the male researcher also comes from the standpoint of a queer Hispanic male in physics, and he may gain some epistemic privilege himself from his varying viewpoints. To support the trustworthiness of the research a validator was employed who has identities different from the main researcher and thus comes from a different standpoint herself. By bringing together multiple standpoints in the research process, a stronger objectivity is formed and more reliability is gained (Anderson, 2012).

This FST framework has practical implications for data collection and analysis. FST seeks to generate knowledge from women's experience without imposing the views of others. FST informed the construction of open-ended questions that do not guide or lead participants. It also influenced the data collection by informing the interviewer to talk about what the participant wants to talk about, and explore ideas important to them that may not have been considered by the researcher. In the analysis phase, FST suggests that the researcher will constantly think carefully about the experiences of the participants and how they may have been shaped by their outsider status. It will also influence the researchers to continually inspect their own projection of their experiences on the women, and make sure the interpretations stem directly from the data.

Research Design

This project utilizes qualitative research methodology to answer the four main research questions. Data was collected through the use of face-to-face in-depth interviews that were subsequently transcribed and qualitatively coded. Analysis involved the development of codes which were then used to construct larger themes (Creswell, 2007; Marshall & Rossman, 2011). In the analysis process a validator worked with the main researcher to ensure accurate analysis. The following sections outline this process in detail.

Sampling, Subjects, Access, and Setting

This study will explicitly focus on women graduate students in physics, and astronomy. The subjects recruited will need to meet three specific requirements to participate:

I. *Gender identify as a woman.*
II. *Be pursuing a PhD in astronomy, physics, or astrophysics.*
III. *Have passed their qualifying examinations (or equivalent).*

The first two requirements are to ensure that the research is collecting data from the intended demographic. The third requirement controls for the success and year of the participants. By interviewing women who have passed their qualifying examination, I am collecting data from a group of participants who have demonstrated that they have the content expertise to succeed in their PhD programs. The qualifying exam is a step in most physics PhD programs where students are tested for their content knowledge and must pass to continue in the program. Students who fail the exam are often given a master's degree and ejected from the PhD program. Previous research on women in physics has suggested that students who have and have not passed their qualifying exams are different (Hollenshead et al., 1994). By holding this as a requirement, it controls for one more variable in the project.

To recruit participants, the investigator first created an email list of potential candidates at three US institutions. One of these institutions were selected for ease of travel to conduct a pilot study, and the other two were selected based on their programs having prominent research agendas in astronomy and physics. All applicable students at these universities were targeted for recruitment in the full study but not during the pilot study. The candidate email list was populated by consulting online department websites and through contacting research group leaders. The initial contact email outlined the study and asked for volunteers. Once all volunteers were identified, another email asked for demographic information and sent a letter of consent describing all the risks and benefits of the project (Creswell, 2007). It has been suggested that 20-30 participants are sufficient for a qualitative research project and this will be the goal here (Creswell, 2007). This study included 21 participants in total, more details can be found in Chapter 3.

All interviews were done in person during weekend-long site visits for the pilot study and weeklong site visits for the full study. The location and time of the interviews were decided between the researcher and participant based on mutual convenience. The location was selected to offer a place where the participant can discuss their experiences freely and not be restrained by near persons or potential fear of loss of confidentiality. This is in line with research methodology that suggests the situation and context of data collection can affect the results (Hesse-Biber, 2007). It is necessary to create a setting that allows for optimal discussion and comfort. Typical locations included coffee shops, offices, conference rooms, and even sitting on the water or being cramped in a storage room. All of these locations were chosen by the participants.

Data Collection Methods, Procedures and Instrumentation

Data was collected via one-on-one, in-depth interviews (Creswell, 2007; Hesse-Biber, 2007) based around six main questions. The goal of this data collection methodology was to allow the participant to tell her story in a way meaningful to her and allow her to bring up experiences and stories that she sees as important. The interviewer posed additional follow-up questions as appropriate to allow him to understand the interviewee's experiences as deeply as possible. Follow-up questions revolved around themes such as advisors, undergraduate research, family, and career goals.

The interview protocol is a list of themed questions to be discussed through the conversational interviews. This protocol was designed using five open-ended questions as suggested by Creswell (2007). Open-ended questions are broad questions that allow participants to respond in a wide array of ways. This allows the participant to choose to discuss what is important to him or her, but central to a theme of interest to the researcher. A final sixth question was added to leave all interviews on a positive aspect of the participants' experiences. This strategy was adopted from a 2009 study of physics faculty where the author left all faculty members discussing a positive aspect of their careers at the end of each interview (Hermanowicz, 2009). The themed questions that were used as an interview protocol are listed below:

1. Tell me about the pathways that led you to physics.
2. Tell me about your experiences as an undergraduate student in the classroom and with faculty.
3. Tell me about your experiences as a graduate student in the classroom and with faculty.
4. What are your current career plans?

5. How do you feel your experience has been different because you are a woman??
6. What accomplishments are you most proud of so far?

All of the participant interviews were audio recorded and transcribed verbatim by the interviewer or a hired transcriber (Marshall & Rossman, 2011). During the interviews, the researcher also took field notes in a journal, writing down ideas and impressions as the conversation progressed. Immediately following the interviews, the researcher wrote down his thoughts to provide additional insight during the analysis process.

Given the flexible nature of the interview protocol, the interviews differed somewhat from participant to participant, but the list of above prompts was always used (Hesse-Biber, 2007; Reinharz & Davidman, 1992). Consistent with FST, this flexibility allowed the researcher to pursue relevant ideas or events that are important in the participant's life, but that the researcher may not have considered. The first step in participant interviews, and most important, is building rapport (Creswell, 2007). It has been suggested that the interviewer can affect an interview and change the answers of a participant (Hesse-Biber, 2007). Ensuring participant comfort is key to prevent skewing data. Engaging early on with the participant is important so they can be comfortable with the researcher and their responses can be trusted. In order to foster participant comfort, each interview was preceded by casual conversation about the campus, the city in which the university is located, or many other topics.

Before the official interview and audio-recording began, the researcher engaged in conversation to discuss his intentions, the purpose of the research, and the roles the participant and interviewer play together. This set up the interview to be a collaborative encounter allowing co-production of data (Hesse-Biber, 2007, p. 180). Candid discussions about the researcher's role and background were designed to help the participant and interviewer "acknowledge difference" so they can "seek meaning" together (Hesse-Biber, 2007, p. 181). This was an attempt to truly give voice to participants and allow their stories to unfold while the researcher tries to listen very carefully and recognize his own ignorance when hearing the participant's experiences (Hesse-Biber, 2007, p. 183).

As stated above, each interview focused around six basic questions. In the course of the conversation the researcher ensured that all questions of interest had been addressed and did not necessarily address them in the order listed above. This recognizes the non-linearity of lived experiences and allowed participants to choose how they express their lives (Hesse-Biber, 2007). After the data was transcribed, it was be sent to the participants so that they had an opportunity to change or omit what they feel is appropriate. This practice is what truly makes this effort collaborative and gives the strongest voice to the participants.

Data Analysis

The researcher and a hired validator simultaneously went through the analysis process together to ensure trustworthiness in the process. This allowed the data to be seen from two different viewpoints. Analysis proceeded in an iterative cyclical process (Figure 5). This process began as soon as the first interview was conducted. The interviews were first read in their entirety and then coded line-by-line to look for actions and experiences (1) relevant to the participant's educational experience and pathway (Charmaz, 2006). These actions codes became part of a codebook that was used for future analysis. After the first interview, the analysis of subsequent interviews was compared to all past interviews to look for commonalities and potentially missed codes (2).

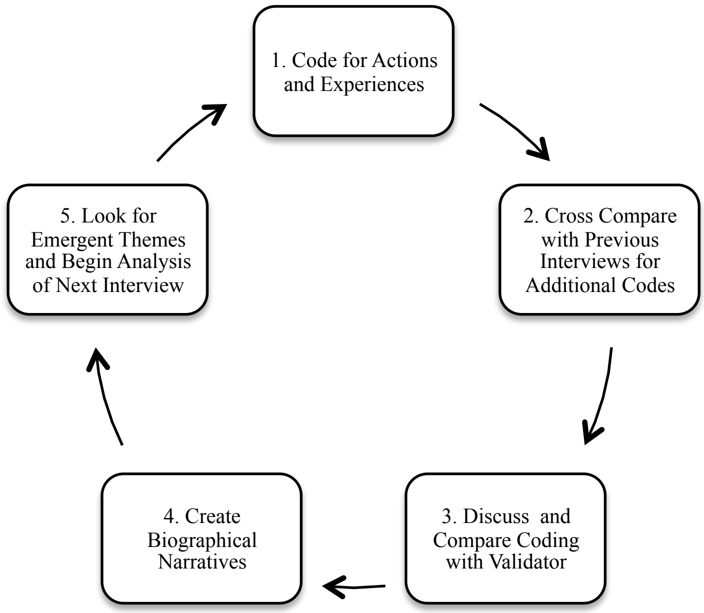

Figure 5 Procedure for analysis

The third phase of the analysis was a discussion and code comparison between the researcher and validator (3). Following this stage the main researcher created a biographical narrative for the participant that describes their lived experience and contextualizes the action codes within the participant's life. These were short hand written sketches that the author could refer to when thinking about codes associated with their experiences. (4). Lastly, the researcher and validator looked for groupings of codes across the interviews and used these groupings to develop themes (5). Themes are larger units of analysis that may describe multiple aspects of the participants' lives. For example, the codes of being *Ignored by Men*, *Giving Different Tasks,* and *Comments Towards Gender* would comprise the theme *Micro-Aggression.*

As with all qualitative research, methods used in this study involve are significantly influenced by the backgrounds and experiences of the researchers. The study was carefully designed to ensure rigorous results that can be trusted by others. This section will summarize the trustworthiness of this research following the commonly-used framework developed by Lincoln and Guba (1985). They suggest four approaches to ensure trustworthiness: (1) being in the setting for a long time, (2) sharing data with participants, (3) collecting multiple modes of data, and (4) sharing data with colleagues (Lincoln & Guba, 1985). The methods presented above support the trustworthiness of this study. Respectively, (1) the researcher stayed at two of the campuses for a weekend and two for a week to become immersed in the setting, (2) allowed for reflexive feedback from the participants on their interview transcripts, (3) collected data from multiple participants at multiple universities, and (4) discussed emerging results with the second analyst. The collection of multiple modes of data (3) was difficult because the content of interviews surrounded participant's pasts. Consequently, the best approach to fulfill this suggestion was be to capture data both in the form of demographics and their own interpretations of their lived experiences. Demographics illuminate more about individuals by showing the education of their parents, race identity, and degrees amongst others. These aspects of a person's life can impact their access to resources (economic privileged) and societal barriers put before them (race privilege). Taking these steps will help to ensure the trustworthiness of the analysis and results.

The Researcher

Within this study the researcher must acknowledge, accept, and contain his role as the research tool (Creswell, 2007). With regards to the participants, he shares many similarities but also has strong differences that could potentially affect his analysis and interpretations. It is his job as the research tool to be aware of potential biases to the largest extent possible and to develop research procedures to minimize the influence of these biases on his collection and interpretation of the stories of the participants (Marshall & Rossman, 2011).

As the researcher, I share several qualities of the participants. I am a graduate student in physics education, I am an "other" in academia twice over (a queer Hispanic), and I have conducted research in both physics and astronomy. I received a bachelors degree in astrophysics, completed the core curriculum of graduate physics as part of my masters degree in science education, and I worked at a national physics lab for four years to support myself when I was an undergraduate and graduate student. All of these qualities are similar, if not identical, to the participants I will interview. We have all experienced physics and astronomy deeply and throughout our young adult lives.

However, I cannot assume I have experienced these in the ways my participants have. I recognize that though I have done research in these fields, most of it was at the undergraduate level. Further, although I am an "other," I am not a woman. I have experienced these fields as a biological male and a gender-identified man. Therefore, I recognize that my experience is not the same and cannot be superimposed on my participants. However, I can draw on my experiences of marginalization to reflect on and attempt to understand the experiences of my participants.

As a graduate student who has studied physics, I also bring personal biases and opinions when talking about the field. As the researcher, I managed my own beliefs and biases by journaling about them throughout the project. When I came across an experience I have shared with a participant, it was be necessary for me to write about my experience and how it differs from that of the participant. I also journaled about how it could affect my results in an attempt to prevent this bias. The process of journaling helps to ensure trustworthiness of this study by allowing me to constantly reevaluating my analytical approach. This also helps me to become a stronger student, scholar, and person.

In addition to my personal efforts to control my biases as the researcher, I also enlisting a second researcher to participate in some of the data analysis activities. This will further support the trustworthiness of this study. A graduate student in sociology, Melinda McCormick, who specializes in qualitative research in issues of gender and religion served as this second researcher, or validator. Ms. McCormick coded and analyzed the data separately from me for comparison of our results. Ms. McCormick was able to approach the data from a different and complementary viewpoint. Ms. McCormick is a woman in graduate school and also a single mother. This standpoint allowed her to see codes and themes that were not always apparent to me as a man in graduate school who is not a parent.

Delimitations

The limitations of this study are many, but do not hinder the ability of the project to answer the specific research questions. Broadly, the project lacks the breadth of diversity within physics. By only involving significant data collection at two universities, the results may be significantly biased by individualized experiences that may only be associated with the two selected universities. Finally, as with all qualitative studies, the perspectives and backgrounds of the researcher will shape the results. As discussed above, efforts were made to reduce this limitation, but it is not possible to fully eliminate it.

Conclusion

To understand the experiences of graduate students in physics and astronomy in-depth interviews were be conducted with 21 women in physics or astronomy graduate programs at three research universities. All women graduate students in these fields who had passed their qualifying examinations were invited to participate in the study. Data collection and analysis was done with a feminist standpoint theory lens to ensure an adequate focus was put on women's unique position within physics. Analysis proceeded with a validator and within an iterative qualitative process focused on answering the four guiding research questions.

CHAPTER 4. RESULTS

This chapter presents results from the study. Each research question will be addressed in terms of relevant themes that emerged from this study. The chapter begins by describing the participants in the study and the analysis process.

Participants

Results presented in this chapter come from interviews with 21 women at three universities. Interview invitations were sent to over 57 women at these institutions. At one institution the invitation was sent to a "women in physics" group by a third party. Consequently, the total number of invitations was larger than 57, but unknown. Most potential participants were identified from the websites of three research universities. Email addresses of women were collected from their websites and by contacting specific faculty at each institution. All participants had passed their qualifying exams except for two, and two participants were also post doctorates at the time of their interviews. Including participants who fell slightly outside of the original three criteria was necessary considering the overall small numbers of women in academic physics and astronomy.

Participants in this study were selected from three research universities specifically chosen for their prominent graduate programs in physics and astronomy. All three universities had graduate physics and astronomy programs ranked as being in top 30 within the USA. Two of these astronomy programs were both ranked higher, being in the top ten nation wide. Only two interviews were conducted at the first institution, one in physics and one in astronomy. These were preliminary interviews to pilot the interview protocol and data collection. The majority of the interviews were conducted at institution 2 and 3. Institution 2 included 12 interviews, 7 in physics and five in astronomy. Two of the interviewees were post doctorate scholars at the time of interview, but the interview focused on their recent experiences as graduate students in physics.. The third institution included 7 interviews, 3 in physics and four in astronomy (Table 2).

Table 2 Participants by Institution		
	Physics	Astronomy
Institution 1	1	1
Institution 2	7	5
Institution 3	3	4
Total	11	10

All results will be provided using pseudonyms. Considering the small communities in which these participants work, more details on their demographics will not be given. This is done in order to actively protect their stories from being revealed to persons in the field, and respond to the concerns a few participants disclosed to me. Table 3 below lists all participants with their pseudonym and field.

Table 3 Participants

Astronomy	**Institution**	**Physics**	**Institution**
Janis	1	Stevie	1
Annie	2	Janet	2
Cyndi	2	Joni	2
Bishi	2	Tina	2
Pat	2	Joan	2
Kate	2	Marie	2
Barbra	3	Nancy	2
Melissa	3	Taylor	2
Paula	3	Susie	3
Sarah	3	Tori	3
		Olivia	3

Analyzing the Data to Develop Codes and Themes

The raw data used to answer the research questions were the interview transcripts. The analysis of these transcripts began as soon as the first transcript was typed. The first transcript was read without predetermined codes or looking for any particular experience or idea; this is known as open coding (Charmaz, 2006). The transcript was read carefully using the Hyper Research software package, which allowed the input of digital codes. These codes evolved from the transcripts and typically represented experiences or actions of the participant. For example, if the student described conducting undergraduate research this was marked as a code. Actions were also codes, for example if a participant worked with other students this was marked as a code.

The first transcript reading and application of codes began a cumulative codebook. The second and third transcripts were then read using this codebook to look for common experiences and actions. New codes also emerged. . Older transcripts were then re-read to apply newly found codes in a process called constant comparison (Charmaz, 2006; Creswell, 2007). In this way the older transcripts were constantly re-read when new interviews were conducted. In total there were 169 codes that were applied 814 times (See Appendix B).

In addition to applying codes to the transcripts, each transcript was discussed and surmised into written biographies to ensure that codes could be revisited in the contexts of their lives. The biographies were only about a paragraph in length and gave a oruch overview of the participant's life. This allowed the researcher to quickly refer back to their biography if he wanted to understand a code in the context of their life (See Appendix C for an example). In this process, a validator also coded the transcripts for discussion with the main analyst. Once the coding and biographical discussion process was complete greater meaning was given to the codes by assembling them into themes that addressed the four research questions.

Themes were groupings of codes that gave the individual codes greater meaning and the ability to address the four research questions. For example, some individual codes such as *Good Communication* and *Research Support* from faculty advisors would be put under the umbrella code of *Faculty Mentoring*. Such a theme is defined by the codes while also linking the individual codes together. In contrast to the open-ended coding, themes were specifically developed to answer the four research questions.

In total there were 17 final themes to answer the four research questions. These themes were comprised of the coded experiences of participants that related to the four areas of interest: (1) undergraduate experience, (2) graduate experience, (3) projected career, and (4) gendered experience. These themes are listed in Table 4 below with a definition.

Table 4 Themes

	Research Question	Frequency	Definition
Studied With Other Students (UG)	1	15	Studies with other students for home work and exams
Friends With Other Students (UG)	1	5	Developed friendships with other physics/astro majors outside of the classroom
Support from Post Doctorates (UG)	1	11	Had research and academic support from post doctorate scholars
Support From Faculty (UG)	1	9	Had research and academic support from faculty
Studied With Other Students (G)	2	16	Studies with other students for home work and exams
Friends With Other Students (G)	2	6	Developed friendships with other physics/astro majors outside of the classroom
Support from Post Doctorates (G)	2	6	Had research and academic support from post doctorate scholars
Support From Faculty (G)	2	8	Had research and academic support from faculty
Non-Academic Job	3	8	Wanted to pursue a job outside of academia (e.g. policy)
Teaching University	3	7	Wanted to pursue a tenure track job at a teaching intensive university
Research University	3	2	Wanted to pursue a tenure track career at a research intensive university
Not Sure	3	5	Did not know what they wanted to do for a career or had a large list with no particular goal
Wants Children	3	11	Wanted to have children
Children Compatible with Tenure Track Career	3	4	Thought it was possible to have a career on the tenure track and have children
Children Not Compatible with Tenure Track Career	3	5	Thought it was not possible to have a career on the tenure track and have children
Lifestyle	3	10	Had a particular lifestyle in mind that often involved time to pursue life goals beyond their careers (e.g. hobbies and a family)
Benign/None (Gender Discrimination)	4	5	Experienced no gender discrimination or felt being a woman was beneficial
Micro Aggression (Gender Discrimination)	4	7	Experienced micro aggressions, or rather, small experiences of subtle and sometimes unconscious gender discrimination
Egregious (Gender Discrimination)	4	5	Experienced over gender discrimination such as sexual harassment or assault

Using Themes to Answer the Research Questions

Participant responses that fit into each theme and pertained to the relevant research questions were then grouped into documents that were the accumulated knowledge of the participants' experiences. This allowed the validator and myself to brainstorm the overall meaning of these themes and easily compare each participant's experiences. These documents were read and discussed to gain a comprehensive understanding of how their experiences addressed each research question.

The following sections will present the results related to each research question. They will be addressed in terms of the relevant themes. The themes were not exclusionary and many participants are included in multiple themes answering a particular research question.

Research Question 1: *What experiences as an undergraduate student helped these women persist in their field?*

Each participant had her own unique story as to how she traversed and prospered in their undergraduate educations. It is possible to make the claim that they all prospered because each participant was interviewed as they were attending well-ranked graduate programs. Although every story is different, common themes arose that supported many of these women. These themes are: studying with other students, peer friendships, post doctorate support, and faculty support. The first two of these themes relate to peer support and the last two relate to mentoring. How each participant fell in these categories is summarized in Table 5. The following section will dissect each of these themes and provide salient examples.

Theme: Studied With Other Students

An important academic survival strategy discussed by many of the participants was using study groups and collaborative learning to finish homework assignments and prepare for exams. Paula in astronomy explained that it was this group work that helped encourage her when she was tired or couldn't get the problem:

…we would just meet to work on problem sets um, but what was really helpful about it was just knowing that other people um, were struggling with it and it encouraged you to work longer because, you're working by yourself in your room, you just get frustrated at some point and you're just like fine, I'm just going to turn this incomplete, I'm tired of thinking about this but, um when you got, when you got other people there I guess you can kind of draw on their, I don't know, their tenacity. You can help them, and, yeah it makes it a lot better. (Paula, astronomy)

Table 5 Research Question 1 Themes

		Studied With Other Students	**Friends With Other Students**	**Post Doctorates**	**Faculty**
	Janet				
	Joan	X			
	Joni				
Physics	Marie	X			X
	Nancy	X	X	X	
	Olivia	X	X	X	
	Stevie				
	Susie	X			X
	Taylor			X	X
	Tina	X		X	X
	Tori	X		X	
	Annie	X	X	X	
	Barbra	X	X		X
	Bishi	X		X	
Astronomy	Cyndi	X	X	X	
	Janis			X	
	Kate	X			X
	Melissa			X	
	Pat	X		X	X
	Paula	X			X
	Sarah	X			X

The students described meeting in various places. Bishi in astronomy recalled that they had a specific room to meet where students could collaborate:

...we all had this one building with a reading room where we all did our homework and you know there was groups that were made who did homework but then there was definitely be like, "Guys, you got number 2, we're having trouble, like our group is having trouble." So it was actually a very um, coherent environment, which um, not coherent, like uh, not compromise, what's the word, um, when you help each other? (Bishi, astronomy)

Annie in astronomy also recalled a physical location where students would gather:

...a lot of collaboration with my, both my friends and, you know we would just go to the library and there was that other group of physics students sitting across the room and sometimes we'd go ask them, um, just studying harder. (Annie, astronomy)

For some students they didn't need to utilize study groups until their more advanced courses. Nancy in physics explained that her and her classmates worked a lot together in their later years, and also had a special place to meet:

... [we] definitely would work a lot together. In fourth year, or end of third year, I remember more we had a room or, a landing at the top of the stairs with a lot of chalkboards and couches and stuff... when things started getting hard, we started working together a little bit more. (Nancy, physics)

By working with other students these participants built themselves a network of support to make it through their undergraduate courses. For some of the students having a space to meet was important, as they knew they could always go there to work with other students. It should be noted that some students in the study also reported not working with other students. Their reasons varied, from being an older student who was going back to college for physics, or being a student who preferred working in isolation. For some of these students their study work turned into a more personal endeavor through the building of friendships.

Theme: Peer Friendships

Fewer students discussed friendships with the students they studied with. As this was not a direct question in the protocol it may have been a symptom of the researcher. However, some participants did spontaneously bring up their friendships. It is plausible to suggest that having friendships in their program may have supported their persistence.

Barbra in astronomy discussed her friendships with other students:

> *Uh yeah, we became really good friends, quite a few of us. I'd say that I had about, 3 or 4 really close friends in physics and then maybe 2 others that were in astronomy, so just a handful.* (Barbra, astronomy)

For Olivia in physics her friends were also the same people she studied with:

> *…like three girls in the classes. Me and these two other girls. So we were always really close and we always, we always just hung out all the time. Hung out and studied and hung out and hung out…the three of us became really good friends.* (Olivia, physics)

Annie Also described her friendships as being with women who she studied with.

Building friendships was an important experience for some these participants. Often times these friendships grew out of their study groups. Such relationships may have been a key component to building a community for these students and helping them persist in their programs. Study groups and friendships with students show one side of student support, peer support, but many participants also described support come from the hierarchy above them. Or rather, post doctorate researchers and faculty members.

Theme: Support From Post Doctorates

Undergraduate research is a critical component for students hoping to be accepted into graduate degree programs. Of the participants all did undergraduate research except for three women in graduate physics. Of these women, two did not have undergraduate degrees in physics. Securing a positive, productive experience that fosters the growth of research skills may significantly help students as they continue into their fields. When participants discussed their experiences in undergraduate research and who supported them through their work a surprising result was found. It was not primarily other students or graduate students that supported them, but post doctorate researchers. The role of post doctorates in many of the participants' lives helped them learn research skills, encouraged them, and supported them into graduate school. The post doctorates were available to give support and sometimes described as being close by and specifically there to help students.

For Janis in astronomy, she had a negative relationship with her undergraduate research advisor. But for her actual research she didn't work with him but the post doctorate:

> *..his post doc was amazing… [laughing] I worked with her… not him [the faculty advisor]! So, uh, the advisor was just there to sign the papers and be in charge, but I really worked with the post docs. Yeah. She was amazing, taught me everything she knew. So many tricks of the trade. I learned an entirely new language from her.* (Janis, astronomy)

For Annie in astronomy the post doctorate she worked for not only trained her in research but also supported her to help her get into graduate school:

> *…she was a post-doc, and she, basically is just sort of the advisor that teaches, she teaches you everything she tries to put you in the best position they can for grad school and I don't know when the idea of grad school*

occurred to me, but by the time I was working with her it was my career goal to go there. And so she gave me a really good project that led me to a paper which I published. She was essential in getting me into grad school, sort of the writing of the application essay type stuff… (Annie, astronomy)

Bishi in astronomy also discussed how the post doctorate she worked for helped her get into graduate school and shaped her approach as a researcher:

> *So he was great, I mean he is the reason why I'm in grad school and that too like how great grad school is because he gave me a great recommendation, and he's well like known in the community and he's just really good to shape I think who I am as a researcher.* (Bishi, astronomy)

Bishi went on to explain that she was only able to build this one on one relationship with him because he had time to devote to her. She now sees him in his new faculty position with little time to devote to new students:

> *…so um so he's just really busy right now, and so I was able to actually get in before that meaning like we actually developed like a personal relationship and to this day when I go back and work with him I'll just sit in his office and work and like you know be able to just be like "Hey, stop him in the middle of his work and be like help me with this, where as a lot of students who now meet him aren't able to develop that relationship with him because, he's just so busy and you know…* (Bishi, astronomy)

Tina in physics talked about how having post doctorate around as part of the lab group gave her a sense of not being isolated:

> *…but I think yeah, it was nice having people there to like interact with and talk to and, just so you didn't feel like so isolated um, yeah, but that was a very good experience…* (Tina, physics)

Mentoring for these women came from not only faculty, but also post doctorate scholars. For these women post docs were important, primarily in their research. This is not to say that all relationships with post docs were positive. In the case of Olivia in physics the post doc was described as not wanting to work with unskilled under graduates. In addition to post doctorate support, though, these women did also receive support from faculty as described in the next section.

Theme: Support From Faculty

Faculty's role in these participant's lives as undergraduate students will be looked at from a perspective outside of the classroom. This was largely how these women talked about their interactions with faculty. Faculty were important for their role in encouraging students, showing concern, and being teachers of physics and astronomy outside the classroom. For some students though, this relationship was lacking.

Encouragement was described as an important aspect of their relationships with their faculty advisors. For Paula in astronomy it was her advisor's advice that helped her persist when she was considering leaving her undergraduate institutions:

> *…I almost left after my first year I really wanted to, I wasn't sure I could do it anymore. Um, but I was kind of pressured into staying in science by my father and uh my advisor um also, really encouraged me to stay and like believed that I could do it and, and he the point that the girls who stick it out in physics are uh, are always the best, like they're always in the top of the class where as the guys is like sort of the middle of the road guys are like "Ok, I'm not the best but I'm in the middle that's good enough, I can stick it out." But the girls in that class position always need to um, and he made the point that you know, that if I find myself in that position that doesn't mean that I'm not good enough that I should only quit if I wasn't interested anymore.* (Paula, astronomy)

For Barbra in astronomy she described her advisor as having *'faith'* in her and an encouraging force in getting her to apply to graduate programs:

> *…he had like a lot of faith in me and I could really, maybe almost too much faith in me, (chuckle) but I feel like, that was, that was a big help because, that was around the time when I was, applying for grad schools and I wasn't even sure if I wanted to apply to grad schools and he really encouraged me, and I thought that was, um very positive.* (Barbra, astronomy)

Marie in physics saw her professors as being overwhelmingly encouraging and positive:

> *They were really friendly, really encouraging um, really just about every professor I had was really interested in undergraduate education and really making sure that students were understanding what they were saying, understood what they were doing and really felt like they had resources.* (Marie, physics)

Kate in astronomy talked about how the professors were there for them and would ask what was going on if their performance was slipping:

> *…professors like, they knew us all on a very personal level, if we weren't doing well they would like talk to you and [want to know] what was going on.* (Kate, astronomy)

For Tina and Susie in physics their professors helped them learn material outside of class. Tina explained:

> *…and he was, he was very good on like um, one on one time…in the beginning especially like meeting with me and kind of giving me like mini lectures to introduce me to a lot of the stuff. Um and so it was very good*

because like he explained a lot of things, and I learned a lot and was able to be like okay, yeah, I can get this. And gave me good advice and like getting me going on certain things and like try this and do this. (Tina, physics)

Susie decided to study physics late as an undergrad. She found support from a professor who would help her dissect the material outside of the classroom when she asked:

…like I had my professor rederive like spherical to Cartesian coordinate transformations. I still remember this. We went over that on the board like three times, because I just couldn't get my head around that coordinate change. That's very physicsy, and I hadn't been in physics land. So yeah, everyone was just really patient with me. (Susie, physics)

Not all of the participants reported helpful and productive faculty relationships. Janis in astronomy and Joan in physics both had negative experiences with their undergraduate faculty advisors. Janis, as discussed above, primarily relied on her advisor's post doctorate for help due to his poor attitude towards her:

Oh, it was horrible. I did not like him. At all… all I learned [from him] was how much debt I accumulated from being an undergrad far away from home… and he questioned me whether my degree was worth it. He actually said that to me "How much do you have in debt? Do you really think it was worth that to come here?" There are some not nice people in the field [laughs]. (Janis, astronomy)

Joan had an advisor that she never talked to and who offered her no advice. She admitted that she could have asked him for help:

So in physics in undergrad I had basically no advising whatsoever. Um I had an advisor but he was old and deaf and um I didn't appreciate him enough to ask him questions and he never offered advice. (Joan, astronomy)

Faculty were important role models in the lives of many of these participants. They offered support, educational assistance, and guidance. For others their role was deleterious and unhelpful and some discussed them as purely professional or only with respect to the classroom environment. Clearly, though, faculty are one component in the success of undergraduate women in physics and astronomy.

Research Question 2: What experiences as a graduate student helped these women persist in their field?

As with their undergraduate journeys, these participants had varied and unique paths that lead to their success and up to date experiences as graduate students finishing their dissertation research. However, the codes on these experiences can be condensed into the same four themes as presented above: studying with other students, peer friendships, support from post doctorate scholars, and support from faculty. The first two relate to peer support and the last two related to mentoring. Of these, the relationships with their advisors were described most frequently and arguably had the strongest impact on their experiences. For those students who did not discuss their relationships as being positive, they often were unsupported or even hindered by their faculty mentors. In some cases post doctorate scholars acted in their place to support these students, similar to Janis' experience in undergraduate research. The following sections will be presented by theme describing the experiences and stories of the participants. Table 6 summarizes the four themes.

Theme: Studied With Other Students

Many of the participants described the importance of study in groups for completion of not only their course work, but also their qualifying exams. Qualifying exams are a gateway test that grants entrance to students to the PhD candidate level. This is a stage where many students may decide to get a masters degree in their field and leave their PhD program.

For Melissa in astronomy study groups were an activity all her first year peers participated in, followed by smaller sub groups in the later years:

> *I'd say for the most part our first year we'd all work together. And then by that second year we kind of grouped off because one or two have to study it's like get down to business. Yeah.* (Melissa, astronomy)

Table 6 Research Question 2 Themes

		Studied With Other Students	**Peer Friendships**	**Support Post Doctorates**	**Support From Faculty**		
					Positive	***Mixed***	***Negative***
	Janet						X
	Joan	X				X	
	Joni	X	X		X		
Physics	Marie	X			X		
	Nancy						X
	Olivia	X	X			X	
	Stevie						X
	Susie	X				X	
	Taylor	X	X	X		X	
	Tina			X	X		
	Tori	X					X
	Annie	X	X	X			X
	Barbra	X				X	
	Bishi	X					
Astronomy	Cyndi	X					
	Janis						
	Kate	X					
	Melissa	X				X	
	Pat	X	X	X		X	
	Paula	X		X		X	
	Sarah		X			X	

Janis in astronomy also relied on study groups with her classmates. She described her incoming class as being a small tight knit group that always worked together:

My incoming class was four students. After the first semester it was three. You take classes with the class either in front or behind of you. Its always two years put together. So class size is from 4 to 8. My class size was always six. And we were all in the same office, we work together day and night. (Janis, astronomy)

Cyndi in astronomy used study groups to get through tough problems, although she primarily worked on her own:

…there was a lot of collaboration um, you know the homework we would, pretty much more or less do it all our own until we would run into problems, you know come find each other and ask each other questions and then if we couldn't figure it out then go ask the professor. (Cyndi, astronomy)

Joan in physics used her study group not only to complete assignments but catch up on material she did not learn as an undergraduate student. She felt like her role was different as a graduate student because she was the one asking for help rather than being the helper:

…we all worked together on homeworks some amount. I am used to being the one who figures out the answers and then teaches everyone else…my learning style um is to be the teacher um. And all of a sudden it was completely turned around and I was the one who knew nothing and everybody else could figure these things out and I felt like I couldn't. Um which was rough. Um to state it lightly…it was it was very frustrating because many of the problems other people had seen before and knew how to do and knew little tricks for that I had just never been exposed to… (Joan, physics)

Tori in physics viewed her study groups as creating an atmosphere of cooperation, to her they showed that there was no competition in her cohort:

I think that there was uh, there was a good enough group of people…in my year that did homework together, that like viewed it not as a competition but as a like, we all need to, like let's all help not fail this… (Tori, physics)

Olivia in physics felt that studying with others was a necessary tool for physics. Unlike Tori she felt that there was some competition, but that it was *'friendly'*:

…I kind of feel like that's the only way to get physics course work done. You have to work together… [There was] friendly competition. I feel like there's always one or two people who are like well I'm obviously the best and I dunno, I just sort of roll my eyes at that. Like whatever. (Olivia, physics)

In addition to using study groups to persevere in the classroom some participants also discussed their efficacy in preparing for the qualifying exams. Their explanation of these experiences were similar in scope, style, and formation to those of their course work study groups. Similar to their undergraduate experiences, the relationships these women formed with their peers sometimes extended beyond the classroom.

Theme: Peer Friendships

Friendships with other students arose for a few of the participants. For Taylor in physics this was out of necessity because she felt the students all did not know people at the location of their graduate program:

..we um did a lot of stuff together, we went for bike rides, we ya know ate dinner at peoples houses and had parties and whatever else other people do. I mean everyone was not from around here and I think that's how most people made friends, ya know just hanging out with the physics department. (Taylor, physics)

For Janis in astronomy these relationships extended from the constant contact she had with other students. Her friendships even included a significant other:

> *And that's also how [my boyfriend] and I met. Because we both didn't sleep [laughs]. Hes a year behind me. My second year and his first year we were in classes together. You don't sleep. You spend all your time with these people, you get, you become very close [laughs].* (Janis, astronomy)

Annie in astronomy partially chose her graduate program because she felt the students she met on visiting weekend were very social together:

> *…one of the reasons [I came to this graduate program]…is that when I visited, everyone was really social with each other um we had a really good time on visiting weekend.* (Annie, astronomy)

Although friendships with other graduate students were not ubiquitous across each participant's experience, they were important to the ones who discussed them. Similarly, only about a quarter of the participants discussed post doctorates as being a support mechanism. But for those who did, they were often very important relationships.

Theme: Support From Post Doctorates

Support from post doctorate scholars was a key help to some of the participants. They were described as being present for day-to-day issues such as programming bugs and writing research papers where as faculty were more available for big picture issues. Paula in astronomy echoes this idea:

> *He [the post doc] was the person I worked with on more, on a day to day basis like he would come in and be like "Today we're going to do this." and, you know, "This is how we're going to do it." and there were some*

undergrads in the lab and they taught me things like, "Oh you gotta turn the screws this way". Things like that. (Paula, astronomy)

For Pat in astronomy she had an advisor who was described as being very busy and not having much time to work with her. She did, however, find help from the post doctorate in her group for more time consuming issues:

> *I've been working a lot with him lately the [post docs]. Um, I had some code that was giving me weird results so he's sort of the first person I went to help me understand this…He was really good about sitting down with me and just sort of, you know giving me different diagnosis I can run.* (Pat, astronomy)

Annie in astronomy had a poor relationship with her advisor, so she relied on the post doctorate she worked with to help her navigate research and the job search process:

> *…a post doc that I know um, that who's sort of my go to on job stuff like "Oh, how do I write this or write that um, can I see some examples of, like your statement of research or, whatever. And he was, he shared them with me, he also reassured me that you know, people get jobs out of grad school typically.* (Annie, astronomy)

For Taylor in physics the post doctorate who was in their lab actually helped students as part of their job:

> *I mean he sat right there, he was surrounded by all of us students, and I think that a large part of his job was um, just helping us, ya know helping us learn all kinds of, answer all the silly questions we had about C++ and um, he was kind of like our go to contact. Like, um so my advisor would meet with us every week and, or whatever a few times a week and discuss like what we were doing in our projects and what we ya know, wanted to do. Kind of like*

bigger questions and then the post doc would handle like ya know, how do I write a class or something, I don't know something very specific. (Taylor, physics)

For the participants who discussed the role of post doctorates in their lives they were seen as important people who aided their persistence. Post doctorates often acted in place of busy or unhelpful advisors when students needed help. Though these relationships were important; the dominant support, or discouragement, came from these participant's formal student-advisor relationships.

Theme: Support From Faculty

The professional and personal relationships students built with their advisors were both complex and significantly impactful on their experiences as graduate students. These relationships, or lack thereof, shaped how these students learned research skills, wrote their theses, and applied for academic jobs. Within this theme there three sub themes describing the support they received: good, mixed, or bad. This section will be organized around these three themes and presented in the order listed above.

Positive

Many of the participants reported having very supportive advisors that encouraged them, had good communication, and/or helped them learn necessary research skills and navigate the academic process. For Janis in astronomy her advisor helped push her through the PhD process. At one point her research and pathway were stagnant and she needed a nudge to keep moving. Janis had a meeting with her advisor and her committee who told her she wasn't making enough progress, but she used this review as something to motivate her. Her advisor, as well, was present to support and help her through this slump in her pathway:

At first it did, I was really sad… but it has given me the kick to get things moving. So, I've been talking to my advisor every day since then…Wow…And really pushing forward, getting things done. Because we need this code to work. And just last week I hit the Eureka moment where the code works so we can run our simulations now. (Janis, astronomy)

Earlier in our conversation Janis was very optimistic and excited about her advisor. She described him as always being available to help and someone she enjoyed talking with socially. This was contrary to her negative experience with her undergraduate advisor:

…we talk to each other all the time through instant messenger. And the weird thing is, we are actually friends on Facebook and Google +. He is always available. And he is very approachable. Where as my undergrad advisor was not approachable at all. And I wouldn't even, I don't think I would talk to him socially at all [laughs]. Where as [current advisor, called by first time] I would talk to socially anytime. (Janis, astronomy)

Cyndi's experience also highlights the importance of this positive communication and relationship described by Janis. Cyndi switched advisors after coming to her graduate program and working with one person. She explained her relationship with her first advisor:

I tried working with a female faculty member when I first arrived, but had another personality clash because she wanted me to "toughen up" when I asked for help and told her I felt lost working on my project. (Cyndi, astronomy)

Cyndi wanted to be herself and did not want to *'toughen up'* in order to be an astronomer. Her advisor also did not give her the support she needed to succeed. All of this may possibly stem from the fact that her advisor was trying to strengthen her as a scholar because she was a woman in a male dominated field. The idea of women having to be strong is easily understood when consulting the historical experiences of women in physics (Des Jardins, 2010).

When Cyndi set out to find a new advisor she didn't focus on what kind of research they did, but rather their personality:

> *I was intentionally picking topics that I had no background or no knowledge of, um, and so it was more important to me that I could communicate with my advisor um, when I undoubtedly got stuck on something or had no idea what I was doing.* (Cyndi, astronomy)

She found the relationship she needed in a new advisor. She also described him as an advisor that pushes her:

> *…he's really great he, um, he, we have weekly group meetings so um, so I see him uh at least once a week, we talk about what I'm doing, um he reads all of my paper drafts and puts up with all my questions and, what's good is he also really pushes me, um, you know which sometimes, sometimes gets really irritating, but I know its good for me and I know that its making me a better, its definitely making me a better scientist.* (Cyndi, astronomy)

Kate in astronomy also switched from her initial advisor to a new advisor for similar reasons as Cyndi. She even switched from a position that had funding to one that didn't just to have a more productive relationship. She explained her advisor to be someone that helped her develop as a graduate student:

> *…he's very encouraging and, getting you to form your own ideas and speak out which is definitely, part of the transition from undergrad to grad like, think for yourself scientifically and not just like, do what you're told.* (Kate, astronomy)

Joni in physics began her research career with almost no research experience, unlike most of the participants in this study. Consequently, she had to catch up in her graduate program and acquire skills that many others already had. She found her advisor to be supportive in this process and there to guide her learning:

> *…he's pretty helpful…I didn't have much experimental um experience or research experience before coming here um so he's definitely been helpful and in showing me little like tricks of the trade…he's very open to uh talking about…Whatever questions I have I guess and explaining or trying to think about like why something might be behaving in some way.* (Joni, physics)

Good support was hallmarked by strong communication, pushing students, and encouraging overall success. For some participants they sought out this relationship and for others it was given to them when they chose their research area. What is clear is its positive impact on their graduate school experience.

Mixed

For the majority of the participants their experiences with their research advisers were more complex than just being positive or negative. They had mixed experiences and feelings that lead to a more complicated interaction. Sarah in astronomy's relationship with her advisor typifies this idea. She described her advisor as being nice and always available to talk, but she met with him it was hard to get her ideas across and find a way forward in her research:

> *He's a nice guy, um it's really hard communicating with him though…I'll have like a whole list of things I want to talk to him about and like maybe one will get finished talking about like he gets so sidetracked and like on different tangents…You basically just end up talking about what he wants to talk about, but I guess that doesn't bother me so much cause he's like, I feel like he's such a kind person and also um, I, this sounds kind of negative but like one-*

dimensional. I feel like what, what he's displaying to you that's like, that's like it that's all he's thinking or feeling. He's not hiding anything from you, like he's just experiencing what he's thinking and feeling ya know, and he's very nice um, but yeah. (Sarah, astronomy)

Her advisor meant no harm, but ended up negatively impacting Sarah's success. For Barbra in astronomy her advisor was enthusiastic of her ideas but also lacked the ability to give her the solid guidance she needed:

…like every idea that I bring up he's like "Oh you should, you should do that. That would be great."… there's no filter, right so I just have to like pick and choose what I'm going to do and I feel like I don't get a lot of big picture guidance from him on that, in terms of the science, I mean like any science question I come to him like he's very competent, with in terms of, project direction or like project ideas or like designing a thesis I feel like he has not been very strong with that so it's been, I feel like I've been a little bit misguided. (Sarah, astronomy)

Some of the participants struggled with how little time their advisors had to work with them. Melissa in astronomy worked around this by sending emails with her question in the subject line. Pat in astronomy felt she could go to her advisor if she needed but things had to be quick, fortunately she had a post doctorate in the lab to her support as discussed previously:

Yeah, she's, she's so busy and she has so many people under her, you know? So it's a little different than my undergrad relationship with my advisor, um, so now, everything is very quick, get to the point, you know, what do you need type things, um, so a little different in that respect. Um, but it's still good like, I always feel like I can come to her if I have a problem, uh, If I email her she emails me back right away, which doesn't always happen with other advisors. (Melissa, astronomy)

Susie in physics had an advisor who was unavailable to help her with learning experimental techniques in the lab. Olivia in physics had the opposite problem of Susie and Tori. She wanted more autonomy in her work:

> *He's super hands-on which was super great when I was a younger grad student, and now that I'm an older grad student [I don't need that].* (Olivia, physics)

Taylor in physics also had a complex student-advisor relationship. Her and her lab were very social, which included outdoors trips and backyard barbecues. However, when it came to her dissertation her advisor was very unhelpful. She didn't have a sense of what her dissertation would be on and felt her adviser didn't as well:

> *I just, I worked with an engineer here to design the mounts and we need to put some detectors in them um, but at that point I guess I started kind of arguing with my advisor a bit. Not arguing so much but just like, I wasn't clear that this was a, I didn't understand that how this could be a dissertation project, like how am I going to write a physics dissertation about how uh we made some parts out of copper and they didn't work so we made some new parts out of copper…* (Taylor, physics)

Eventually she and her advisor quit working on this project and switched to something different.

For these participants their advisor relationships were complex and included many personable individuals who lacked direction and technical support that these participants felt they needed. Sometime too much help was given or not enough preparation was received. Their experiences highlight the often complicated human relationships we all face in life. For the next participants, though, their relationships were purely negative.

Negative

For a few participants their relationships with their advisors can only be characterized as negative. They suffered from blatant discouragement, poor communication, and refusal to help. For Annie in Astronomy her advisor was not available to help her with her thesis. The advisor also actively discouraged her while she was applying to post doctorate positions:

> *Breakdown of communication [pause]. Um, I really feel like I've been lost on my thesis and, if she'd been more active in checking on me and helping me along [I would be better off].* (Annie, astronomy)

> *Um she's also been like, when I've been writing my applications for post docs scholarships just totally flat out said I wasn't going to get the NSF, which I, I didn't get, but I was, I was definitely, I wasn't rejected on the first round, they were holding on to me…but she was like "you're not going to get that." She was very negative about my job prospects, which I thought was really bizarre cause if I'm not getting a job, (laughs)…so at that point I really needed reassurance that everything would be ok and she was not providing that at all.* (Annie, astronomy)

Fortunately for Annie she found support with a post doctorate in her lab whom aided in her job application process. As a side note, Annie is now employed herself as a post doctorate.

Another relationship struggle some participants had were advisors who could not gear the right level of support for students in their research. For Tori in physics she needed help learning to computer program:

> *…I would even go talk to a professor [her advisor] and he tried to help me but it was just all over my head, I had not had any programming classes which was probably, I don't know if they realized this or not [laughs] and after like a couple months I kind of felt like just really overwhelmed and like, they I was*

not catch-, I was not, they weren't giving, there was not any scaffolding to help me like get to the place they wanted me to be doing stuff at. (Tori, physics)

Tori tried to cope with this and other struggles in her research by setting up a weekly meeting with her professor, but he refused to see her:

I went and asked my advisor like, I don't think I'm being, I said, I don't think I'm being productive enough, can we have a weekly meeting like for fifteen minutes where I just come tell you what I did. Like, [laughs] I think that would be helpful. [laughs] Like so I didn't, so I don't just get, I don't just feel like confused and not confident and then do nothing. Like I need to keep working and stuff. And then he said, no. (Tori, physics)

Nancy in physics had similarly poor communication with her advisor whom she finished her masters degree thesis under before switching to another graduate program.

I would ask her questions she would like respond a week later. Like, I need to know this, like I realize that you have a million things to do but you offered. She put the project to us…I encountered like a problem in the project going with this approximation, you know reading literature isn't actually valid, we can't really, you know, she's like "Oh do it anyway"…She was not a pleasant woman. (Nancy, physics)

In addition to the issues of poor communication and discouragement, two participants had advisors that were not supportive when they faced personal issues in their departments. For Janet in physics her advisor wasn't even aware of her presence when she joined the lab:

…the PI just was never in the lab…I had been showing up like several days a

week. Um it was probably a month or two before he realized I was there. And then he's all like so do you want a 600 which is like the reading course. (Janet, physics)

When she did become an official part of the lab she found her position difficult. The professor was not an expert in what she was doing and there was no formal hierarchy of who to go to with scientific issues:

…one big thing is ya know this isn't his main field and so he's not super uh knowledgeable about things…the lab operated somewhat independently for a long time. Um the people who've been in the lab since then are very used to being completely on their own and head of everything. And so it can be quite chaotic because there is not like a hierarchy or structure or um anything like that. (Janet, physics)

Janet's advisor never acted in the role of advisor but was said to act as if he was a graduate student.

…he has this like romantic view of grad school. And he tries to be it's this weird thing were he tries to be like buddy buddy um and then like there's not this like supervisory role. (Janet, physics)

This understanding of his role in the lab became particularly troublesome when Janet was facing hostile and sexist language from a lab mate. She raised her concerns to her advisor who promptly did nothing and only laughed it off as a passing event.

Stevie in physics faced communication breakdowns with her advisor:

I think part of it is he never saw me as a graduate student because I worked for him as an undergraduate. And, he just never really made the transition of treating me like one of the other graduate students…he didn't really like me to take charge of anything. And I find that very frustrating because I like being *in charge of things. I think part of what grad school is is you learn to be in charge of some project. And, bring it to, you know, completion, you know, that's the idea of the dissertation. Um, he didn't really care about any of my career goals or any of my career aims. You know, I couldn't talk to him about what kind of job I wanted. I couldn't talk to him, even, my dissertation project after a while. Like, we had a project when I started, that I was really passionate about, and I thought that this was awesome. But every time I would meet with him to discuss it he would change the goals for it…* (Stevie, physics)

This relationship forced Stevie to find a new advisor. This search was hastened when her advisor refused to deal with another group member who told Stevie she should be in the home and not doing physics. This will be discussed more below.

For these participants their graduate advisor relationships were troubling and detrimental to their graduate careers. At least for Stevie and Nancy they found new advisors where as Janet coped by pushing through and Annie relied on the aid of a post doctorate. What is clear from their stories, and those of others, is that the advisor plays a central and important role in a student's life. They can both help and hinder their success and either mitigate or create feelings of discouragement and incompetence. The women here who described their experiences are those that survived and made it to the final years of their doctorate. They are resilient. It is not possible to say what the experiences of the students who dropped out are, but we can focus on those who have made it and learn from their journeys.

Research Question 3: What are the desired career pathways of these women after graduation, and what shaped these goals?

The expectations and thoughts these participants held about their potential careers varied by their individual experiences, desired lives, and expectation of the job market. This section will provide results detailing their career goals and what considerations are shaping these goals. Their varied career interests fell into four main themes: industry (non-academic jobs), teaching university tenure track positions, research university tenure track positions, and uncertainty. This is summarized in Table 7 below.

Table 7 Research Question 3 Themes I

		Industry	Teaching University	Research University	Not Sure
Physics	Janet		X		
	Joan	X			
	Joni				X
	Marie	X			
	Nancy		X		
	Olivia				X
	Stevie				X
	Susie	X			
	Taylor	X			
	Tina	X			
	Tori			X	
Astronomy	Annie			X	
	Barbra		X		
	Bishi	X			
	Cyndi		X		
	Janis	X	X		
	Kate				X
	Melissa		X		
	Pat				X
	Paula	X	X		
	Sarah		X		

Some participants are in multiple columns. Participants were put into the column they described as being their most desired career, in the case of a few participants they had multiple significant goals. For participants with did not know what they wanted to do or listed multiple ideas with no distinct goal they were labeled *Not sure*.

Table 8 Research Question 3 Themes II

		Wants Children	Compatible with Tenure Track Career	Not Compatible with Tenure Track Career	Lifestyle
	Janet				X
	Joan				
	Joni	X	X		
Physics	Marie	X		X	X
	Nancy				
	Olivia				
	Stevie				
	Susie				X
	Taylor	X	X		X
	Tina				X
	Tori	X			
	Annie				
	Barbra	X			X
	Bishi	X	X		X
Astronomy	Cyndi				X
	Janis	X			
	Kate				
	Melissa	X	X		
	Pat	X			X
	Paula				
	Sarah	X			X

Within the participants' explanations of their career goals two important themes arose: (1) children and (2) lifestyle. In these discussions the participants primarily talked about lifestyle issues and not the careers themselves, although it did sometimes come up (e.g. wanting to teach). The focus in this section will be lifestyle concerns and children. Participants frequently talked about their interest in having children and how this may conflict with potential academic careers. They also discussed wanting to be able to live a lifestyle that involved more than just their work, and felt that the academic life may not be compatible with this desire. These themes are shown in Table 8. Below I will outline each of the career paths participants were interested in and conclude with an exploration of the desired lives they wanted to lead.

Theme: Non-Academic Career Goals

Industry jobs in my analysis are described as non-academic career pathways. In other words, these are jobs that may be found in companies, at research facilities, or in the government. Some of the participants felt that this kind of career would be best for their personal and professional goals. Table 9 summarizes the career goals of these participants. It should be noted that both Janis and Paula in astronomy also talked about potential careers at teaching universities.

Table 9 Non-Academic Career Goals

Field	Participant	Career Goal
Astronomy	Janis	Outreach at a large company (e.g. Boeing)
	Bishi	Researcher at a telescope
	Paula	Science Policy
Physics	Susie	Consultant
	Taylor	Staff Scientist
	Marie	Science Journalism
	Tina	Industry or Government
	Joan	Peace Education

The actual career ideas themselves are not as interesting as the reasons and motivations these participants had behind their goals. For Paula in astronomy she felt that she did not want to manage research like many professors. She suggested that instead she would either teach or go into science policy:

> *I'm pretty sure that I don't want to be the type of professor that is here at this institution. I don't want to be um, a research manager, I'm more interested in teaching um, I think I might be interested in outreach, Um, I'd like to learn more about what opportunities there are for me in policy. Um, I know that there is a post doc in D.C., uh for people with PhDs in science who are interested in policy. I'd like to look more into that.* (Paula, astronomy)

Bishi wanted to work at a telescope collecting data, but was also open to the possibility of taking another job writing code. She wanted to do this for multiple reasons, one being that her field of astronomy had few positions to offer graduates:

> *…our um, field is taking a really big hit in terms of faculty positions, and uh when I get into the field I thought what I was walking into was, ok 6 years of grad school, and then a post doc position and then a faculty position. That's what like anyone around me…have done, but um I mean the protocol now a days is almost like, you have to get a couple of faculty, I'm sorry, post doc positions like, so you get 1, 2, to 3 year post doc and then you go to a second and then maybe even a third I, I definitely know people in their 3rd post doc and then maybe you get your faculty position, you know?* (Bishi, astronomy)

Beyond a lack positions in the traditional academic path described by Bishi, other participants discussed lifestyle concerns as the reason they would seek alternative careers.

Susie chose to be a consultant because she wanted to have a *'life'*:

> *I'd like to have a life. The consulting is wonderful, because I get to pick and choose my projects and have—I'm my own boss, and I have my own—you know, I decide what I'm going to work on, I decide when I'm going to work on it. I just don't like the academic machine, it's exhausting.* (Bishi, astronomy)

Susie had first hand experience of academia from watching her father in the field while she was growing up:

> *…[I] saw my dad growing up spending so many hours grading papers and doing research. It just seems soul draining. I'd rather do something where I—the other thing that I like about the consulting is that I feel like I'm going in, doing something, helping people with something, and then getting out. I feel*

much more like my time is going towards improving the world. (Susie, physics)

Taylor in physics saw the life her advisor led and it was not for her:

Um, I feel like, I like working in physics and I like working in academia but um I don't really like the lifestyles that I see among most of the professors I know, you know like my advisor in general I think he works like, he must work 80-90 hours a week you know like he is in the office like ten hours a day and then he is working from home and he works on the weekends, and he works like on the airplane while he's flying to conferences you know? Like I don't think that that is a realistic thing for me to do, or a thing that I would want to do. (Taylor, physics)

For Marie in physics, her aversion to the faculty life evolved from her interest in having a family. Interestingly, she discussed originally wanting to pursue the academic route:

…originally I wanted to be a professor but actually just since being here I've noticed there is a lot more pressure on the professors and maybe it's just compared to [names of two universities] where [name of undergraduate university] would get primarily undergraduate is the focus and here it's more a research institution and pressure on professors to give good lessons which takes a lot of preparation and to be able to talk things through with students and do good research and apply for grants and have administrative duties and I don't want to be that busy um I would also like to have a family later. So I've been looking for things that are compatible with the family lifestyle. (Marie, physics)

Tina echoed the desires of Marie and Taylor. She wanted a distinct work and personal life:

I'm really tired of just like homework coming home and having to like do stuff like work on um, problems and things like that. I want to be able to have like my work life and then come home and have my personal life… I wanna have a easier time separating them. (Tina, physics)

For many of the women who wanted industry careers they chose them for personal reasons. They wanted to lead lives where they had control, time for themselves, and maybe time for a family. They sometimes saw the lives of their advisors and professors as incompatible with this goal. This finding also emerged in the lives of participants seeking other careers.

Theme: Teaching Universities

For many of the astronomy participants and a few of the physics participants, a career at a teaching intensive university seemed to be the ideal goal. Broadly these participants chose to pursue teaching intensive universities for two reasons: (1) they valued teaching and (2) the desired the perceived lifestyle of pursuing this career.

The value of teaching was an important aspect of pursuing a university teaching career for some of these participants. Janis and Melissa in astronomy built their appreciation of teaching through informal means. Both had extensive experiences teaching astronomy in outreach efforts to the community. Melissa talks about her outreach being a significant accomplishment even though it may not be favorably seen by the research community, this involvement supported her interest in pursuing a teaching career:

…and I'm setting up like a um an outreach program for elementary age girls so I feel like being involved in that aspect has been an accomplishment which is ironic because I feel some people look down on those kind of activities…I wouldn't feel proud of myself if all I did was my own research instead of participating in the community. (Melissa, astronomy)

Paula in astronomy sees teaching as something that needs to be valued more by the astronomy community. Science education as a child was what motivated Paula and was something she felt was important:

> *I think that's [teaching] really important and doesn't get enough importance from academics, um, and especially in a field like astronomy because if were not conveying what we're doing to the public, then everything that we're doing is kind of, meaningless I mean, who cares if we have, really amazing telescopes if no one knows what we use them for. Um, it's just, and for someone like me who really developed an interest in, in science and, particularly this field because of things that I learned as a child, you know from, classes or from popular magazines and things like that, um, it was, you know, it was, for me the foundation of all my, a large foundation, part of my interesting in learning in general, school in general. Um, and I think that, um astronomy is a field that, inspires a lot of people popularly.* (Paula, astronomy)

Nancy in physics saw teaching as something that is particularly impactful. In a discussion of her future career and potential pathway in teaching, Nancy talked about how research could be '*insular'* and that she preferred to pursue something with greater impact:

> *…why are we doing this little bit of research? Why do I care about this tiny specific little thing? Which I'm going to have to care about for a number of years to get a PhD (laughs). F that, you know. Um, and things like that like focusing on these one little little problem for my life isn't necessarily appealing. I'd rather be doing something that not necessarily makes more of a difference, but, has more impact.* (Nancy, physics)

Barbra in astronomy also discussed the importance of teaching and how she would like to put a focus on it in her career. This made her interested in working as a professor at a teaching intensive school. In addition to her interest in teaching Barbra wanted to live a balanced and low stress life. She felt that a teaching intensive school could give this to her:

> *...I know that my life is always going to be, more important to me than it is to a lot of professors, and I guess cause there's a huge range of how people deal with a work life balance um, but I don't feel um, I don't feel like I want to have the balance that I see the majority of the time and my work will never be important enough to me that I'm going to devote 60 hours a week to it and um, yeah. So I fell like uh, the deal with a smaller school is that there's a time for teaching and then there's time for research and that, at least my impression is that, I guess I don't have a lot of, uh evidence but my impression is that it would be um, a little bit lower stress environment, in that sense, yeah.* (Barbra, astronomy)

Cyndi in astronomy was also looking for a teaching university, one aspect important to her was having human interaction:

> *...the goal is to, um, find a job at like a four year college...where I can teach and do research but where the emphasis is on teaching. So, um, I basically decided, I enjoy doing research, but I really don't like sitting in front of my desk for 8 hours a day with very little human interaction.* (Cyndi, astronomy)

Beyond human interaction, Cyndi didn't want to have to live through the traditional academic path of multiple post doctorates to only have the chance at getting a tenure track job and then the possibility of getting tenure. She felt that she wanted to lay down *'roots'* and eventually start a family:

> *...my biggest thing against uh, against kind of the traditional academics, you know academic path is, I don't want to have to do 4 post docs and then, you know get a faculty job and then maybe hopefully get tenure like, I just, I don't,*

want to have to wait, until I'm 40 to get job security, you know? I don't, I don't want to have to move every 2 or 3 years, you know, I wanna be able to lay down some roots and you know and eventually like start a family and stuff and I can't imagine doing that on, on kind of that traditional like career path, and, you know I like teaching so I feel like I have a viable, alternative, career path just like waiting for me, so I just, I don't wanna have to waste the time and energy moving around every 2 years and going from post doc to post doc to post doc and hopefully maybe getting a tenure track job, I just don't want to deal with that (chuckle). (Cyndi, astronomy)

Sarah in astronomy echoes the concerns of Cyndi, she doesn't like the academic life or lifestyles she sees her professors leading. She wants a career where she is not overwhelmed with tasks:

…they [professors] also, they have so many things to split their time between ya know: research, undergrads, grad students, teaching, uh writing grants, publishing papers, ya know like it's just like it's too much. I think that's a lot and I, I don't think that they can, they can't do all of those things well, they drop it a lot, ya know like they either drop their teaching, or like ya know, I don't know they just can't do it all, it's too much I think for one person to do. Um and I don't think I want that kind of lifestyle for myself… (Sarah, astronomy)

Sarah also discussed wanting a family and how she felt that might be very difficult as a professor. Interestingly, she quickly explained that she felt professors at her small liberal art undergraduate institution were able to perform this balancing act:

…they [professors at liberal arts college] didn't make it seem so hard!...I didn't feel the same way about them as I do about my professors here [professors in her graduate program]. Uh, ya know like [research mentor] she had two kids… (Sarah, astronomy)

Janet in physics saw one of her research mentors as a model of what she didn't want to be. Her career goals were either a teaching university or community college:

> *She [research mentor] was super intense…that was actually something that made me a little nervous about whether or not I wanted to continue into science cuz…I don't want to be like that…work was the number one priority period. Like that is the number one thing ya know. Where she would talk to me about how ya know they'd be doing Christmas for their kids and she'd run out to the observatory if they clouds cleared or something ya know she's just very much like this all work all the time and um I remember being like crap, I don't know if I'd want to have like that kind of a life.* (Janet, physics)

These women wanted a career at a teaching university for their own reasons, but most either valued teaching or wanted a lifestyle of work life balance that they perceived as being prevalent for teachers at teaching intensive universities. The issue of family was raised by many of the participants, they felt the research intensive tenure track would create many obstacle for having children. This was something they didn't want to give up, in addition to their other life interests. Cyndi put this theme best: *"There are other things that are more important to me than my career.'*

Theme: Research Universities

The fewest participants had explicit interest in pursuing a tenure track position at a research-intensive university. Of all the participants only one in astronomy, Annie, and only one in physics, Tori, wanted this path. Annie admitted that although she wanted this career she had to be realistic about the tough job market. In addition to doing research she also looked forward to mentoring students:

> *I'm I would really like to, my current aim is faculty at uh a institution sort of like [research intensive university]…I want to do research and teach. Um, So*

far I've really liked mentoring students and so I definitely want to be able to have students. And, aside from that I'm not sure what else I would want to know of the institution um, so like prestige isn't necessarily big deal or, I don't know, I'm trying not to be too picky about my eventual job because I heard they are pretty hard to come by... I think, I think I'm more headed towards an R1, currently. (Annie, astronomy)

Tori in physics also wanted to follow the research-intensive path:

…what I would love to do… I think, is be a professor in a physics department, umm doing physics ED [education] research, umm at like a R1 university…there's a couple reasons that I think, that seems in my head to be good, which is I, that's where I've gone to school…big schools, lots of stuff going on, lots of research. I like research, I like to be supported. I don't really want to be just teaching classes, umm but I think I could do that already to a large degree. Like if you just wanted me to teach intro, if I just want to be an instructor, or lecturer or work at a community college, just teaching. That would be okay, but I don't think that's really what I would, I would rather be doing like more research oriented things. Umm di-, yeah I mean I don't know, I don't really know what R2 level is like, is that sort of like half research, half teaching or something like this? Umm also probably fine, umm I guess. I don't want to live in the middle of nowhere, I think… (Tori, physics)

It is interesting to see that only two participants felt strongly about pursuing research-intensive. In the case of Annie she had no interest in a family and a very supportive husband who was willing to move with her. In the case of Tori, she did want a family, but took her family as an example that it was possible:

I would want a family…I was raised in a family with two working parents, and we went to a lot of summer camp. And after school stuff, and that was fine and I feel like I turned out to be a pretty decent person. Anyway! [laughs] Umm

> *or, I'm not in any way I thought I, I didn't think it was a deficit as a kid, so. So I don't think having a job as a professor is nec-, is not compatible with having a family, right now. I do recognize how much time it is, and so I think it would be hard to have like a two professor family. [laughs] A two tenure track family or, or I don't know if that would need to be negotiated later?* (Tori, physics)

In Tori's desire for a family she admitted the difficulties and time she would have to spend away from them. However, she felt she could compensate for this time away from her children by placing them in the care of others.

Theme: Uncertainty

Not all the participants were certain of their desired careers. Some were open to many possibilities or felt they just did not know yet. For Olivia in physics she felt that her research was sort of meaningless in the context of the wider world, she wanted a career that would be interesting and impactful. However, she did not know what that career would be, although she mentions the possibility of becoming a professor:

> *I dunno, um, I mean basically I wanna work I wanna do something that's interesting. And like I said, useful. And that has, like where I still have enough time to spend with my family. I dunno if that exists but that would be the ideal so I dunno, um I like building stuff. I'm good at it. Uh I think I think I would enjoy being a professor. But I worry that it would be so consuming. It's just a very like, just it seems to be like, the people who succeed are the people who just like really lose themselves in that job. So I'm not certain that's a good particularly good option.* (Olivia, physics)

For Joni in physics she saw this decision as being farther down the road. She was waiting to make her career decision:

> *…I could see myself in a lot of places and um I think it's kind of farther down the road. You know maybe three or so years away. So I'm waiting to see a little bit more where I think I am there. But ya know obviously I could see myself staying in academia or I could see myself possibly working for a national lab or there's also the possibility of going into like a a tech industry or something like that. Um or possibly like doing something completely out of site of physics. Who knows…* (Joni, physics)

Pat in astronomy was also very uncertain where her career might lead, what she knew was that she'd like stability:

> *That's a good question. (laughs) I don't know. I, I, I would like stability, you know, at some point. If, (pause) um, yeah if there is a way to do astronomy and still be able to do that and not, have to move every two years, I don't know what that is right now, it doesn't seem like there are many options, its like you either, you know, do the tenure track route or, yeah, so I'm sort of looking into maybe there is another option, where you could maybe teach or, I don't know.* (Pat, astronomy)

Kate in astronomy echoed her willingness to pursue multiple potential careers:

> *I'm open for anything. And um I can see myself at a liberal arts school like my undergrad advisor, I can see myself at a top research institution. Um, yeah I'm kind of open to any possibilities in the future. It depends on what comes along and what's the most interesting at the time…* (Kate, astronomy)

These participants had not settled their mind on a career, partially due to their youth in their programs and not knowing what may be available. In most of the conversations, though, they did bring up the potential of being a professor.

Career Summary

As expected, these women had diverse career goals that could be summarized into four main themes: (1) teaching university, (2) research university, (3) industry, and (4) not knowing. Within these four themes two threads emerged of children and lifestyle. The participants largely (about half) saw themselves as leading lives that involved more than just work, they wanted time to themselves and time to raise children. Many felt that these goals were incompatible with a position at a research-intensive university, and perceived teaching intensive universities as being places where they could have both a personal and work life. What is interesting is that the least discussed career option was a career at a research-intensive university. A large portion of these women wanted careers outside academia in a variety of unique career paths such as science policy and working in a national lab.

Research Question 4: What are the types and magnitude of distinctly gendered experiences that these women have had in physics and astronomy?

One of the core interview prompts that the women in this study responded to asked about their experiences being a woman in physics or astronomy. Their individual gendered experiences varied dramatically from person to person. Their cumulative experiences, however, can be condensed into three main themes: benign or none, micro injustices, and egregious offenses. Table 10 below summarizes which participants fell in each of these categories; the columns are not exclusive. Each theme is discussed in detail in the following paragraphs.

Table10 Research Question 4 Themes

		Positive	None	Micro Aggression	Egregious
	Janet			X	X
	Joan			X	
	Joni			X	
Physics	Marie		X		
	Nancy				X
	Olivia			X	
	Stevie				X
	Susie			X	
	Taylor		X		
	Tina			X	
	Tori			X	
	Annie			X	
	Barbra			X	
	Bishi		X		
Astronomy	Cyndi				X
	Janis		X		
	Kate			X	
	Melissa			X	X
	Pat	X	X		
	Paula			X	
	Sarah			X	

Theme: Positive or None

For some participants they felt they had not experienced any gendered experiences in their graduate program. Taylor from physics explained that:

> *I guess I don't really feel that, as a woman, I've had a very different experience in physics than a man would.* (Taylor, physics)

Some gendered experiences can be positive, such as receiving a scholarship for women or getting access to mentorship or other resources. For Pat in astronomy she felt that being a woman was an advantage to her because it allowed her access to programs for women in science that gave her research experiences:

> *…being a woman in physics/astro has actually helped me…I have actually benefited from programs aimed at reaching out to women in science.* (Pat, astronomy)

Marie was more critical of her feeling towards never having a gendered experience. Although she reported never having one, she explained that it may be because she had a mother PhD Engineer as a role model:

> *I grew up thinking of course women can do whatever men can do…and then I realized oh that's because I already have [a] role model.* (Marie, physics)

Other women in the study did report gender discrimination. The following sections will focus on their experience

Theme: Micro Aggressions

The majority of participants experienced micro aggressions. These are discriminatory events in their lives that are subtle, sometimes indirect, and sometimes unconscious on the part of the aggressor (Sue, 2010). For many of these participants these injustices manifested themselves as being given differential tasks than men, feeling out of place due to the surrounding culture, or not having their voice heard. These individual experiences are the codes that make up the theme of micro aggressions.

In Janet's physics lab she was called on when things needed cleaning or to organize her group's conference travels. These were tasks never given to the men in her lab, she recalled:

> *…when the lab needed cleaning, I was put in charge and a comment was made that 'women are cleaner' or another time 'women are more organized.* (Janet, physics)

For Joan she felt out of place in physics due to comments by other graduate students. She felt particularly isolated and left out of jokes that referenced women as objects and heterosexuality as a compulsory norm:

> *One male student regularly goes up to other male grad students and says, "you know what you need to win a Nobel prize? A hot chick." Once he told me that I would not win the Nobel prize because I did not have a "hot chick." In the interest of breaking from heteronormativity, I asked him what would happen if I got myself a hot chick. In response, he called me his pet nickname, "crazy girl," and laughed.* (Joan, physics)

Paula in astronomy felt uncomfortable as an undergraduate because she felt that she always stuck out, and that women faced issues the men did not. This is labeled as a micro aggression because her feeling of isolation stems from a history of exclusion in physics that created this phenomena for her:

> *…it was, hard as an undergrad, um, to be the only girl in the classroom because I felt so conspicuous… that might have been part of why I was*

constantly questioning whether I belonged there… and there was certain things that guys just don't need to worry about as much as women do because the academic system is, it's built on a history of men being the people in the field… (Paula, astronomy)

One key experience shared by multiple participants was their voices not being heard in the classroom or within their lab groups. For Kate in astronomy this exclusion meant not being able to participate in the boy's study group until she out performed them on exams:

…But nobody would…tell me when they [study groups] were [meeting]…After the first semester I think they realized that I was smarter than all of them (laughs)…Then they liked to keep me around, (laughs)…(Kate, astronomy)

In her astronomy research group Barbra felt that her voice was not heard as often as her male colleagues. She explained that her male counterparts would yell out their ideas when she felt uncomfortable to do so. She suggested this may be a characteristic many women have and is a micro aggression because how the men interacted in the environment impacted how she felt she could interact:

…I feel like it's more typically female to be, you know more quiet or introspective or docile and not just "This is what I think it is." And I'm not going to say that unless I know where as I feel like my male colleges will just, say what they think um, with a lot more, vigor and just like confidence… (Barbra, astronomy)

Micro aggressions were experiences that may not necessarily derail a student's career, but affected them in a particular moment and in a particular way. These sorts of experiences, accumulated over time, may have a significant impact on a person's career. Being ignored once at a meeting may not feel like a significant loss, but being ignored every time could effect someone's participation, research, and access to resources. Though no data was collected to this effect, it may be a possible outcome.

Theme: Egregious Offenses

For some of the participants I labeled their negative experiences as egregious. This was assigned to experiences that were explicitly harassment. For one participant this was lewd jokes and comments that made her want to leave the lab, for another it was overt and endangering sexual harassment, and for two others it was fellow graduate students telling them that a woman's place is in the home.

Some of Janet's physics lab colleagues made comments in the lab that were derogatory towards women and made her feel uncomfortable:

> *…there have been uh situation[s] with a past group member that made some very inappropriate comments… a joke about date rape and a joke about domestic violence…I talked to my advisor about it…nothing was ever done about it.* (Janet, physics)

Nancy in physics turned down an older graduate student who came on to her. She was not interested him outside of their professional relationship. He immediately became angry with her and enraged when ever she was around:

> *He was obsessive, violent towards objects, I just wanted to get away from him…he punched holes in the wall because I happened to be in the building…He was angry at me…he didn't respond to 'leave me alone'.* (Nancy, physics)

Nancy reported this experience to her department and asked that he not be assigned as her TA for a graduate course the following semester. The department still put him as her TA, only to remove him at her further request halfway through the term. The student in question never faced penalties for his actions against Nancy, in turn Nancy left prematurely to finish her research at a national lab to avoid being around her harasser.

Both Stevie in physics and Melissa in astronomy were told they didn't belong in their fields because women should be at home raising children. This overt discrimination was at the hands of fellow graduate students with whom they had to work. For Stevie this meant she couldn't access lab equipment needed to conduct her research:

> …he*'s not too fond of women, in general. And he made a point to make sure I understood that …if I asked for something like, I want time to do experiment stuff…. He wouldn't give it to me.* (Stevie, physics)

Stevie approached her advisor about this issue but he would not act. She eventually left to join another research group in order to finish her PhD. In a similar situation, Melissa was told by a fellow graduate student that she should be in the home while she driving up a mountain to a telescope:

> *I was observing with someone …and [he was] just going on about why women can't do science because they should be…taking care of babies and [I] should be thinking about having babies soon... It was…frustrating like I literally like couldn't even deal with this person…I just feel so disrespected…* (Stevie, physics)

Melissa was also met with silence when she reported the issue, but partially because she requested that her advisor do nothing. However, through the grapevine a woman professor found out and removed the offending student. Cyndi's experience was the only one that happened before college, in her physics class she was told she would be a waitress when she told her physics teacher she wanted to be a physicist.

All of these women experienced pervasive gender discrimination or harassment that could have significantly impacted their persistence. They, however, all found ways to continue in their graduate programs. It should be noted that only one person found actual resolution to her situation, and this was because a female professor found out about the offense and immediately sought action against the harasser. For the other three persons, they were met with silence or did not report the incidents.

CHAPTER 5. CONCLUSIONS

Introduction

This conclusion chapter will begin by briefly summarizing the answers to the four research questions. The remainder of the chapter will take a holistic view to identify implications that are broader than the individual research questions by connecting the results of this study to other relevant research. The first two research questions are about mentoring and support. Answers to these questions point to the importance of creating structures where students can help each other and mentors can help students, leading to persistence at both the undergraduate and graduate levels. The third research question is about career trajectories. Answers to this question identify how the careers that these women desire are largely determined by the lives they desire, which sometimes included the goal of having children. The final research question has to do with gender discrimination. Answers to this question describe evidence of significant discrimination in physics. Much of the gender discrimination appears to be unconscious and socially engrained into both men and women. This chapter concludes with suggestions of future research and revisits the idea of the culture of physics and astronomy and how this may impact women's success. Before tending to these research questions this review will first discuss the finding that women's experiences did not appear to be significantly different in physics than in astronomy.

Physics Versus Astronomy

An initial goal of this project was to compare the unique experiences of women in physics against women in astronomy. This was thought to be an interesting comparison because it was presumed that women in a field with more women would have significantly different experiences than those in a field with very few women. Such differences may have included more discrimination in physics, larger barriers for these women to persist through, or more hostile attitudes towards their participation. It may have also been found that women in physics had less mentoring and research opportunities compared to women in astronomy.

This was not what was found in this study. Women in both physics and astronomy had strikingly similar experiences, and were supported and hindered similarly through their programs. What this suggests is that the aspects that help women succeed are true regardless of the number of women in the field. Meaning, that having supportive advisors in the form of faculty and post doctorates gives women the skills they need to persevere. It could very well be that the number of women in astronomy is higher because more women have access to these resources. What can't be known is why women may have quit these programs or what impassable barriers existed because this study only looked at those who made it to the final stages of their graduate programs.

Within this immense similarity two small differences can be seen and are worth discussing. First, when considering the women who experience overt sexual harassment from peers or persons above them, only one person found resolution in her conflict. This person happened to be in astronomy. The professor who supported her and resolved the issue even when the student didn't want to was a woman. In the case of the three physicists only two spoke up and neither received any resolution from their male peers.

The second difference was the constant uncertainty the women in astronomy felt about the job market. They all talked about there being few jobs in academia, so private industry was almost a necessity. This idea was not mentioned by the women in physics. Concerns about jobs expressed by women in astronomy are valid when consulting jobs information put out by the American Institute of Physics. In 2008 there were around 150 PhD graduates in astronomy and only 36 new job searches to departments of astronomy (AIP, 2013). That's about one job for every 4.2 PhDs in any given graduation year. The number of potential applicants may be much higher than the PhD output because many PhDs do multiple year post doctorate positions, so any one position may have multiple years worth of post doctorates applying for the job and make this ratio much larger. Of these 36 job searches there were only 19.5 actual hires resulting in 1 hire per 13.3 new PhD graduates for that year. Interestingly, the odds in physics are better. In 2008 there were 529 new faculty job searches and about 1,200 graduates with a PhD in physics. That is about one recruitment for every 2.3 applicants. Overall, though, women in astronomy were similar to those in physics than dissimilar.

Research Questions 1 and 2: Mentoring and Support

This section answers research questions 1 and 2 which focused on the undergraduate and graduate experiences of these women that helped them succeed. The themes in each of these questions were nearly identical; consequently they are answered together in one section. Following the presentation of results from this thesis, these results will be considered in the context of the larger body of literature.

Mentoring and Support: A View From the Thesis

I. *What experiences as undergraduate students helped these women persist in their field?*

II. *What experiences as graduate students helped these women persist in their field?*

A key theme supporting these participants in their (under)graduate persistence was the mentoring they received from faculty and post doctorate scholars. The relationships these participants thrived on were one-on-one and transferred important skills and advice to these women. As undergraduate and graduate students they learned research skills, how to write publications, and gained insight for applying to graduate programs and post doctorate positions.

In some cases it was not faculty these participants had mentoring relationships with, as might be expected. For a number of participants faculty role models were either unavailable or unwilling to serve as mentors to students. In these cases post doctorate scholars often supported students (e.g. Janis, Annie, See Tables 5 and 6). They taught them research skills, helped them apply to graduate school, and were available on a daily basis. This phenomena occurred at both the undergraduate and graduate levels. These women needed someone to help them in a meaningful way that required a time commitment on the side of the mentor. Faculty were often described as being busy, and may have not had this time. Post doctorates were described as being in the lab and available, becoming the de-facto mentors for those women who could not find the support they needed from their faculty mentors.

The participants in this study were largely mentored and supported by men, not women. This, of course, may just be a function of men's dominance within these fields. Though examples of positive women role models were present (P aula, Kate, and Janis) counter examples were also present (Cyndi and Annie). In the case of Cyndi she avoided women mentors because they attempted to *'toughen'* her up when she didn't want to change her personality. Pointing out the negative experiences some of these women had with women demands also pointing out the negative relationships many of them had with men faculty (for example Stevie and Janet). In the case of Stevie her first faculty mentor was unsupportive of her research goals and silent when she faced gender discrimination. For Janet, her advisor ignored her concerns with male colleagues in the lab as well.

No participant in this study completely survived their programs without having some form of support. The participant who came closest to not having a mentor was Stevie, but even she found some support after switching to a new advisor. Advisors provided research support and professional opportunities for students. They were also sources of encouragement and professional guidance when students needed it. In some cases though, advisors exhibited behavior the students did not want to emulate. For example, Taylor saw her advisor working 80-90 hours a week and she did not want that for her self. For Taylor her advisor acted as a deterrent to her continuation in academia.

In addition to support that students gained from mentoring, they also found some support from other students. This form of support most often came in the form of study groups. These groups worked together to persevere through their classes and pass their qualifying exams. In some cases, students also built meaningful friendships and even intimate relationships. These study groups more often than not were comprised of both men and women. For at least a few participants (Annie and Tina), though, their groups were described as being primarily women. Further discussion on the gender of their friends did not emerge in the interviews.

What is clear about these women's (under)graduate experiences was that mentoring and support was key to their success. This support came from multiple places and varying levels, ranging from professors to students. It was not necessarily one person or one experience that got them through academically, it was a combination of many. Support and mentoring for them was multi-layered and multi-tiered.

Mentoring and Support: A View From the Literature

The literature exploring the importance of mentoring women to increase their persistence has largely focused on the relationships they have built with faculty (Bettinger & Long, 2005; Carrell, Page, & West, 2010; Fairlie, Hoffmann, & Oreopoulos, 2011; Ragins, 1997; Ragins & Scandura, 1994). Positive faculty-student contact has been shown to be an important factor for students by improving student satisfaction and success both within and without of the classroom (Astin, 1993; Kuh & Hu, 2001). Most importantly, student persistence has been shown to be increased through contact with faculty in the forms of collaborations, mentorships, apprenticeships and more (Milem, 2003; Pascarella & Terenzini, 2005; Reason, Terenzini, & Domingo, 2006; Sadler, Burgin, McKinney, & Ponjuan, 2010).

One concern the literature raises on the importance of mentoring is the tendency of mentors to choose mentees who share their social identities (e.g. gender, race, sexual orientation) (Eddy & Gaston-Gayles, 2008; Leggon, 2010; Ragins & Scandura, 1994, 1997). Literature on women in STEM has revealed that having women instructors can often support the future persistence of women students (Carrell et al., 2010; Fairlie et al., 2011). However, other work has suggested that women instructors do not support women student's persistence and may even hurt it (Bettinger & Long, 2005; Price, 2010). This conflicting literature shows an unresolved research problem illuminated further by the results presented here.

Research Question 3: Career Trajectory

This section answers the third research question about the career goals of participants in this study. Following these results from the thesis will be a view from the literature before redesigning the reigning model for women's careers: the pipeline. It will be suggested that the pipeline should be replaced with a pathways model to fully understand women's careers when completing a PhD in physics or astronomy.

Career Trajectories: A View From the Thesis

III. What are these participants' desired career pathway after graduate school, and what shaped these goals?

The career goals of these women can be summarized into four themes: (1) non-academic jobs, (2) teaching university jobs, (3) research university jobs, and (4) undecided. A career as a research university faculty member was held by the fewest number of participants. Equal numbers sought careers outside of academia or as faculty members at teaching-oriented institutions. . The disinterest of these highly successful, well-trained women in research university careers strikes a stunning resemblance to the literature and overall trends in physics and astronomy, where women are more likely to be found in teaching-oriented positions.

The women who reported wanting non-academic careers listed a variety of potentials paths. These include science policy, working in outreach at a large company, and becoming a staff scientist. These choices were made so these women could do something they may enjoy while also having more work-life balance. They viewed these options as being more conducive to having a varied life.

Women in this study largely wanted to avoid academic careers because of the deleterious effects they perceived them to have on the lifestyles they wanted to lead, and their desire to have children. Pat in astronomy saw the constant moving of an academic astronomer as a detriment to a child's life, contrasting this is Tina who did not want to have kids but still wanted to live a less work intensive life. Similar to

Tina, Taylor did not want to work the 80-90 hour weeks she saw her research advisor endure. She wanted time for other things in life.

Career Trajectories: A View From the Literature

The data shown in chapter 3 demonstrated that women are less represented in research-intensive institutions (PhD granting universities) and more highly represented in teaching-oriented institutions and adjunct positions within physics. The pathway to tenure at a research university is a demanding and important time in their career. Unfortunately, this time in a woman's life also lines up with her biological clock as to when she would traditionally have children (Mason & Ekman, 2007). This parallel existence of life events require women to make sacrifices in order to accommodate both a career and children. This same phenomena has not only been recorded in higher education but also in law, medicine, and the business world (Mason & Ekman, 2007). Many women in undergraduate institutions have been shown to be unconcerned with the balancing act of work and family (Battle & Wigfield, 2001) but these values quickly shift from the beginning of graduate schools and into careers where women have shown to desire more flexible work hours and time off than men (Ferriman, Lubinki, & Benbow, 2009).

Children have also been demonstrated to have negative effects on womens' careers. It has been shown in surveys of working physicists that men with children report the fastest career growth while women with children report the slowest career growth (Ivie & Tesfaye, 2012). In this same study women also reported having to commit more time to demands outside of their careers, such as domestic work, than men. These problems were further exacerbated for women in less developed countries.

One possible reason that women with children may have slowed career advancement while men with children have faster career advancement could be the role of spouses. A man may potentially benefit from the help of a spouse who dedicates her (assuming heterosexuality) life to their children and home. This sort of arrangement is rarely associated with women who are married to men. In a study of graduate students ten years out from their degree it was found that 9% of women were stay at home spouses as compare to 1% of men (Ferriman et al., 2009).

It may be that women physicists who have children are still expected to act in the roll of caregiver while also being a professional, while as men with children both have a caregiver and someone to support their home life. Even women without children would be impacted by this advantage heterosexual married men have because they may not have a spouse to take care of their homes and personal lives. This hypothesis is further supported when considering that childless women still reported slower careers than men with children. The men may have a resource the women do not, a spouse to help with raising children and taking care of the home. The career goal of Annie to be a research university professor illustrates this point well; she had little desire for a family and a spouse willing to support her career. She was only one of two women in this study to have this career goal.

Pathways Revisited

As discussed in chapter 3, women's pathways in STEM and physics have historically been viewed as a leaky pipeline where women have 'leaked' out at various stages (Figure 6). Authors have recently come out against this model using empirical models demonstrating that women are in fact switching into STEM (Xie & Shauman, 2003) and theoretical models suggesting that a revised conceptualization in terms of more flexible pathways could support women's further entrance into the field (Whitten et al., 2003). The results in this study support this pathways approach into physics, and postulate that this pathways idea should also be applied when considering women's varying careers.

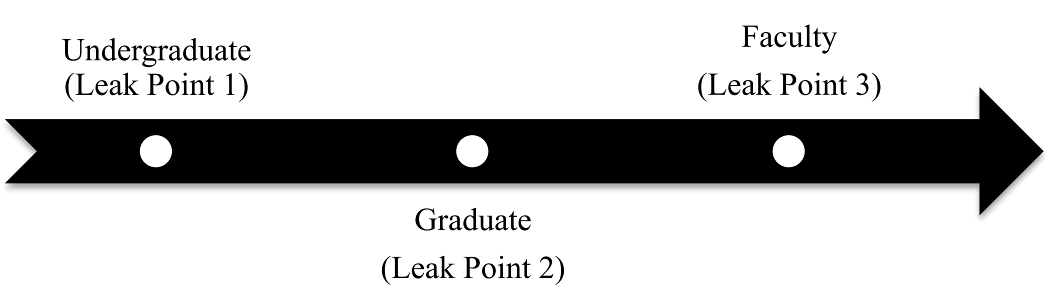

Figure 6 Linear pipeline model in physics

As demonstrated in the interviews some participants saw their desired careers as less prestigious and representing less success than the "expected" career of faculty at a research university. This suggests that the career pathways of these women need to not only be seen as having a variety of options, but options of equal merit that take into consideration the desired lives and potential families these women want to build. This model can be seen below in Figure 7. In this model, people enter a roundabout after completing their graduate education. They travel around the round about taking into consideration their non-academic life desires before choosing their ideal path. Bishi in astronomy is a strong example of this model, she loves astronomy and want to continue in the field but lamented about her desires to also be involved with her family. This caused her to take an alternative route in her career pathway.

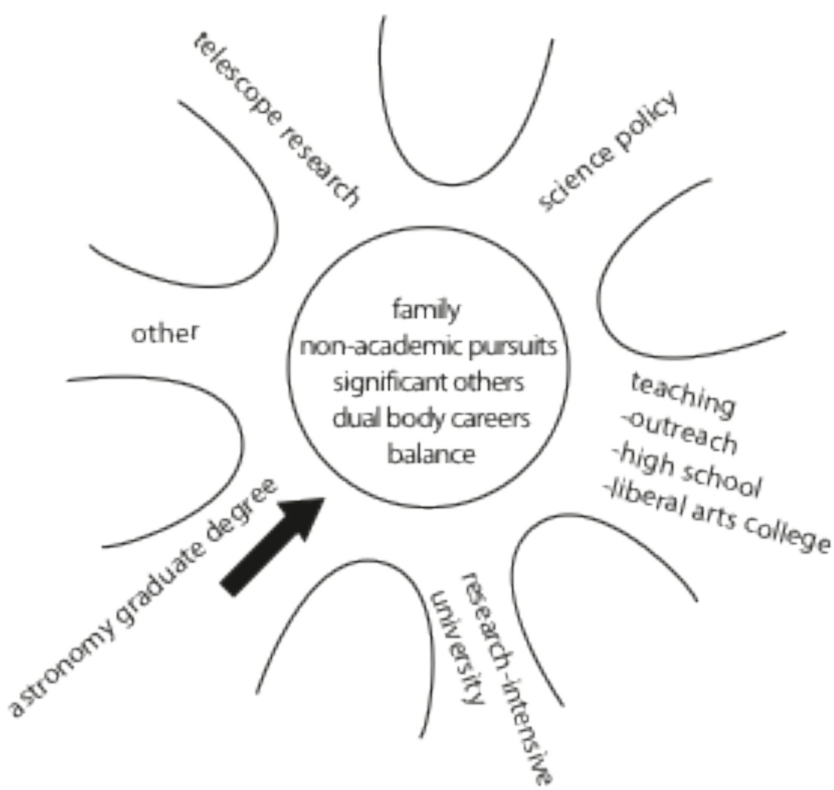

Figure 7 Career pathways model

Research Question 4: Gendered Experiences

This section answers the fourth research question about the gendered experiences of participants in this study. Following the results from this thesis will be a look at the literature. It will be suggested that women still face discrimination in physics and astronomy that is often subtle and unconscious.

Gendered Experiences: A View From the Thesis

IV. What are the distinctly gendered experiences that these women have had in physics and astronomy?

The gendered experiences revealed by the participants illustrated four levels of gendered experiences (1) positive, (2) none, (3) micro aggressions, and (4) egregious discrimination. Although the science education literature has scarcely touched on the issue of gender discrimination, work in other fields has.

Unfortunately, very few participants described their gendered experiences as being non-existent, or in the case of Pat, helpful. For these few participants they never felt that they had experienced distinctly gendered events. Marie, however, was quick to point out that she avoided such experiences because she had a role model in her mother, she was confident and knew she could succeed. Such an attitude may have shielded her from negative experiences because she merely brushed them off or did not notice them. This conclusion is particularly salient when considering a literature that has theoretically and empirically shown that women often times don't see the negative gendered interactions that they may be having (Harding, 2001; Lensen, 2012).

The majority of the participants were aware of some level of small gender discriminations. In the results I defined these as micro aggressions, which is a concept well studied in the literature. Roberts, Swanson, & Murphy (2004) described micro aggressions as the following:

"Microaggression has been described by previous authors as the prejudicial attitudes, affect and discriminatory behavior that pervade daily social interactions (e.g.,(Swim & Stangor, 1998)). According to these authors, microaggression can range in severity from mundane actions such as engaging in rude or dismissive behavior to character assaults (treating individuals as if inferior or dishonest), to more overt, severe behaviors (e.g., harassment) that translate into negative life events for minority workers (Kessler, Mickelson, & Williams, 1999)." (Roberts, Swanson, & Murphy, 2004, p. 2)

Being ignored at research group meetings (e.g. Barbra's ideas not being listened to by men), given differential tasks (e.g. Janet having to organize all travel for her research group), and not being invited to study groups (e.g. Kate being shunned by male students) are clearly examples of micro aggressions. These kinds of offenses against the participants were potentially unconscious actions by the persons around them. For example, Barbra's advisor may have not realized that he was not listening to her, but unconsciously preferenced the ideas of her male colleagues. These unconscious actions are what Sue et al. (2007) call micro invalidations.

In addition to micro aggressions a smaller portion of women experienced egregious offenses that could easily labeled as explicit harassment. These varied from lewd comments (in the case of Janet) all the way to physical destruction of property (in the case of Nancy). In the case of all four women who experienced this level of discrimination, only one found resolution. Three of the four were reported to research advisors, and only in the case of the astronomy advisor was the harasser removed and disciplined. This finding reveals a complacency experienced by these women on the part of their advisors. It is not possible to say why they refused to act, but they did. Although none of these women reported that these offenses ended their careers, this may be because they are the voices of the women who made it. These women are survivors, and may not be representative of the average woman who experiences such egregious offenses.

Gendered Experiences: A View From the Literature

Micro aggressions are small negative interactions that persons of a marginalized group may experience on a daily or weekly basis. Any interaction with someone in a majority group can be subject to such interactions (Sue, 2010). Since their inception, the study of micro aggressions has largely focused on race (Pierce, Carew, Pierce-Gonsalves, & Wills, 1977; Roberts et al., 2004; Sue, 2010), but now they are also being used to understand other groups' experiences, such as women (Lensen, 2012; Sue, 2010).

Micro aggressions are offenses that negate and dismiss a person without the offender even recognizing their actions. Why this might happen is difficult to say. But it is most likely a side effect of cultural rearing that programs us as people to believe that men perform in one way and women perform in others (Butler, 1990). So if we are socially raised to believe that men are the ones that speak and lead then we may by default ignore women and assume men as the ones who should be taking charge. The comments made towards Joan about men needing *'hot chicks'* to win Nobel prizes may have seemed humorous and light hearted to him while being overtly sexist to others, because they revealed the tacit assumption that women are object used by men to succeed. In the moment this sort of micro aggression may not cause significant damage to a person, but over time could result in less access to resources, promotions, or being able to lead in their work.

The natural question, of course, is can these participant's experiences truly be seen as a result of women being viewed differently than men and thus treated differently. The answer to this question can be found by consulting research using empirical designs to reveal gender discrimination in the selection process for jobs and prestigious fellowships. Across time and field it has been shown both for a tenure track position in psychology (Steinpreis et al., 1999) and lab positions at a university (Moss-Racusin et al., 2012) that men are consistently viewed more favorably than women. In these studies identical curriculum vitae were sent out that differed only by the gender of the applicant's name. In both studies male applicants were more likely to get hired, offered a higher salary, and in the case of the lab position said to have more potential for a graduate program than the woman with identical qualifications.

Other studies have also documented the disposition of women to be viewed as less competent or capable than men. Weneras and Wold (1997) studied the gendered differences of applications to a prestigious post doctorate fellowship. They found that for women to be ranked as scientifically competent as men they had to publish either two or three more journal articles in *Science* or *Nature* or 20 more articles in lower impact journals. Another study focusing on letters of recommendation for potential women medical faculty found that women were, more often than men, described as teachers and students while men were viewed as having careers. Women's letters also raised professional concerns twice as often as men. Such literature lends support to the feelings of Paula who always felt she stuck out and was treated different as an undergraduate student.

This literature base demonstrates that women and men, with identical qualifications, are seen differently. Women are seen as less competent and capable than men. This view of women does not differ between men and women reviewers. Both men and women see women as less competent than men. This suggests that these subtle biases are socially engrained and may be the cause of the unconscious micro-aggressions described by the participants in this study.

This sort of discrimination has been largely unexplored in the science community. The field of medicine, though, has produced some work exploring their issues of discrimination, particularly gender discrimination (Carr et al., 2000; Coombs & King, 2005; Nora et al., 2002). Gender discrimination and sexual harassment in medicine have been detected at both the educational (Nora et al., 2002) and faculty levels (Carr et al., 2000). Looking at these studies the authors have found that more women than men report such discrimination. At the faculty level women were 2.5 times more likely to perceive gender-based harassment than men (Carr et al., 2000). Overall in the Carr et al. (2000) study about half of women experienced harassment as compared to a handful of men.

The larger literature on workplace experiences has also looked at gender and sexual harassment (Bowling & Beehr, 2006; Duncan & Loretto, 2004; Ilies, Hauserman, Schwochau, & Stibal, 2003; O'Connell & Korabik, 2000; Willness, Steel, & Lee, 2007). These studies have looked at health outcomes of harassment (Willness et al., 2007), rates (Ilies et al., 2003), and intersectional analysis looking at issues such age (Duncan & Loretto, 2004). A meta analysis of multiple studies showed that 58% of all women in the workplace experienced harassing behavior while 24% experienced sexual harassment (Ilies et al., 2003). Given the consistent findings of workplace harassment in the literature, it is very clear that the harassment reported by the participants in this study is not unique to physics and astronomy.

The impacts of sexual harassment can take a serious toll on women, having been linked to lower job satisfaction, withdrawal from work, and poor health (Willness et al., 2007). For Stevie, her experience caused her graduate career to be extended and caused stress and concern as she searched for a new advisor. Lower levels of sexual harassment reported in this study than in some of the literature may have been a symptom of talking to women that were nearing graduation; more severely harassed women may have quit or left early in their programs. What is clear from the literature and the results in this study is that gender discrimination is alive and well. Such discrimination ranges from the unconscious to the very conscious sexual harassment. The dismissal and silence these women faced when reporting their incidents cannot be allowed. Unless we as a community take a stand against such intolerable actions they will continue. Without remedy physics and astronomy will continue to lose talented people to insidious experiences. Fortunately, the women in this study had tools to preserver such as leaving the country to do research in the case of Nancy and switching advisors for Stevie. But these might not be options that all women have.

Future Research

Further research is needed to both substantiate the claims made here and illuminate the research problems further. A quantitative large-scale study could flesh out the mentoring experiences of women in graduate physics and astronomy and how it shapes their careers. Strong patterns did not emerge in this study, but may with sufficient numbers. In addition it would be possible to use large scale study to map out the career expectations of many women in physics and astronomy. Including a longitudinal component could seek to find out their actual career pathways. Lastly, a survey could also capture the levels of gender discrimination experienced by participants and how this may also have impacted their success.

Qualitative methods could be employed more as well to capture a stronger image of the culture of physics. Isolated interviews do no speak to the many facets of an individual's life or look at day-to-day or month-to-month changes. More in depth case studies of whole departments or programs could get a fine-grained view of a few women's lives and reveal details previously unconsidered by observing their teaching, research groups, keeping journal logs and more. Such an analysis could also dig deeper into the lives of women and unveil the culture they experience. This study would benefit from triangulation and allow the personally observe the participant's experiences.

Future research should also seek to include more diverse persons to share their stories. A large limitation of these results is that they do not include many voices from women of color, who have been shown to very unique experiences in physics and STEM (Johnson & McIntye, 1998; Ong, 2005). Their inclusion is particularly difficult due to scarcity, but is an important voice to include nonetheless.

Conclusion and Implications

This study sought to build understanding and meaning from the lives of women without comparing their experiences to those of men. An important overall finding is that the aspects that supported women in physics were largely the same as women in astronomy. Although astronomy demonstrates larger overall representation of women, this did not translate into a discernable difference of experience.

Each of these women's stories were unique, but they were linked by common themes that acted as a web to hold them up. Fellow students, faculty, and post doctorates alike acted as a support structure to get these women through their courses and research. Students battled tests and homework side by side, and faculty gave students access to the research skills and professional experiences necessary to succeed at the (under)graduate levels in physics and astronomy. Of course not all participants were so lucky, and some faced hostility and discouragement from the very people who were suppose to help them.

This demonstrates that for each person, physics and astronomy are not giant machines that treat everyone the same. The individual experience can be largely determined by the people around a student; in some cases they are harassers and in others they are allies. These environments in which students learn their research crafts and get professional guidance can be seen as micro cultures that exist within the larger physics culture. This micro culture appeared to have the strongest impact on the participants.

As described in chapter 3, physics has been argued to house a competitive male dominated field that imperils women's participation upon their entrance into the field. The cultures of physics and astronomy revealed by these participants fit loosely in this mold. In the culture they described the competition and fighting was largely seen to be attributes of a research career in their fields. These were not described at the graduate level. What was described, though, were ample examples of micro aggressions and a few egregious offenses against these participant's gender. Women were overlooked, ignored, and sometimes harassed. The literature clearly demonstrates that these incidents occur across workplaces, and may not be confined to physics.

The ubiquity of these occurrences may speak to physics and astronomy as a whole, or be a symptom of a field so dominated by men. In either case, the culture of physics and astronomy clearly demonstrates a mistreatment of women at small and large scales within this study. The cultural issues in the field are exacerbated when considering the arduous paths described by these women to become research professors. They saw this path as being one without a personal life or time to support their children. In the case of Tori who wanted this path and a family, she recognized that going down it would require leaving her children in the care of others. Many professional careers are like this, but this is a cultural aspect that can change.

If the pathway to a research career is not altered many women may never go down that road. Mason and Ekman (2007) show that the tenure track needs to be more flexible to the demands of having a family before women will prosper in the academies. But family was not the only concern for these women. The culture of physics that demands all your time be devoted to science, as discussed by Janet, also was perceived to limit these participant's abilities to have lives outside of work. The cultural expectation of physicists and astronomers to always work may not be attractive for women students.

If departments want women students in their programs to persist and thrive they need to ensure that they build an internal culture that supports them as students and people, is intolerant of gender discrimination, and recognizes and supports their potential varying career pathways. As a community we need to begin to shift our expectation that professors always work to one that is more conducive for multiple important facets of a rich life. Including the potential for children and outside interests. If such a reality can be built it may be possible to develop a physics and astronomy culture conducive not only to women students, but all students.

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APPENDIX A: HSIRB Approval

APPENDIX B: Codes

Code Frequency

Name	Participant Field	
	Physics	Astronomy
Astro Professors More Friendly	0	1
Astronomy to Physics	1	4
Breadth of Exp-MISC	3	2
Breadth-Academic Experience Outside of PHY	8	2
Breadth-Interests outside of PHY	2	0
Breadth-Jobs outside of phy	6	2
Breadth-Music	1	1
Career- Few job available	0	3
Career- Industry	3	4
Career- Other	7	4
Career- Other Important Things in Life	6	0
Career- Outreach	1	5
Career- R1	6	3
Career- TI	6	8
Career- Wanted one so not struggling	1	1
Career-Location	1	3
Chair-Encouraged having kids	1	0
Close With Other Undergraduates	0	0
Community	8	14
Community- In it together	1	3
Competition	2	5
Competition -None	0	0
Conflict- Other Students	0	1
Confronted Failure	0	0
Connections or Exposure	0	12
Culture Shock	0	1
Discouragement	7	5
Education-Collaboration With	0	0
Education-Enjoys	1	0
Ethics	1	0
Family Importance	0	2
Family Kids-Couldn't have in grad school	0	1
Family Kids-Not Possible at R1	3	1
Family Kids-Possible at R1	3	2
Family Turmoil	0	0
Family- Doesn't want a	1	3
Family-Kids- Stay at home Spouse	0	0
Family-Kids-Possible at TI	1	1
Family-Wants a	2	7
Female Camaraderie- Post-Docs/Faculty	1	5
Female Camaraderie-Other Students	6	4
Female- Female professors G	0	0
Female- Prefers working with	1	0

Female- Women in lab	3	0
Female-Female Professors UG	1	2
Female-Few Other Women	2	7
Female-Other Women	2	3
Fractured Identity	0	0
Friends with other students-G	4	6
Friends with others students-UG	3	4
Gendered Experience	17	15
Grad School- Struggles	2	3
Grad School-Looked for women faculty	0	1
Greatest Accomplishment	10	10
Guidance	1	3
Had to go to graduate school	2	4
Hands on Experience with Science	4	0
Happy	0	0
Health Issues	0	3
High School Prep-Bad	0	1
High School Prep-Good	4	2
Impact/Help People	11	3
Labmates-Helpful	2	0
Labmates-Unhelpful	0	0
Learned New Skills-From Advisor	0	0
Lifestyle	10	6
Location of Graduate School	3	11
Location of UG School	0	5
Male Students-Didn't talk to	0	2
Male Students-Talked to	0	0
Masculine Traits	0	3
Math Enjoyment	6	2
Math Too Abstract	2	0
Mother-Daughter Relationship	0	1
No College Guidance	0	0
Outreach	4	7
Overcommitted to other things	0	0
Partner- Concerned About	0	1
Partner- Flexible	0	5
PCSE Science Experience in Middle School	0	2
PCSE-Science Experience in High School	2	3
PCSE-Science in the home	9	4
PCSE-Scientist in Family	11	5
People	0	2
PER as apart of Physics	3	0
PER Chooser	2	0
PER Controversy	1	0
PER Didn't know about	1	0
PER How They Found Out About	2	0
PER Switcher	3	0
PER Why They Are Interested	3	0
PER- UG Res.	0	0

PhD in Physics-Wanted	0	0
Physical Safety	1	0
Physics Isolating	1	0
Physics- Chose Major pre-college	1	0
Physics- Intro Class important	1	0
Physics- Struggle in Courses	2	6
Physics-Competitive	0	0
Physics-Didn't know what was	4	0
Physics-Enjoys	1	0
Physics-Trad. Res	3	0
Positive Profesor Interactions	1	5
Prestigious Fellowship	0	0
Problem Solvings	0	1
Professional Connections	0	1
Professional Development	0	4
Programs/Student Groups	0	0
Pushed	0	1
Puzzle	2	3
Qualifying Exam Stressful	0	3
Research Adivsor - Wants a Personable One	0	3
Research Advisor -Choice Research Field Because of	1	0
Research Advisor- Bad Relationship	4	11
Research Advisor- Communication Good	8	3
Research Advisor- Different at beginning than end	2	1
Research Advisor- Friends With	2	1
Research Advisor- Has Two	0	4
Research Advisor- Relationship Bad	5	10
Research Advisor- Relationship Good	10	4
Research Advisor-Absent	4	8
Research Advisor-Communication Bad	6	3
Research Advisor-Pushes	0	3
Research Autonomy-G	0	1
Research Autonomy-UG	0	0
Research Group for Convenience	3	0
Research- Enjoys	0	1
Research- Schedule Conflicts in Group	0	0
Research- Simliar Identity as Advisor	0	0
Research-lack of resources	1	0
Research-Resources	0	6
Research-Same Field as UG in G	0	0
Role Model	0	6
Role Model-Wants to be	0	0
Science Policy	0	1
Serendipitous Discovery of Field	0	2
Sexism-Overt	1	0
Sexism-Subvert	7	0
Smarter Than The Boys	0	1
Success- Different View of	0	2
Support-Familial	4	10

Support-Other Students	3	2
Support-Professors/Advisors	15	19
Support-Student Group/Program	2	1
Suppport-Post Docs	7	7
Switched Major to Physics	0	1
Teaching Experience-Informal	3	1
Teaching Experince- UG TA or LA	0	0
Teaching- Can do more than just	0	0
Teaching- College	0	1
Teaching- Did While a Highschooler	0	1
Teaching- Does not enjoy	0	0
Teaching-Enjoys	3	7
Teaching-High School	1	0
UG- Small School	0	3
UG- Struggled	0	1
UG- Women's Colleges	0	5
UG-Research	6	18
Undergrad-Close with students	0	0
Undergraduate Research	6	0
Unhappy/Depression	0	0
Wanted to be a Scientist Young	3	1
Weapons-Doesn't want	2	0
Work-Life Balance	3	0
Worked Alone	4	0
Worked on hw with other graduates	9	11
Worked on HW With Other Undergraduates	15	9
Worked on Qualifying Exams w/other G	1	5
Worked on Research with other G Student	0	1
Subfield Totals	379	435
TOTAL	**814**	

APPENDIX C: Example Biography Excerpt

Pre College

Person was seen as intellectually gifted from a young age and encouraged by her grandfather to use her gift:

> *My grandfather would tell me that, you know, "you gotta use this to do something important, this is a gift"…. He encouraged me and thought that that was a good thing, and he tried to push me to do something that made things good… it spoke to me.*

She enjoyed math early on and took many AP sciences classes in high school. However, she could not comprehend what a science career looked like so she decided initially to only major in math during college:

> *In high school I really loved math, none of the sciences really, really felt like they were good explanations about what you did on a career path because in biology they tell you the parts of animals but they don't really tell you what a biologist does. Chemistry was at least a little bit closer to having an easily understandable career path, because you could be a chemist and work at a drug company…Um, biologist, I had no clue what they did and I assumed they categorized animals all day which sounded boring…in physics I had no idea because we spent physics classes building bridges out of popsicle sticks.*

Undergraduate

Person's first choice of major was math because of her skill at it during high school, she didn't initially choose a science because she couldn't foresee a career in biology, chemistry or physics. She was very focused on a career so she had enough money to sustain herself:

> *I grew up some place very poor so the most important thing in my life was making enough money so I could eat every day [laughs]….I was verv very focused on getting out of that life and getting into a life where I had a job. That was a long term successful job…*

Person eventually found math to be too easy and wanted to double major in a science. As a freshmen she was placed into a nuclear physics research group as a professorial assistant and enjoyed her modern physics class, these experiences led to her choice of physics as her second major. She felt she could change the world by pursuing the toughest degree possible:

> *I started with a bachelors in math in college, um, and I didn't really find it very challenging. The course work was pretty straight forward and I already*

knew I wanted to do a double major and I tried to decide kind of what the hardest thing I could possibly do was. And I was leaning towards science anyhow as my double major so I picked physics, umm. I took a intro course in it, uh, and it seemed interesting and it seemed very difficult and challenging. And, uh, I was looking for where I felt I was doing the hardest thing I possibly could, because I think, that's how I could best change the world.

Person noticed the low number of women in her undergraduate classes and figured many women left physics because of gendered traits. The ones that remained, she said, shared similarities with the men:

I think that a lot of the incompetent women sit through undergrad and go "wow, this is hard, and I don't belong here" because that is statistically a woman trait… is sitting there and going, you know "I'm not good enough to do that" where as guys are a lot more likely to say "this is hard but I am going to charge forward and do it anyways". Um, its just two different statistical approaches. I don't think it's necessarily a characteristic of the women who end up in physics. They are usual the ones who go "this is hard but I'm going to charge forward too". In that sense we get more personalities that are aligned in physics no matter what gender you are.

As an undergraduate Person still was not sure what one did with a physics degree or possible careers. However, she felt that to be a physicist you had to have a PhD. She also had a firm belief that you should do what you're good at, and she was good at physics. This led her to applying and going to graduate school in physics:

…[as an] undergraduate I never really got a clear understanding of what the different fields of physics were and what careers especially in the different fields of physics were. So I probably would have done something very different if I had understood.

…you can't do physics with an undergrad degree. You have to have a graduate degree of some sort. Um, so, I went into physics grad school. It was the next logical step and the hardest thing to do.

…but there aren't a lot of people who have what's needed to be really great scientists. Really great researchers. It important to do that if you can.

Graduate

As Person transitioned into graduate school she knew she was going to study nuclear physics. She chose nuclear physics because of convenience, she continued working under her same advisor and at the same institution as her undergraduate university:

> *…I thought it went really well so I just kept doing it… I wasn't really sure what else was out there and it was safe…rather than try to go out and figure out what else was going on. So it was really just coincidence and what was easiest for me at the time [laughs].*
>
> *Part of it was just familiarity. I knew what to expect, so it was a little bit less intimidating then going out and trying to find a new advisor at a completely different school where I didn't know what they did already. So the familiarity was really important, I already had an idea of what would be going on. Um, I also really liked the advisor, he was really nice to me when I was an undergrad. He introduced me to a lot of neat science stuff, so, you know, I figured that this would be a good experience*

In the course work phase of graduate school Person worked on her own. The classes came easy to her, except her experienced in theoretical classes. She felt the classes didn't give her career skills, which is what she came for.

> *I tried not to interact with most people in the classroom, umm, it was… in the lower level classes there was no real need to, the intro grad classes were easy enough. That, I didn't feel a need to ask people for help…*
>
> *I don't really enjoy theory classes at all…. I'm glad we have theorists and all, but my gosh those classes make me miserable and they don't teach me things that are helpful for my career.*

Person's interest in career training was apparent in all avenues of her graduate training. She felt as if her former undergraduate advisor, and now graduate advisor, was not giving her the helping hand she needed. She also felt he never saw her as a graduate student:

> *So I didn't really expect that, I would have to go on my own so much for my career path. I thought that my advisor would have a bigger hand in directing me towards a career. Or helping me figure out what I needed to do to have a physics career. So that sort of surprised me in grad school. Being, a little more career training and a little bit less, doing more odd jobs for the same professor.*
>
> *…he never saw me as a graduate student because I worked for him as an undergraduate. And, he just never really made the transition of treating me like one of the other graduate students.*

Person's first research advisor was not only no help in her career goals, but he also did not provide her with opportunities to take charge of experiment. She also had a further disconnect, in which she couldn't even talk to her advisor about jobs:

> *…he didn't really like me to take charge of anything. And I find that very frustrating because I like being in charge of things. I think part of what grad school is is you learn to be in charge of some project. And, bring it to, you know, completion, you know, that's the idea of the dissertation. Um, he didn't really care about any of my career goals or any of my career aims. You know, I couldn't talk to him about what kind of job I wanted.*

Person's frustration continued because the advisor was uninvolved with the lab and favored his former students who were coming back as post-doctoral researchers in lieu of her. They were allowed to be charge of experiments when she wasn't:

> *He didn't come to experiments, so he never, you know, saw what was actually going on. He didn't come to the lab for years… He didn't know what hours I was working for years. Even though I had told him very straight forward 'this is when I am working'. Um, so, he was just so uninvolved that I don't think he really saw what was going on or cared to correct it.*

> *…there was no opportunity for me to be in charge when I was at that point that they [former grad students] had started of being in charge of experiments. So, you know, they weren't moving on and he wasn't making them move on. I asked him nicely, you know, I want to be in charge of this… and…. These other students are really… I'm glad they are coming in to help us but its making it difficult for me to start taking charge of experiments and learning the things I need to know to get a dissertation done.*

> *…he really wanted to avoid any social issues. So if I said 'look you gotta cut this grad student from being in charge for 12 hours of the experiment to eight so that I can do four hours of being in charge and get some practice in' and he was like 'no I'm not dealing with it, its your problem'.*

………. END