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Are the Predictors of Women's Persistence in STEM Painting the Full Picture? A Series of Comparative Case Studies

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ABSTRACT
This study provides an in-depth picture of five university level women who entered a large American university with a declared science/engineering major. Comparative case studies are used to highlight how predictive factors regarding persistence in the current literature do not cover the unique and varying experiences that lead to women's decisions to stay or leave their science/engineering majors. Specifically this study focuses on the following predictive factors: parental support and education level; pre-college preparation; ability to identify with the culture of science and engineering. These narrative life histories delve in to each woman's perceptions of her experiences, thereby revealing their personal stories of identity within the science and engineering cultures. This study highlights a new way of viewing coping strategies that enable persistence and provides evidence for the role that science/engineering departments play in leavers' trajectories.

KEYWORDS: Women; Gender issues; Science; Engineering; Persistence

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INTRODUCTION

This study[1] provides detailed qualitative case studies of five women who represent the complexity and variation in women's persistence in science, technology, engineering, and mathematics (STEM) fields. Women's persistence in STEM is a major concern for educators and policy makers because women remain underrepresented in STEM fields despite the increasing number of programs and policies that aim to improve this underrepresentation (Leggon, 2006; McGrayne, 2005; National Science Foundation, 2007). Previous research in women's persistence in STEM fields has indicated a variety of factors as predictors of persistence including: parental support and education level; pre-college preparation; and the ability to identify with the masculine culture of science and engineering (Brickhouse & Potter, 2001; Carlone, 2004; Dick & Rallis, 1991; Eccles, 2007; Farmer, 1997; Jones et al., 2000; Ong, 2005; Rayman & Brett, 1995; Seymour & Hewitt, 1997; Williams & Ceci, 2007). Some of these studies have focused on only one of these factors without explaining the larger cultural and historical issues that affect women's persistence.

This study falls within framework of research that demonstrates the complexity of STEM persistence for women in masculine dominated fields (Brickhouse & Potter, 2001; Carlone, 2004; Johnson et al., 2011; Jones et al., 2000; Ong, 2005; Slay & Smith, 2011). This study adds to previous research, particularly in response to Johnson et al.'s recent study (2011) focusing on case studies of minority women within STEM fields and the complex interactions of STEM, gender, and race/ethnicity. Like this previous research, this study highlights the ways in which the experience of each of the participants in this study can align and conflict with current literature. By conducting narrative life histories with each of these women the researcher was able to discover where contradictions between previous research and the experience of this sample occurred. The researcher was also able to explore how each of these women perceived their experiences. This study indicates that research is necessary to better understand the complexity and the varying interpretations made by women in STEM majors that affect their persistence.

LITERATURE REVIEW

Women have historically been underrepresented in STEM fields throughout the world, particularly in fields like physics and engineering (Anderson, 1995; McGrayne, 2005). In the United States, the passage of Title IX of the Educational Amendments Act of 1972, ignited some improvements to education and the working conditions for women (Anderson, 1995; Carpenter & Acosta, 2005) by increasing women's access to STEM degrees and STEM fields (American Association of University Women, 2010). However, women still represent less than a third of degrees and employees in STEM fields, a proportion that is even lower in fields like physics and engineering (National Science Foundation, 2007). This is a particularly troublesome statistic since STEM fields are lucrative in terms of the power they hold within society and the contribution they can make economically to both the individuals working in the field and the nation for whom they work. Currently, the American government is contributing large amounts of money toward programs that aim to increase the number of students persisting in STEM fields with the goal that this increase will improve America’s economy and technological dominance globally (Chang, 2009; Tessler, 2008). One of the obvious areas where the government can improve the number of American citizens pursing STEM careers is to improve the underrepresentation of women in these fields (Wyer, 2001).

The Causes of Women’s Underrepresentation

Researchers have cited various reasons for this underrepresentation and educators have attempted to address these in K-12 and college classrooms (Williams & Ceci, 2007). Some theorists contend that women’s underrepresentation in STEM is caused by the cultural and social attitudes that prevail in American society, which portray women as inferior to men in these fields (McGrayne, 2005; Williams & Ceci, 2007). Studies that focus on the predictive factors associated with women’s persistence in STEM often focus on measurable items such as parents’ education level or whether or not a parent works in a STEM field (Dick & Rallis, 1991; Farmer, 1997). Quantitative studies that have measured these items have found that women whose parents have a college degree or higher and have one or both parents working in a STEM field have a higher probability of persisting (Crisp et al., 2009; Eccles, 1994; Rayman & Brett, 1995). The methodology of these studies does not allow these researchers to observe the complexity of women’s persistence, which can affect the transferability of these results to all women.

STEM interest and persistence has also been linked to schooling as well. In elementary and secondary school classrooms, teachers are socializers for students. Research indicates that female students are socialized differently than male students in schools (Jones et al., 2000; Zohar & Bronshtein, 2005). Classroom observations have indicated that science and mathematics teachers, regardless of their gender, tend to provide male students with more support, opportunities, and praise than female students (Carlone, 2004; Jones et al., 2000; Olitsky, 2006; Sadker et al., 2009). This lack of practice due to denied opportunities and the prevailing cultural attitudes that promote women’s sense of inferiority and marginalization in STEM fields puts women at a greater disadvantage when they enter university (Carlone, 2004; Jones et al., 2000; Nosek et al., 2002; Olitsky, 2006).

Once in university, studies find that women continue to experience a sense of marginalization based on the culture of STEM departments. They are outnumbered by their male peers in their science courses (Leggon, 2006), and they encounter few female role models and professors (Leggon, 2006). This lack of women in the field and the isolation that women experience has been referred to as the “chilly climate” (Shakeshaft, 1995, p. 74), which has been credited as a major reason that female students leave STEM fields once in college (Seymour & Hewitt, 1997; Shakeshaft, 1995). This chilly climate combined with the masculine language and culture of many STEM fields affects women's ability to identify with these fields (Carlone, 2004; Lemke, 2001; Ong, 2005). Female students often have a conflict between their own cultural influences and the language and culture of STEM (Johnson et al., 2011; Lemke, 2001; Olitsky, 2006; Slay & Smith, 2011), which can prevent members from these marginalized groups from persisting (Jones et al., 2000; Olitsky, 2006; Ong, 2005).

The research summarized in this literature review shows that there are three categories that appear to be the most influential in affecting women's STEM persistence. These are: family support, including parental education level and work in STEM; pre-college STEM preparation, which includes the effects of teachers on female students' STEM interest; and female students' ability to identify with the male dominated fields of STEM, particularly fields such as physics and engineering. This last category can be further compounded due to the intersection of gender with ethnicity and/or race (Johnson et al., 2011; Ong, 2005). Some of the studies that have indicated the importance of these factors were based on quantitative methods (i.e. Crisp et al., 2009; Farmer, 1997; Rayman & Brett, 1995) whereas others were based on smaller qualitative studies (i.e. Carlone, 2004; Ong, 2005). The goal with this study was to utilize narrative life histories to allow participants to describe the influences on their STEM choices. These methods allowed the researcher to determine if these categories of predictive persistence were still evident in the participants and if so, how women's perceptions of these categories affected their abilities to persist or leave their STEM career?

The participants comprised female fourth year university students who had entered university with a declared STEM major[2], indicating their interest in a STEM career. This study was part of a larger qualitative study of 26 women who entered a large University (State University) in the southeastern United States in the fall of 2006 as STEM majors (Hughes, 2010). To aid the analysis, the researcher also utilized the combined conceptual framework of Eccles' expectancy value model of career choice (2007) and Carlone and Johnson's (2007) framework of science identity formation with Butler's conception of gender as an ever changing and often influential aspect of one's identity (1999).

CONCEPTUAL FRAMEWORK

The goal of this study was to understand the life-long process whereby women experience STEM subjects and then choose whether or not to persist in these subject areas for their careers. Because STEM fields are often considered male-dominated and research has shown that this conception affects women's persistence negatively, it was also important to frame the conception of gender and the role it can play in STEM persistence. Consequently, the researcher combined Eccles' expectancy value model for career choice (2007) with Carlone and Johnson's framework for science identity formation (2007) to help frame the process wherein individual's weigh their experiences and relate these to their decisions regarding STEM careers. These combined frameworks and the relationships between their various features can be found in Figure 1 below.

Figure 1: The Interrelationship among the Theories

Stage in Science Identity Process (Carlone & Johnson, 2007)	Corresponding Expectations and Values for Success in STEM field (Eccles, 2007)
Competence	Expectation of Success
Performance	Attainment, Intrinsic, Utility, and Cost
Recognition	Gender (Butler, 1999)

According to Eccles (1994; 2007), career choices are influenced by a number of cultural and individual concepts. The cultural concepts include the influence of gender roles and cultural stereotypes, socializers' (parents, peers, and teachers), and achievement/abilities in science and mathematics. All of these factors are also part of the literature explaining the influences that affect women's persistence (Brickhouse & Potter, 2001; Carlone, 2004; Dick & Rallis, 1991; Eccles, 2007; Farmer, 1997; Jones et al., 2000; Ong, 2005; Rayman & Brett, 1995; Seymour & Hewitt, 1997; Williams & Ceci, 2007). Eccles (1994) also identified individual concepts, including an individual's interpretations of these cultural experiences. These interpretations can help to shape an individual's goals and decisions, particularly if children are exposed to stereotypes and these are reinforced by socializers, such as the idea that girls are not as naturally inclined in science and mathematics as boys. Children will also begin to measure and evaluate their own achievement and abilities based on others around them (Eccles, 1994).

These cultural influences, combined with the individual's perceptions and experiences, culminate in the final two parts of the expectancy-value model: expectation of success and the value a person attaches to this success (Eccles, 1994; 2007). According to Eccles, one's expectation of success is influenced by one's confidence in his or her abilities. This confidence level is also affected by the estimated difficulty of the tasks required for a chosen career. In STEM careers, an individual's beliefs regarding his or her abilities are influenced by that individual's performance in science and mathematics courses and by the support he or she receives from socializers (Carlone, 2004; Rayman & Brett, 1995). Carlone and Johnson (2007) discuss this aspect of persistence through the first part of their framework for science identity: competence. In Carlone and Johnson's framework individuals will develop a stronger science identity if they can demonstrate skills and sufficient scientific knowledge, which the authors define as competence. As individuals develop their competence they will assess whether their abilities in science can result in success in science or expectations of success (Carlone & Johnson, 2007; Eccles, 2007). These expectations of success and corresponding competence are further developed through performance (Carlone & Johnson, 2007). Individuals develop their identity and increase their perceptions of success by performing their skills in various settings.

During this performance stage, Eccles (2007) identified four subjective task values that each individual assesses to ultimately make a career choice. These values are defined as attainment value, intrinsic value, utility value, and cost. Attainment value indicates how well the career fits in with one's identity. Intrinsic value is the interest or enjoyment derived from a career. Utility value indicates how well the career fits in with current and future goals. And finally, cost refers to the negative aspects that might be perceived to be associated with the career (Eccles, 2007). As individuals are performing their skills they can assess whether the STEM culture and the required skill set for success within these fields, fits with their identity and whether they have continued interest in these fields. The performance stage also allows individuals to determine whether these skills and the related career fit with their goals and are worth the cost (Carlone & Johnson, 2007; Eccles, 2007). Both the expectation of success and the value one places on a particular career are unique to that individual and depend on the individual's experiences and the individual's own interpretation of those experiences (Eccles, 2007). Figure 1 shows how all of these concepts are interrelated; an individual can improve their competence through ongoing performance in different settings. Also individuals can change their expectations of success or the value they give to that success depending on changing views of their competence or performance in certain settings.

Carlone and Johnson (2007) add to Eccles model with a third piece of the science identity framework: Recognition. Individuals cannot fully see themselves as scientists/engineers if credible experts do not recognize them as such. Recognition can include a variety of forms such as: grades on examinations for faculty courses, being chosen for research internships with faculty, being chosen for presentations, publications, or awards by faculty. For women, persistence within STEM fields (including recognition) can be constrained by science community members' stereotypes that marginalize individuals based on race, ethnicity, and gender. Slay and Smith (2011) refer to this concept as "stigmatized cultural identities" (p.86). Butler's conception of gender was chosen to address this aspect of women's trajectories within STEM. Butler (1999) questioned the definition and understanding of gender as a "natural fact" versus a "cultural performance" (p. xxviii). She defined gender as a discursive formation shaped by the culture that creates it, specifically the male-dominated system. Butler (1999) admitted that individuals have agency in the process of identity construction; however, she questioned how much of this identity construction is purely chosen by the individual rather than influenced by cultural norms. Therefore, because women's persistence in STEM fields is based on individual experiences along with cultural attitudes (and often biases), the best way to understand STEM career choice is to understand participants' conception of gender and STEM over their lifetime.

METHODS

According to Creswell (1998), narrative life histories focus on a person's story and how the larger social and cultural experiences are interpreted and framed by the individual. In this study, the researcher wanted to determine how these experiences and factors affected the participants' STEM persistence and how they maneuvered through the culture of STEM. To show the reader this process in more depth, the researcher chose to use two sets of comparative case studies that compare a 'leaver' to a 'stayer' and a third individual case study to highlight the added role that ethnicity can play in women's abilities to identify with STEM. These case studies were selected because they exemplify common comments and conceptions articulated by all of the 'stayers' and 'leavers' interviewed for the larger research study. These case studies also provided the richest sources of data through their own story telling.

The first set of interviews occurred during the summer of 2009 and focused on the life history of each participant. The interview questions drew from the conceptual framework and focused on experiences and epiphanies within their lives that they remembered as being highly influential to their decision to work in a STEM field or not (Creswell, 1998). Each participant had her own storyline and accompanying map, which allowed for easier cross-case comparison to identify the similarities and differences among 'stayers' and 'leavers' and their career choice decision paths. This storyline along with the transcribed interview was sent to all participants as a form of member checking (Creswell, 1998).

The second set of interviews occurred during the spring of 2010 to identify whether any of the participants' career choices or plans had changed as they approached their graduation from university. (One of the women, Brenda, who was originally a 'stayer' in 2009, left her major during the interim between the first and second interviews.) The second set of interviews served as a source of validation and triangulation by identifying whether individuals were still part of their original 'leaver' or 'stayer' cohort and what each person's plans were after graduation (Creswell, 1998). These cohorts were determined based on State University's (SU) definition of STEM majors. Each person's career plan was also considered and categorized according to the National Science Foundation's (2007) STEM careers.

Analysis

During each interview, the researcher wrote down reflective notes, comments, and questions (Creswell, 1998; Miles & Huberman, 1994). After transcribing each interview, the interview and the notes were reviewed and combined into memos for each participant (Creswell, 1998). After the original interviews with all twenty six participants were completed, the researcher reread each participant's memo and the original interview transcripts and developed themes based on this review and the original conceptual framework. Memos were created for each of these themes (Ryan & Bernard, 2003). Subsequently, the researcher reviewed the data to find individual 'stayers' and 'leavers' who best exemplified the experiences of the groups ('stayers' and 'leavers') and provided the richest sources of data. Because the STEM fields of physics and engineering have the lowest representation of women (NSF, 2007), the researcher chose to focus on comparative cases within these fields to determine whether the culture of these fields was particularly influential on women's choices.

Although interview data, particularly life histories, are based on perception and memories, this does not bias the results of this study. These perceptions are commonly considered the factors that affect women's STEM career decisions; therefore, it was important to this research that the participants provided detailed descriptions of their perceptions. These perceptions were unique to each person and led to the participants' decision to stay or leave STEM fields. Consequently, the reality was not as important as the perception of these events that led to each individual's decision to stay or leave STEM fields.

These comparative cases exemplify the role of the following factors in women's STEM decision process: Family support and role in STEM; success in high school as predictor of success in university; and perception and identity as indicators of persistence. A final stand-alone case study will be described because it highlights another aspect of identity: the intersection of ethnicity and gender in STEM fields where women of color are particularly underrepresented (Johnson et al., 2011; Ong, 2005). These case studies highlight the complexity of the decision process that moves beyond one factor and involves many factors, as the for this study conceptual framework demonstrates.

RESULTS

Two Paths within Engineering

The Cases

Kristen and Penelope both entered university planning to become engineers. Kristen's father had a background in a STEM related field since he worked as a computer programmer and was attending school for his PhD in computer science at the time she entered university. In high school, Kristen was successful in her mathematics and science classes. Her advanced mathematics skills (competence) were evident in her acceptance and success (performance) in AP calculus in her senior year. She had support in her science and mathematics pursuits from both her parents and her teachers. Her teachers recognized her competence and encouraged her to pursue engineering in college. She decided to pursue engineering for both intrinsic reasons and extrinsic reasons. She described her intrinsic rationale as, "I felt like I could always find the answer. I think that is the reason why I decided to go into engineering because it was so definite and it was something that was attainable because I knew the answer was there". She also indicated that she was partly motivated by the high salary that engineers typically make (extrinisic).

Neither of Penelope's parents worked in a STEM field. Yet, she did have high competence in science and mathematics classes during her pre-college schooling as evidenced by her grades. (In American High Schools, course grades are measured by a grade point average. Penelope's grade point average was a 4.0, indicating she had received the highest possible grade in all of her classes.). When Penelope came to State University (SU) she decided to join WSTEM (for further details of the initiative see Hughes, 2010), a living and learning community on campus for female STEM majors where they lived together in a dormitory and were given research and tutoring opportunities, to meet other women who were interested in mathematics and science. She was aware of the underrepresentation of women in STEM fields and thought WSTEM would help to provide her with support. As a first year student she decided to pursue chemical engineering. She made this decision based on research she had done on engineering careers in secondary school. “I looked into it and it just struck me as interesting” (intrinsic). But she was also motivated by the perceived difficulty of the major, “It was the hardest major so if I didn’t succeed in it, I would have overcompensated already for whatever I would fall into.”

The Literature

These cases highlight the role of parental STEM experience and pre-university preparation as predictors of STEM persistence. Research has found that ‘leavers’ tend to cite a lack of preparation for their choice (Eccles, 2007; Seymour & Hewitt, 1997). However, this exemplary case comparison shows that high school success is only one factor that influences STEM career decisions. Based on the information in the section above, it would appear that both of these women had adequate preparation and equal performed competencies. Both of these women had little experience with engineering before university. And both of them based their career choice on the misconception that engineering provided attainable answers (Duschl et al., 2007). Both of these women were motivated to become engineers because of their interest along with some extrinsic motivators (for Kristen her desire to make money and for Penelope her desire to help others). Kristen had a father who worked in a STEM field whereas Penelope did not. A factor that research indicates increases the likelihood of persisting in STEM (Brickhouse & Potter, 2001; Dick & Rallis, 1991; Eccles, 2007; Farmer, 1997; Rayman & Brett, 1995). And yet, Kristen was the individual who left engineering.

The Decision Process

Kristen’s decision to pursue engineering was based on her misconception that engineering problems always have a definite answer (Duschl et al., 2007). Once she started her courses she began to realize that her interest in mathematics was waning. She realized that she was not deriving any enjoyment or intrinsic value from her STEM courses despite performing competently in these courses. Then her introduction to engineering course gave her a clearer picture of what a career in engineering would be like. “It [the description of her future career] didn’t fit my idealized perception of what I would be doing and that’s when I decided since I have always loved history, even though it doesn’t give you a definite answer, it’s something that I could always have fun at…so I decided to switch to that”. Here Kristen described the lack of interest in her engineering related classes that affected her persistence.

Kristen also claimed that the “teaching style” in her engineering classes decreased her interest, “A lot of these math and science classes are done in larger rooms versus my high school where I could just walk up and bug the teacher or raise my hand.” This comment highlights the lack of recognition Kristen was receiving from her professors, which affected her interest and ability to identify with the subject (Carlone & Johnson, 2007). Kristen also described an inability to identify with the other students in her major:

> Science is just so much more uptight. The same way where I was a bit of a perfectionist, they as a general group of people…I mean minus a couple ones here or there where they are more laid back. I just saw the science culture as something that as a general rule, the really good ones were very uptight, the semi good ones were still uptight and the ones that were sucking were uptight because they were sucking. They're a much more tense culture.

This perception of engineering majors as uptight did not fit with her own sense of identity. As a result, she changed her major to Classical Civilizations, where she enjoyed her courses and felt like she fitted in better with her peers. Kristen contradicted the predictive factors of past research because she had a parent who worked in STEM and demonstrated high competence in science and mathematics before college. These two factors tend to predict success in STEM and yet, she did not persist. Her rationale for leaving aligned with qualitative research in that her sense of not being able to identify with her peers in engineering made it difficult for her to persist (Carlone & Johnson, 2007; Johnson et al., 2011). However, this inability to identify with the major was not related to gender or a lack of female role models, rather it was her overall sense that her peers in the major were "uptight". Kristen's life history raises an important issue that is not addressed fully in current research: she maintained competence in STEM but lost interest because of the perceived culture of STEM. Kristen's unique path highlights that the culture of STEM departments may force competent individuals to leave, which is alarming since these individuals are those who could theoretically persist based on their competence. This result poses the question as to what role STEM departments have in the underrepresentation of women in STEM through their own culture, not just the lack of critical mass. In direct contrast, Penelope recognized the gender bias within engineering and yet chose to stay.

Penelope entered university planning to become a chemical engineer. She enjoyed calculus and chemistry in high school and thought that chemical engineering would allow her to pursue those subjects. However, after her freshmen year she realized that chemical engineering focused more on "micro-organisms and the structures of the different elements and stuff". During her freshmen year she began to develop the perception that chemical engineers "were always in a lab coat with goggles looking at a beaker". Her perception was based on the pictures and videos that she saw in her classes. Then after her freshmen year she worked at an internship at a chemical engineering firm. She described her experience as "we're always in the lab, you never see outside, it's artificial light, artificial air". Her experience at the lab solidified her decision to change to environmental engineering because she felt she would have more opportunities to work outside. She believed she was competent in either engineering field, but one (environmental) fitted better with her interests and goals.

As far as her experience within the major, Penelope believed based on her observations of the female professors in her department that "all the female professors I can think of are extremely in over their head it appears. You never see them slowly walking they're just running from one place to the next, so busy, just bogged down". She also felt that women have to prove themselves in order to be taken seriously in engineering: "Like you have to prove yourself big time to be taken as serious as a man who's just as educated or un-educated as you are. But like I don't say that you're looked down on but you're not as highly trusted". This comment indicated her perception of women as a culturally stigmatized group who were treated differently than men in the male dominated field of engineering (Slay & Smith, 2011). The comment also highlights her coping mechanism for this gender bias by reframing the bias, changing it from negative opinions regarding women's abilities to lack of trust. By changing her conception to lack of trust she was able to frame the bias in a way that it could be challenged by proving herself as competent as opposed to viewing it as bias that is culturally embedded and more difficult to overcome.

Penelope also mentioned the lack of a critical mass of women in engineering: "If there's nothing out there telling you it's possible or fathomable to be a woman in engineering… I think that that hinders women a lot in the field because they don't see it, like I didn't see many women in the field". According to Penelope, the stigma for women continued on into the engineering workforce where prospective employers questioned female candidates' commitment to the field because of their possible family choices. She described this concept of family planning conflicting with career commitment as the reason "women aren't wanted in the sciences". Again, she could frame these negative views in terms of a lack of trust, something that she as an individual woman could overcome as opposed to the culture of STEM that would be more difficult to overcome.

Penelope wanted to stay in the engineering major, a field where she believed women would be discriminated against for family plans and where women had to work harder to be taken as seriously as their male peers. In doing so she contradicted most research in STEM persistence. She did not have a family member in STEM and she saw her gender as a stigmatized group within engineering. Her reason for persisting in her engineering major was based on the peer support she found there, the recognition from her peers and some credible members of the engineering faculty as someone who belonged in the field along with her framing of the bias within her field. She saw these gendered issues as the cost that was worth the end result: an engineering career. She was willing to prove herself among her male peers and accept the culture of engineering because she enjoyed the subject matter and was able to frame the gender bias within the field in a way that she felt could be overcome.

Based on past research, both of these young women should have left their STEM major: Kristen because of a loss of interest and lack of peer support, and Penelope because of her recognition of the gender bias within STEM. The use of qualitative methods, allowed the researcher to uncover the complex reasons for Penelope's persistence. She not only found peer support and recognition from credible members of her field, but she was also able to redefine the gender bias in a way that allowed her to see possibilities of success. This case highlights the role that coping mechanisms or redefinition strategies, as Slay and Smith (2011) refer to them, can play in women's persistence. It also raises the issue that Kristen had as a competent student who had lost interest in the field. Kristen could have persisted based on her competence, but chose to leave because she could not fit in with the STEM culture. This result demonstrates that STEM departments could play a role in keeping competent women in STEM if they re-address their culture.

The Role of Identity

The Cases

Heather and Brenda entered SU with an interest in the masculine dominated fields of physics and chemical engineering[3] respectively. Heather's father and grandfather both worked with electronics and gave her opportunities to take apart machinery at home to understand better how things work. Her mother was an elementary school teacher but stayed home with Heather and her sister when they were young. Her mother would conduct science experiments with her children when they were younger.

Throughout elementary and middle school Heather was in the gifted program where she was able to gain more hands-on experiences that activated her interest in science and mathematics. Her interest in physics developed during middle and high school due to her participation in a national science competition for many years. Through these competitions she was able to perform her competency in the subject area and was recognized as competent through the awards she received (Carlone & Johnson, 2007). She credited her high school physics teacher for getting her interested in a physics career as well, another example of a secondary school mentor recognizing Heather's competence. She was motivated to pursue physics at SU because of the challenge and difficulty it posed for her.

At SU she joined WSTEM because she was interested in paid research opportunities and she wanted to live with other women interested in STEM fields. She participated in research at SU and worked in a physics internship during a summer. The director of WSTEM was a physics faculty member who helped Heather find research opportunities and encouraged her pursuit of physics, which demonstrated Heather's recognition by a credible member of the physics community (Carlone & Johnson, 2007).

Brenda planned to major in chemical engineering because of an intrinsic interest in the subject. Her mother held a bachelor's degree and at the time of the interview worked as a homemaker. Throughout primary and secondary school, Brenda considered herself competent in science and mathematics based on her grades and the recognition she received from teachers, just like Heather. Her interest in a chemical engineering career began in middle school due to her participation in the gifted program where she credited the hands-on science activities as strengthening her interest. Then in high school her chemistry teacher introduced her to engineering. She participated successfully in engineering competitions, which also increased her interest and allowed her to perform her competency in other venues.

Brenda majored in chemical engineering as a first year student at SU because she planned on working in a position that focused on the environment and had an intrinsic interest in the subject matter. Like Heather, she chose to join WSTEM because she wanted to live with other women interested in STEM. Once at SU, she took advantage of the paid research opportunity. She also attended a summer engineering internship that she learned about through the WSTEM director. In each of these experiences she was able to successfully perform her competency in engineering and have these performances recognized by credible members of the engineering community (Carlone & Johnson, 2007). Through these opportunities, she, like Heather, was also able to see the types of careers available to her and determine whether these aligned with her values (Eccles, 2007). Both of these women's trajectories sound similar, yet, Brenda switched to chemistry education[4] soon after our first interview.

The Literature

These young women were similar in terms of their experiences and their attitudes toward STEM. However, the real difference between them started once they entered university. To understand this, it is necessary to reiterate the literature regarding identity in STEM. Research suggests that when an individual does not see STEM as fitting in with their perceived identity, then they will have to alter their identity to fit in with their chosen field or they may choose not to pursue it at all (Carlone, 2004; Duschl et al., 2007; Kahveci et al., 2007; Ong, 2005; Seymour & Hewitt, 1997; Slay & Smith, 2011). Studies indicate that individuals' perceptions of STEM, particularly women's, are important to their persistence and ability to identify with STEM careers (Brickhouse & Potter, 2001; Losh et al., 2007; Olitsky, 2006). Other theorists show that the gendered image of science and scientists prevents many women from feeling like legitimate participants in STEM fields (Harding, 1997; Kahveci et al., 2007; Slay & Smith, 2011). In the cases of Brenda and Heather, both of these women were majoring in STEM fields that were dominated by men. These women recognized their membership within an underrepresented group (women) that could be considered a culturally stigmatized group within science (Slay & Smith, 2011). However, each of them framed their gender in a different way that affected their persistence.

Heather claimed that although there were fewer women in many STEM fields she "believed that this was changing". Heather, like Penelope, utilized a coping mechanism that framed the underrepresentation of women in a way that made it more likely for her to be able to overcome it. Heather also did not focus on differences between men and women, which helped her to frame her beliefs in a more optimistic way. Brenda, however, described distinct differences between genders. She believed that women are better leaders than men, claiming that "women think more deeply about issues". She recognized the underrepresentation of women in STEM fields but framed this according to differences between men and women, saying, "women were not pushed as hard as men". Brenda's description was not done in the same way as Heather's. Brenda's explanation of difference put the blame on the STEM culture not pushing women as hard as men, something that she could not easily change or envision changing on its own. Therefore, she struggled with seeing the possibility of her success in STEM. The next section will show how this difference affected Brenda's sense of belonging to a culturally stigmatized group and consequently led to her decision to leave STEM, whereas

Heather's focus on similarities between genders helped her to fit in (Slay & Smith, 2011).

The Decision Process

Like the previous case study participants, during university both Heather and Brenda experienced frustration with their STEM majors, particularly when their misconceptions were challenged. Heather described physics as, "there's not a whole lot of 'we know this absolutely, definitely'. It's 'I think this is how it works, and let's test it and see'". She expressed her irritation with this saying that it was a "real learning experience for [her] because I'm used to saying, 'Oh OK this IS the answer, this IS what we're looking for'". She was able to accept this aspect of physics by redefining it for herself as an interesting and fun aspect of the field, "that's the neat thing about physics, we don't know. We have ideas but we really don't know what's out there, we don't know everything there is to know about it. So that's why it's more fun". Here Heather articulates her initial frustration with the uncertainty of physics. She also describes her acceptance and current enjoyment of this uncertainty after spending more time in her major. This was a redefinition strategy of the field so that it could fit in with her identity.

Brenda described science as "concrete" and resulting in "definite answers". She had difficulty accepting the challenge to these misconceptions once she spent some time in her major. At the same time she also began to question her identification within her major. During her first interview, she explained that "science has nothing to do with me. I like fantasy type things, I'm just wide open and science is just the complete opposite of me but I enjoy it". This comment indicated the conflict Brenda had internally. Despite enjoying engineering, she did not fully identify with her perception of the field which eventually affected her persistence.

Brenda struggled to put herself in the "mindset" of an engineer. Even as a third year student[5] she was still struggling to identify with engineering; describing her peers as the "nerds of the nerds". She explained how she made an effort to be different from her peers: "I try to go home and take showers as often as possible. I see a lot of students in my classes and if I ever turn out to be like that, we're going to have issues". Her comment about not wanting to "turn out" like the other students indicated her desire not to be part of the engineering student culture. Rather than seeing her gender as culturally stigmatized, she turned this concept back onto her peers in the same way she blamed the culture of STEM for not pushing women as hard as men (Slay & Smith, 2011). She stigmatized these students into nerds**,** who did not dress up, or have a social life outside of the engineering building. She purposely tried not to be recognized by others as an engineering student, which speaks to her lack of identity with this major and eventual career (Carlone & Johnson, 2007).

Brenda's inability to identify as an engineer, and in some cases her active separation of herself from her peers, combined with other factors to affect her persistence. She began to feel that she was working very hard and yet still not understanding or performing well in her classes. She described situations where she was often crying in her professors' offices over her frustration with "not getting it [the homework or exam problems]". It was at this time she began to doubt her competence in engineering due to her performances in tests (Carlone & Johnson, 2007). She began to believe that the stress she was feeling was not worth the eventual engineering career, which led to her decision to change her major to teaching. In her first interview with the researcher, she did not frame her workload in such a negative way. It appeared that competence emerged as a negative factor along with other factors that made her question her sense of belonging (i.e. lack of fit with the culture of STEM and the sense that it treated women differently than men, along with doubts in her own competence, made her question her ability and desire to persist).

Brenda's experience contradicts the literature in that she had positive experiences in her post secondary major through her internships and research opportunities. She was recognized by credible members of the field, but she could never fully identify with her peers. This raises two current research issue: few studies focus on 'leavers' and the complex role of identity and competence. It also raises the issue of what role STEM departments have in addressing the culture that causes individuals, like Brenda, to question their sense of belonging. Brenda's conflicting sense of belonging was in direct contradiction to Heather's redefinition strategies that helped her identify with her major and persist.

Like Brenda, Heather experienced frustration with the difficulty of her major but in the end felt that the challenge was worth it. "I'm OK at physics, it is a challenge for me. But even though it's hard and even though sometimes I just feel like I'm beating my head against a brick wall, it is just so cool". In fact she was motivated to persist in physics because of the difficulty: "So ultimately I was drawn to physics because it's difficult. This is something that not a whole lot of people can say that they can understand". Consequently, Heather found the subject matter interesting and something that she enjoyed and wanted to be a part of (Eccles, 2007). She also saw herself as competent within the field (Carlone & Johnson, 2007).

Unlike Brenda, Heather was able to find supportive peers and professors who she wanted to emulate: "Physics is one of those communities where everyone gets along. There's always that interplay of ideas. It's a very open community because everyone's working towards the same goal". This comment highlighted Heather's positive experience with her physics peers that helped her to identify with the individuals in physics as well as the content. Heather felt that her performances within her major were recognized by credible members of the physics community (i.e. professors and upperclassmen) (Carlone & Johnson, 2007). Consequently, Heather maintained her interest and identity as a physics student that helped her to persist. Heather saw possibilities of success in this male dominated field because she was able to frame this dominance in way that allowed her to see herself overcoming it.

The role of coping mechanisms was best articulated by the final case study. The participant highlighted how redefinition strategies look when an individual is part of two culturally stigmatized groups within STEM based on gender and ethnicity. This final case also highlights the contradictions that she accepted in order to persist.

The Role of Ethnicity

The Case

Research asserts that race and ethnicity can combine with gender to play a role in STEM and other career decisions (Ong, 2005; Slay & Smith, 2011). Researchers who have studied retention rates in colleges and universities have found that many women and minorities who leave and even those who stay in STEM majors often describe a sense of isolation and marginalization within their science classes because of their minority status (Franzway et al., 2009; Ong, 2005; Seymour & Hewitt, 1997; Shakeshaft, 1995). Previous research indicates that those women who persist in STEM fields participate in various redefinition strategies to help them identify with the field, including denying the existence of gender discrimination (Bianchini et al., 2000; Hartman & Hartman, 2009; Jorgenson, 2002; Seymour & Hewitt, 1997) or altering their identity to fit in (Ong, 2005).

Ong (2005) described this concept of altering oneself to fit in as the "negotiating of three incongruent realms" which in her study were gender, race, and physics (p 598). However, this third realm could be any field in STEM that has an underrepresentation of women (NSF, 2007). Ong found that the women in her study reported being judged on their success as a member of two contradictory categories: being feminine and being a competent scientist. In STEM fields, being feminine can be in direct conflict with being a recognized scientist (Carlone & Johnson, 2007; Slay & Smith, 2011). Ong (2005) found that minority women in her study had to deny parts of their personality or behavior that could be labeled as feminine or identified as belonging to a minority ethnic group in order to fit in with their physics peers.

Only one of the participants mentioned her ethnicity as having an influence on her experience in her STEM major. Like the other cases, she does not fit exactly into previous research descriptions, but her experience does highlight some aspects of the incongruent realms of gender and ethnicity in STEM fields and the complex impact the negotiations between these have on persistence. Rosa was born in Central America. She moved to the United States when she was sixteen years old. Her father held a master's degree in business and her mother held an associate's degree, both of these degrees were acquired in Central America.

When Rosa first came to the United States she experienced discrimination in her secondary school: "My advisor didn't let me take any honors classes because he basically told me that I wasn't really that smart, [because] I came from a different country". This is a trend that research confirms often happens to Hispanic students (Crisp et al., 2009). Rosa said "everyone thought I was dumb or something. I guess it's the image they have of Latin American immigrants so I just kept doing the best I could". "Her best" included winning her first ever science fair competition. Despite the original setback of being placed in lower level classes she worked her way into advanced STEM classes and graduated with a 4.24 GPA, demonstrating her competence, performance, and recognition within science and mathematics (Carlone & Johnson, 2007).

Throughout her secondary school experience, Rosa claimed that her parents were supportive; however, she indicated the cultural tendency for her parents and other parents from her home country in Central America to give their sons more freedom. This cultural influence was first evident in her description of differences between men and women: “Women’s image plays more of a role. You don’t want your image to be rotten because then the honor of your family goes down. So I guess men are freer in that sense”. She also described how her family’s culture influenced her upbringing mentioning the distinct difference between how she and her brother were treated: “My brother could go out with our friends whenever he wanted whereas I had to be home to cook and take care of my dad. My dad doesn’t lift a finger. My dad was raised like that. I don’t like it because it’s very frustrating”. She rationalized her family’s behaviors as part of their culture. She was frustrated with her parents’ contradictory treatment of her and her brother. She felt that she should have the same freedoms as her brother, but then retracted her statement by saying that these freedoms could have led to questions about her morality.

To rationalize the conflict and frustration she felt, she often referred to her parents’ actions as evidence of their love and support. For instance later when she was in university as a biochemistry major with a mathematics minor, she described this “support” again:

> My parents encourage me to succeed but sometimes they think it’s easier than it is. They have high standards and goals for me. Sometimes they’re a little bit demanding like, ‘you need to graduate in 3 years’. And I’m like ‘I’ll try’ but I don’t know if that’s going to happen. They are demanding because they know if they demand it of me, I’ll demand it of myself and then I’ll continue to be driven by it.

Based on Rosa’s description of her parents, it was evident that her culture had an influence on her values and her view of the role that women should play in society. Despite disliking having to stay home and cook for her father, this aspect of her culture still influenced her perception of gender since she thought women made more morally pure decisions and that her first motivation for her career choice was helping others: a gender stereotypical rationale (Seymour & Hewitt, 1997).

Rosa’s educational trajectory would be best described as that of an ‘overachiever’. She spoke four languages, Spanish, French, English, and Japanese. She is “driven to succeed” and was extremely successful at SU, winning an undergraduate research and creativity award for work she did during her research project with a professor of biochemistry. Rosa also had a number of research internships at the university. She believed that these research opportunities were the most beneficial for her. She described her participation in these research positions as “empowering, because it gave me more confidence in my abilities. These experiences demonstrated her competence, performance, and recognition by credible others in STEM.

Despite all of these successes, Rosa still felt that her gender and her ethnicity played a role in how some of her peers treated her as a member of two culturally stigmatized groups within STEM: women and Latinas (Johnson et al., 2011; Ong, 2005; Slay & Smith, 2011). In response to her gender she said:

> In classes people have a pre-determined opinion of women. Women are basically thought to be average or the ones who are failing the class, or who don't know anything, or who are going to bring your grade down if you study with them. But then when I start explaining things to them, they're like, 'OK, I'm sorry'.

Rosa saw her gender as a source of negative judgment for her male peers, wherein, being a woman was automatically judged as being inferior. Like Penelope, she felt that she successfully falsified this pre-judgment because of her performances of her competence in STEM classes; however it was a source of frustration.

She also believed that her ethnicity played a role in people's pre-judgment of her abilities. "I've noticed that some people have a certain, pre-judged opinion of me because of my ethnicity. But when they get to know me I can see their faces change, you know when I actually talk to them". When the researcher asked her to explain this pre-determined opinion she described a situation where she felt that her ethnicity was judged. In her research lab, she mentioned a male graduate student who despite being told her and another woman's nationality continued to refer to them as Mexican, thereby ignoring their cultural heritage. She ignored these comments but saw them as a sign of disrespect to her and an ignorance of the differing cultures among Latin American countries. Rosa also viewed these comments as discriminatory despite not saying anything to the graduate student, and she brought them up as evidence of pre-determined opinions based on her ethnicity.

In this example she, as a Latina, was being stigmatized (Slay & Smith, 2011). She, like the participants in Ong's (2005) study, described the difficulties that being a minority (Hispanic) within STEM created. However, unlike the women in Ong's study, Rosa never felt that she needed to change her personality or identity to fit in with her major, rather she participated in Slay and Smith's (2011) concept of redefinition, focusing on her competence and acceptance by other credible members of the culture and excusing the negative experiences as exceptions not the norm. Based on her successful recognition within her major by credible members of her field, she could see herself as both an aspiring scientist and a Latina. She saw the major and eventual career as valuable and worth the negative experiences she occasionally encountered. She also believed that she identified with the majority of her peers in her major.

Rosa maintained two contradictory identities (being Latina and being a scientist) throughout her life history (Ong, 2005). She held on to her cultural perceptions that women are morally more pure. She also continued to cook for her father when she returned home. These actions indicated that she saw herself as fitting in with her cultural identity, her gender identity, and her identity as a researcher. Although it can be argued that biochemistry, with a critical mass of women at the undergraduate and graduate degree level (50%) (NSF, 2007), could be a more inviting place for women, even with this critical mass, Rosa's cultural identity as Latina would place her in a culturally stigmatized group, which is also evident by her description of her experiences within the major.

Rosa could perhaps alter herself to fit in when she is working with her department versus when she is at home with her family. However, due to the limits of the research methodology, the researcher could not observe her in either of these settings to address this question. However, this case indicated the combined impact that gender and ethnicity have on a woman's experience in STEM fields. Her experience highlighted the role that competence, performance and recognition can play in helping members of culturally stigmatized groups redefine both their identities and the identity of their chosen career (Carlone & Johnson, 2007; Slay & Smith, 2011). Rosa maintained her interest in her chosen field, despite some negative experiences, because she was recognized by credible members, and she was able to identify with both the field and her peers which helped her to see the costs of minor discrimination as worth the end result (Carlone & Johnson, 2007; Eccles, 2007). She utilized coping strategies to frame the negative experiences as exceptions to the norm and relied on her competence as evidence of her sense of belonging within STEM. Rosa, as a competent student, should not have to continue to prove herself each time she meets new peers, as she indicated she needed to at the time of this research. She should also not have to encounter ethnic bias from people in positions of authority within her field.

DISCUSSION

The conceptual framework for this study helped to guide the articulation of the process of decision making about the choice of continuing with a STEM major at university. As this framework indicated, the process is not as clear cut or simple as expected because of the masculine nature of STEM departments that still exists. Each of the 'stayers' in this study participated in coping strategies, yet none of these strategies were exactly the same, indicating the lack of universal explanation for how women persist in the masculine fields of STEM. Researchers often find that 'stayers' are able to persist because they take on more acceptable gender roles so that they can identify with the masculine fields of STEM (Ong, 2005). Penelope, Heather, and Rosa all utilized coping strategies which redefined the gender bias of their STEM departments. Penelope framed these in a way that allowed her to see possibilities for her individual success by proving her competence. Heather believed that these gender biases were lessening, which provided her with a framework that also allowed her to see possibilities for success. Rosa chose to view the gender and ethnic bias she encountered as exceptions to the overall culture of STEM. None of these strategies fit within previous research indicating that women either take on an androgynous view of gender that fits their chosen STEM field or they simply ignore gender bias within their fields (Bianchini et al., 2000; Hartman & Hartman, 2009; Jorgenson, 2002; Ong, 2005; Seymour & Hewitt, 1997). Rather each of these women recognized some level of gender bias and yet framed it in a way where they could see potential for their individual success.

The researcher purposely discusses individuality because these women recognized that gender bias existed that could potentially affect other women's persistence, but not their own. This was another aspect of the coping strategies that raises concern. If women who persist continue to use coping strategies that allow them to see only their individual success, then women who cannot develop coping strategies, despite having competence and interest, will continue to be excluded. The result of these coping strategies is similar to that of women taking on an androgynous role in that only those women who are willing to potentially sacrifice aspects of their identity can persist. These coping strategies are important to understand because they could also have implications for these women's future persistence in STEM careers. Some of these coping strategies, or lack thereof, could result in women's decisions to leave STEM careers later in their lives because they no longer work.

The leavers' experiences highlight the agency, or lack of agency, that women have in their STEM career trajectories. Seymour and Hewitt (1997) referred to this as being pushed out of STEM. Kristen and Brenda described trajectories wherein they made the decision to leave STEM for a career that better aligned with their interests and identity. However, one could also argue that these women were pushed out by the culture of their STEM departments. Both Kristen and Brenda lost interest in their chosen STEM field because they found that they could no longer identify with it. For Kristen this was simply based on her perception of her peers, but for Brenda this was based on her inability to identify with her peers and her sense of lowered competency. Both women described their engineering peers as 'uptight' or 'nerds' respectively. This raises the issue of the role that STEM departments have in addressing this perception and perhaps improving women's persistence by instituting policies such as opportunities for networking among peers, informal social gatherings, or guest speakers who can serve as role models of the possibilities within STEM. This result also highlights a question for future study. The 'leavers' no longer saw value in their original STEM career after experiencing the culture of their STEM department. Why did the 'stayers' continue to see value, so much so that they developed coping strategies to remain but the 'leavers' did not?

CONCLUSION

All of these women mentioned gender bias within their chosen STEM department, whether it was historical or current. Each of these women chose a different path to their ultimate result of staying or leaving STEM, demonstrating that there is no universal picture of stayers' and leavers' trajectories within STEM. This raises questions regarding the assumption of some STEM research that there is a common experience for women in STEM or that there are universal predictors for women's persistence in STEM. Each of these cases indicates that the factors influencing STEM persistence at the university level are complex not only in their effects, but also in terms of the individual reactions to these. This study adds to current theories on STEM persistence in that it adds to current frameworks by highlighting an addition: the coping strategies utilized by 'stayers'.

Sadly, each of these 'stayers' had to enlist some form of coping strategy to persist, providing evidence of the continued existence of a masculine culture within STEM departments. 'Leavers', particularly those who demonstrated competence, were unable to see themselves fitting in with this culture and therefore, began to doubt the value of their chosen career. STEM departments, researchers, and policy makers have an important role in addressing these issues and increasing the number of women in STEM fields. But in order to do this, they must recognize the complexity of the process of women's persistence in STEM so that they can improve the current policies and programs that have not fully addressed the cultural issues within STEM department. Without recognizing the complexity of women's persistence, these policies will only allow those individuals who develop coping strategies to persist, and not change the culture of STEM.

ENDNOTES

[1] This study was funded in part by the National Science Foundation Division of Materials Research through DMR 0654118.

[2] In the United States, major denotes the area of study that students choose to pursue.

[3] Women represent approximately 10% of degrees and career holders in these fields in the United States (NSF, 2007).

[4] Brenda was categorized as a leaver because chemistry education and her desired career of teaching were not considered to be science majors at the university.

[5] Brenda was a chemical engineering major during our first interview but switched out of this major by her second.

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