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The Retention of Women in Science, Technology, Engineering, and Mathematics: A Framework for Persistence

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ABSTRACT

Women make up 47% of the total U.S. workforce, but are less represented in engineering, computer sciences, and the physical sciences. In addition, race and ethnicity are salient factors and minority women comprise fewer than 1 in 10 scientist or engineer. In this paper, a review of the literature is under taken that explores the many challenges women encounter when pursing a career in the sciences. It includes a review of the national landscape and discussion of the guiding general retention theories. Finally it proposes a conceptual framework for persistence and proffers a number of research questions designed to delve deeper into the under representation phenomenon.

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1. INTRODUCTION

According to the National Science Founation, women earned more than 50% of the bachelor degrees yet are underrepresented in the science and engineering workforce [1].The purpose of this paper is to advanceknowledge on women in their pursuit of careers in science, technology, engineering, and mathematics (STEM). It aims to provide information about societal and cultural aspects as well as attitudinal, character and educational achievement in the career selection and persistence in the STEM disciplines.The results can be used to develop strategies for the successful retention and increased graduation rates. The literature reveals a plethora of issues that are critical to the recruitment and retention of women in STEM [2], [3]. The attrition of women in STEM has been extensively investigated and some major findings are:

- Numerous factors are involved that impact the advancement of women in STEM [4],[5].
- Qualitative studies indicate their decision to persist in STEM is influenced by the perception of self-efficacy [6].
- Others factors affecting persistence are positive relationships with advisors, mentors, and interest in STEM classes [7].
- Personal choice for leaving is becoming more prevalent in the literature [8],[9].
- Women may need assistance to function in mixed-gender teams, especially when dominated men [10]-[12].
- More similarities in career aspirations are found in STEM (men and women) than the general student population [13],[10].
- Attrition rates are larger for women than men [13] and particularly during the second year of college and beyond [7],[14],[15].

- Women exhibit lower self-confidence than males even when academic preparation and performance are equal or superior [16].
- Professional role confidence is a critical factor in the persistence of women in STEM [17].
- Women anticipate conflicts between work and family in STEM careers and need support to cope with and change these systems [18],[16].

While motivation to improve the representation and retention of women is strong, it must be emphasized that many of the underlying discipline-specific causes have not been fully examined such as in physics [19] mathematics [20], and engineering [21]. This is true even when longitudinal studies have provided critical data about some of the problems and issues [15],[13]. Since the retention and graduation rates of women in STEM will vary based on discipline, this becomes a critical component for investigation. For example Gibbons [2] found that women accounted for only 11% of the bachelor's degrees awarded in computer engineering compared to 43% in environmental engineering. Graduate performance was only slightly better with the exception in biomedical engineering which had the greatest representation of women.

McLoughlin's [22] qualitative inquiry into gender bias found three distinct predispositions: overt, covert, and subtle. While the first two could be anticipated, the last was more latent. It involved a negative feeling among women in STEM that they should be singled out for extra assistance. For some, this may trigger an emotion that they are not as good as their male counterparts. This logic may form the basis of resentment. In contrast, Hawks and Spade's [16] quantitative study found a clear distinction between male and female students in regards to balancing family roles and those of a STEM career. Both studies highlight the importance of giving careful deliberation to the type of survey prompts and interview questions used.

The two studies also demonstrate the potential of mixing the two approaches. They provide direction for how the methods could be employed in a complementary fashion. In survey research, the quantitative results could be enhanced by using individual and/or focus group interviews to discuss the results of the data. Why do women feel the way they do? How might these perceptions affect their choice of career and persistence? Do women think that men really appreciate the need to balance career and family? What should the STEM disciplines do to improve the situation? If women do not feel they fit into the workplace, what should be done to build a sense of involvement?

2. CHALLENGES FACED BY WOMEN

With women accounting for less than 25% of the total STEM workforce [23], the literature suggests the most face some form of adversity in navigating a career path [6]. This seems to be pronounced during the early college years and includes differences in learning styles [24], lack of self-confidence as compared to their male peers [7], and potentially strong cultural influences [16]. All of these appear to have been exacerbated by the lack of female role models [25].

In a longitudinal study Brainard and Carlin [7] observed a precipitous drop in self-confidence for women during the first year with nearly all encountering some barriers by the final year. Brainard and colleague found that most non-persisting women leave during their sophomore year. This is occurring at a time when they have the lowest academic self-confidence and are finding out about acceptance into their academic major. The reasons given for switching (or dropping out) were loss of interest, more appealing non-STEM majors, and discouragement coupled with the perception of low grades. Self-confidence appears to be a key variable, with diverging self-confidence scores between those who persist and switchers. This disparity was not correlated with actual performance, as measured by GPA. Other barriers were: feelings of isolation, discouragement based upon grades, poor teaching, and unapproachable faculty. While many programs have undertaken efforts to improve support networks for women and sensitize faculty to their perspectives, the efforts have not had dramatic results. In fact since 1999 the graduation and enrollment rates have continued to decline [1].

Still other studies have found that the low enrollment of women in STEM is because many who otherwise qualify opt for something else [26]. This finding was echoed by Rosenbloom and colleagues [8] in which personal preference was the largest contributing factor for women choosing to go into the STEM fields. Self-selection has recently emerged as a key factor for not pursuing a STEM career [27],[9] suggesting that the continuing interest in STEM is central figure the persistence of women [28],[29].

In examining gender-based difference several indicators point to a decline in the self confidence of women as they progress through STEM courses [15]. Women tend to rate themselves as less capable problem-solvers with fewer of them planning to continue to graduate school. While women seem to internalize failure and credit others with their success, males (particularly Caucasian) tend to do the opposite [30].

Conflicts between work and family have been observed with strong gender-based differences among STEM students [18],[16]. Women frequently cite lack of confidence and the need to balance parenting with career as barriers to success.Men are more likely to project themselves into a supervisory or executive position than women. These findings suggest that women in STEM anticipate work conflicts. While both sexes value their careers, women have higher values for family, particularly parenting responsibilities.

Gender differences are not limited to career and family issues. Ambrose et al., [6] found that women (more so than men) feel that their profession must be beneficial to society. Talent and training alone are not sufficient for success. This may explain why women outnumber men in some of the biological sciences and environmental fields or describe teaching as a source of satisfaction even when their careers are not traditionally associated with education.

On the surface it may seem that situational factors should propel women to be more successful in college than men. Many are as well prepared as men and have more early success indicators like parents with college degrees, equal or higher SAT scores, high school test scores [15] and conceptual understanding of the sciences [31]. Despite what should be an advantage, in many cases women do not perform as well as men thus creating lower retention rates [32],[33],[1]. This point toward a divergence in the STEM aspirations of men and women and beliefs about their own competence that may be related to cultural and societal differences [34].

3. RETENTION THEORY

There are a number of theoretical perspectives about persistence in college settings that can be divided into two somewhat unique and overlapping camps, developmental and ecological. The developmental stancecome from Chickering's vectors of development [35] and Sanford integration-differentiation theory [36]. At their core is the idea that students go through a process of establishing and then reestablishing equilibrium as they move through college life.This concept, coming from the groundbreaking work of Kurt Lewin [37], posits that as academic and social challenges arise, an individual processes and comes to terms with them and readjusts his or her personal balance in regard to what is happening.

Chickering [35] proposes seven vectors upon which this subtle mechanism is based: competence, emotional management, autonomy, interpersonal relationships, identity, clarification of purpose, and personal integrity. Similarly, Kolb [38] looked at how students go through a progression of development from concrete thinking to consideration of multiple issues and solutions to problems during the college experience. In essence, the student becomes more reflective and mature in their thought processes. All of theauthors incorporate the idea of a continuum as students matriculate and become older.

In contrast, Tinto's student engagement [39],[40], Astin's student involvement[41],[42], and Bronfenbrenner campus ecology [43] models, have more of an environmental perspective for retention or its counterpoint, attrition. The context around the student, institution, academic discipline, peers, attitude, and quality of interaction between students and faculty play a major role in the persistence decision toward a degree in general or a degree in one's chosen area.

The two stances overlap in the value of interaction in the retention equation. For example, for many students, good interaction with faculty enhances the likelihood of remaining in school [44]-[47]. Students perceive it as having higher importance. Similarly, women exhibit characteristics similar to those found in other underrepresented groups such as concerns over student-faculty relationships and personal identity. The need for interpersonal affiliation seems to be influential in regards to staying in STEM.

Other streams of thought are also apparent in the literature [48]-[50]. For example, Kuh and Love [51] suggested cultural propositions that govern or at least affect decisions to persist. One is when the sending culture (where the student is coming from) is similar to that of the receiving environment (university). This type of environment promotes an easier adjustment for the students and leads to better retention [52]. Tied into this logic is that women in math and science courses will be fewer in number [48], [53]-[55]. Smaller class sizes may be particularly relevant to them at the start of their academic career where the attitude to persist may be seriously affected. This could be attenuated as the student goes beyond the first year.

Seymour and Hewitt [56] have raised a serious issue - when some students change majors to non-STEM fields, many faculties view it as appropriate. The students are seen as not academically strong enough for the rigors and demands that science-related fields require or they lack the requisite educational background [53],[54],[57]-[59]. While some of this type of thinking may be accurate, it also reveals a bias that does not fully hold. Seymour and Hewitt found that a percentage of the students who changed majors, had the academic ability to succeed in STEM disciplines. That would indicate there is a partial disconnection between the perception of faculty and the student's actual capabilities.

4. THE PERSISTENCE FRAMEWORK

The guiding principles for the conceptual model presented in Figure 1 is embedded in Prenzel's [28],[29] model of persisting interest and Kuh and Love's [51] cultural propositions that take into account the societal and cultural biases that lead underrepresented students toward lower retention rates.Additionally, the contribution of student interaction with faculty has been well documented [60]-[62],[56],[45] and would include Astin's [42] framework for student engagement.

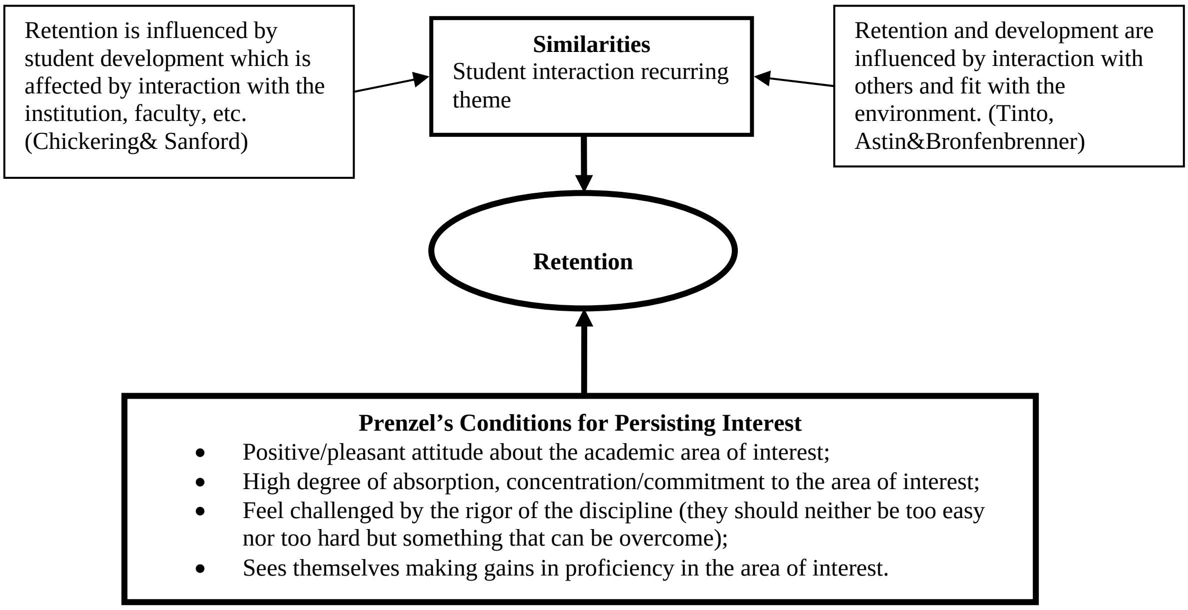

Figure 1.Conceptual Model

The emergence of persistence as a key variable, particularly as it relates to the retention of women, is apparent from the literature [63]-[70],[46],[71],[72]. Along those lines, the primary theoretical framework is Prenzel's [28],[29] persistence of academic interest model, based on four precepts:

- Positive pleasant attitude about the academic area of interest;
- High degree of absorption, concentration, or commitment to the area of interest;
- Being challenged by the rigor of the academic discipline (they should neither be too easy nor too hard but something that can be overcome);
- Recognize gains in proficiency and mastery.

Using this model, White and colleagues [73] studied persistence in the STEM disciplines [74]-[76] and fouind it to be highly predictive with persisters and applicable with women on several points. First, anyone opting for the intensity of study in STEM would be anticipated to have a corresponding high interest in the related course work. For the second premise, it is notable that there is a consistency in the research that successful STEM students spend more time per week than non-persisters in studying. These aspects could be attained as part of the exit interview for individuals that are dropping out or switching out of STEM.

The third and fourth premises are closely associated and have promise for researchers. The dropout rate in STEM occurs most often during the first two years of college. This may occur when students move from lower to higher level STEM courses which have a heavy emphasis on solving increasingly complex problems. These problems often are complicated, coming from real world examples. They are typically multifaceted and require a coherent understanding of the problem and how it might be resolved. This is one of the most critical points at which persistence or attrition occurs.

4.1. Prospective Research Questions

Some potential research questions have evolved from the literature and underpinthe conceptual framework presented in this paper. Derived from earliers studies [46],[47],[73], they are reflected in the persistence literature [63]-[71] and point toward further inquiry. More information is needed about what prompts women to enter STEM, influences their decisions to stay or leave, their pedagogical experiences in the classroom, and recommendations for changes in the classroom and work environment [18]. Some other lines of questioning include:

- Do the cultural and societal norms influence their decision to persist in STEM?
- What aspects of involvement (informal social networks, faculty support and encouragement, etc.) seem to be most conducive for women to persist in STEM?
- How do women view faculty, teaching assistant, and supervisor feedback and interaction?
- Why do women (especially those who are well-qualified) leave STEM?
- Why do women move into and out of STEM?
- What roles do personal factors play in the choice of women to depart STEM?
- How do their experiences affect their choices to depart or stay in STEM?

5. RECOMMENDATIONS

The theoretical framework presented in this paper will advance the existing knowledge base for women interested in pursuing STEM careers. An investigation into the persistence phenomenon will enhance the research and education infrastructure and improve the understanding of how women develop a sense of purpose and become engaged in the classroom. Comprehension of all the reasons why they do not persist in can broaden participation and tap into a source of talent not yet fully realized [2]. The importance of persistence cannot be understated due to its linkage with academic involvement [42] and effect on the sense of purpose needed for academic success [40]. Since the connection between persistence and retention was identified [47] and linked to the major retention theories [46], its role with women has only had a cursory inspection [77]. A more thorough investigation is warranted. The conceptual model presented in this paper provides a framework for investigating the role that societal expectations and attitude have in the decision making of women. The results could yield useful information that would increase the recruitment, retention, and participation of women in STEM.

6. CONCLUSIONS

How can investigators ascertain information about the persistence factors presented in this framework? They can begin by asking if data are collected and evaluated by retention practitioners. If not, they should be incorporated into the programs designed to improve the retention of women in STEM. Any activities that evoke unpleasant feelings should be scrutinized and those that are positive, expanded. They should also emphasize time management activities to help maintain the focus and concentration required in these courses.

There is a rigor in the STEM fields that some students may not fully appreciate. This should be monitored particularly during the early college years. This is not to imply that the curriculum should be void of rigorous courses but rather ascertain if students recognize the difficulty and time commitments required to be successful. Assessments of proficiency should also occur outside of the classroom. For example, researchers could employ a holistic assessment while students were: (a) participating in STEM courses, (b) completing assignments, (c) meeting with professors, (d) interacting with other students, (e) studying, (f) working on group projects, and (g) learning new concepts. This information could be used to evaluate progress and as potential problem indicators. When used in concert with other approaches, these assessments could go a long way to improve the retention of women in the STEM disciplines.

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