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Women and Nontraditional Fields: A Comprehensive Review

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Abstract: This literature-based report aims to synthesis and summarize the existing research on female's (meaning adult women and girls) propensity for enrolling and continuing in the science, technology, engineering, and mathematics (STEM) fields at through university level. To create and maintain a sustainable future, it is essential to support females enroll and continue in the STEM fields. A systematic review of existing research on females in STEM fields has been performed. Additionally, those studies that have focused on environmental factors surrounding female's enrollment and retention in STEM fields were carefully examined as well. A rigorous approach was taken to include only those articles that followed scientific methodology. The intention is to offer an objective review of current empirical literature on propensity, retention, and characteristics of females in STEM fields at university level. Projects with the specific intention of increasing female's retention in STEM were also reviewed and included. The findings suggest that females who enter the STEM field share a profile that includes academic preparation, family support, and nurtured critical thinking skills. Females who persist in STEM fields through their educational career share many profiles such as high self-efficacy, participation in support programs—offered by their home university, and have a supportive environment.

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Academic institutions have the potential to lead the path toward a sustainable future; mainly, science, technology, engineering, and mathematics (STEM) disciplines can offer a substantial unification among many areas of research (Ramaley, n.d.). It is essential to support females in the STEM fields in order to stay competitive across the world and successfully address the environmental and global challenges that are facing our society. Stevens (2010) has suggested that focusing on sustainability without gender equality has created a sluggish progress toward a sustainable world. She further suggested that presence of females in certain academic areas is the missing link in sustainable environment.

Over the last few decades, educational, Nongovernmental organization (NGO), business and governmental institutions at all levels have expressed considerable concern over the lack of female's participation in STEM fields. Despite the fact that females make up approximately 56% of the undergraduate population, they are a minority in certain fields of studies such as engineering (Fadigan & Hammrich, 2004). Higher education institutions are being encouraged to become more diverse and inclusive (Tusi, 2009). Starting in the mid-eighties, Higher Education Research Institutes began expressing concern over a decline in the number of female freshmen choosing to enroll and remain in STEM fields (Seymour, 2002).

Decades after fighting for equality in STEM fields, the gender gap in science has not been resolved and after years of discussions, speculations, and spending millions of federal dollars in programs encouraging females to enter science and engineering, the problem still exists. What causes these barriers to exist and persist (Rosser & Taylor, 2009)? To understand the lack of female participation in STEM fields, it is important to profile those who do enter and stay in the field. Therefore in this review, the existing literature on females and STEM fields were systematically reviewed to provide a profile of females who enter and continue in STEM field.

Tyson, Lee, Borman, and Hanson's (2007) findings suggested that gender gap in STEM happens because STEM is not appealing to female students. Numerous works on various STEM fields suggests a number of factors, which might increase females' enrollment and retention in STEM fields. Many studies have focused on one isolated aspects of this issue. However, there is a need for a more comprehensive examination and analysis of existing empirical research to inform researchers and educational agencies of the advantages, and shortcomings, of related research on gender disparities in STEM majors.

The focus of this literature review is to examine the factors involved in enrollment and retention of females in STEM fields. For this purpose, I have examined studies presented in peer-reviewed journal articles, conference proceedings, and governmental reports with scientifically verified methodology that have focused on issues regarding females participation in STEM fields. The goal is to present a series of plausible factors contributing to the gender gap in STEM fields at university level. This study attempts to answer the following broad question:

Do females who enroll and persist in STEM fields share a specific profile? To answer this broad question the following three questions have been developed:

1. What are the distinguishing profiles of females who enter STEM major at the university level?
2. What are the distinguishing profiles of females who continue in STEM major at the university level?
3. What circumstance could potentially influence females' interest and persistence in the STEM fields at university levels?

To assist with the readability of this literature review the following paragraph offers a short description of its structure. The first section presents a brief description of STEM, the second section describes the methodology and evaluation of the literature review, the third section discusses an important common theme found in the related articles, the fourth section reviews the results related to each research question, and the final section presents the discussion and future research.

STEM Description

The STEM designation can include a varied and vast range of disciplines. Green (2008) argues that STEM consists only of the traditional categories of science, technology, engineering, and mathematics, but also should include fields from social sciences. However, this study defines 'STEM'' with a traditional view to include the fields of science, technology, engineering, and mathematics (Chen, 2009; Havice & Marshall, 2009; Mathieu, Pfund, & Gillian-Daniel, 2009).

Many federal and state efforts intended to improve STEM education have focused mainly in mathematics, sciences, engineering, and technologies (Chen, 2009) and the low presence of females in these fields of studies (Tyson, Lee, Borman, & Hanson, 2007; Rosser & Taylor, 2009).

Pursuit of STEM for Sustainable Society

One shared theme of all studies was the important role of science, mathematics, and technology education in achieving a secure, strong, and peaceful society (Green, 2008). American policies have been supportive of science advancement to keep its leading position in the world (Nelson, 1971). The world's future depends on female's insight and involvement in STEM fields. In order for the United States to sustain its world leadership in science and technology, it needs to expand its female enrollment in STEM fields. Hence, in recent years there has been tremendous effort to develop rigorous scientific, mathematical, and technological educational systems for advancement of STEM. The National Science Board (2003) has released warnings regarding shortages of males and females skilled in higher-level mathematics and science. These shortages not only affect the United States' ability to maintain its leadership in technology, but it also affects world economics.

The changes in Asia and the Far East have caused a great decrease in the number of immigrant scientists and mathematicians. Global competition for foreign scholars and highly trained workers has increased as well. Although the United States is the destination of 22% of foreign students, other European countries are catching up (National Science Foundation, 2006). This threatens countries like the United States, which depends heavily on foreign talent (Mahroum, 2000).

Fletcher (2006) suggested that because nearly one-fourth of the present science and engineering workforce is more than 50 years old and science and engineering professions are growing at about 5%, our ability to fill these technical jobs is losing ground. Foreign-born scientists have made exceptional contributions to the physical science field in the United States. More than half (55.6%) of the peer-reviewed authors in the physical sciences are foreign-born compared to just 20.4% of U.S. born physical scientists as of 1980 (Stephan, Levin, & Young,

2003). To be able to continue our leadership in technology and science in the world and advance in the world market we need to encourage the underrepresented pools of talent to enter STEM fields.

Method

The aim is to review, merge, and explore the multifaceted results from the existing literature and to attempt to explain the factors involved in females' low propensity in choosing STEM as a university major. Also, it is intended to consider government and private supported programs aiming to increase female interest in choosing and persisting in STEM fields at the university level. Studies were selected process based on these criteria: (1) relevance, (2) expertise, (3) empirical characteristic, and (4) quality.

The first step in selecting a scholarly work was its relevancy to the focus of this study, which was "profiling females who enroll and stay in STEM fields at university level." A set of criteria for relevancies was established. Each study had to provide insight into issues surrounding the enrollment and retention of female students at the university level, prior or during their college careers. The search process included peer-reviewed journals, organizations with reputable peer-reviewed processes, book chapters, and governmental reports that presented empirical evidence.

Furthermore, the search included empirical studies from different methodological traditions. The definition of empirical in this review included studies that followed a specific scientific methodology and whose results were from qualitative and/or quantitative evidence rather than opinion and theory. These studies included quasi-experimental studies, correlation studies, survey studies, case studies, focus groups, observational studies, and interviews. The center of attention was narrowed to data based empirical work that highlighted and extracted reliable existing evidence, relating to females and STEM fields. Hence, publications with program descriptions that did not offer analytical results were ignored.

Finally, quality of the research was carefully considered. Only studies that followed the proper and rigorous methodologies suitable to the topic of choice and their findings were justified by their design were included.

The criteria for qualitative studies were different since qualitative design is more flexible and mostly focuses on the human aspect of the research. Qualitative studies were examined as a precursor to quantitative research, or as research that added unique perspective to the complex issue of women's paucity in STEM majors. To consider qualitative studies in this literature review the following questions were asked: Was an adequate sample size used for that particular study? Was proper design used for the phenomenon under the study? Did the study add a unique perspective to the field that previous research missed or was unable to reach with quantitative approaches? Was the study able to relate its findings to existing literature and provide a bridge between identified variables and the previous research? Was the study reliable and valid? In other words, did the researchers ensure rigor in their studies? The studies that followed these criterions were included in this literature review.

Search Approach

The preceding framework was applied utilizing several data sources and periodical journals to locate research on the subject of female enrollment and retention in STEM education at the university level. The search began on electronic databases such as ERIC, Educational Complete, Wiley InterScience Ejournal, JSTOR, and Educational Full Text data sources. Next, related journals including *Journal of Technology Education, Science Direct, Journal of Research in Science Teaching, International Journal of Science Education, American Psychologist, Journal of Research in Science Teaching, Journal of Educational Measurement, Applied Psychological Measurement,* and *Educational Measurement* were searched. To perform the search I used terms such as *females and STEM education, math education at college, gender gap in STEM, computer science, engineering education, information technology, and science education at college.* The key terms used in the search included: *female, STEM, gender gap, retention,* and *enrollment* of *females.*

More than 50 articles were found to be related to the topic. These articles were carefully examined and reviewed to identify those that were specifically consociated to retention and enrollment of females in STEM. The significance of some older studies, published between 1960 and 1980, justifies including their related findings.

In the third step of the selection process, the final set of 40 articles were studied, compared, and further identified for selection in the review. On closer examination, 20 articles did not fit the established framework for the literature review. The rationale for exclusion of the 20 articles was based on one or more of the following: The articles did not focus on STEM-related majors, females' enrollment or females' retention at university level, the studies were not empirical, or were not published in peer-reviewed publications.

The last step in the selection process was to conduct a final search for relevant articles that might have been missed in previous searches. This process added four more articles to the collection for the studies. The final literature review and selection process resulted in totaled 24 studies that were examined for this review.

Results

For clarity purposes, a brief explanation of the structure of the result section is given. Data regarding the first research question, profiling females who enroll in STEM fields is presented in Section One below. Section Two presents data regarding the second research question, profiling females who continued in STEM field. The last section addresses the third research question, circumstance that could potentially influence females' interest and retention in STEM fields.

SECTION ONE: Profile of Females Enrolling in STEM Fields

The first research question focused on an attempt to profile female individuals who choose STEM majors at the university level. While studying gender disparity expands understanding of existing differences in STEM enrollment, it is important to profile those who choose to enter STEM fields (Vogt, Hocevar, & Hagedorn, 2007). What characteristics do these

individuals possess? To answer this question, the articles chosen for review were divided into three topics. First, those articles that studied factors involving female profile in STEM fields were examined. Second, those articles that focus their study on the differences in those individuals who chose STEM fields versus those who chose non-STEM fields as majors were examined. Third, studies on high school students who were inspired to enroll in STEM majors upon entering universities were carefully examined.

The findings of this review revealed that various academic indicators are linked to STEM enrollment. For example, the proportion of students entering STEM fields is higher between students who took trigonometry, pre-calculus, or calculus in high school. Their earned grade point average (GPA) of B or higher was another academic indicator. It is important to mention that calculus is not a prerequisite for entering STEM field, but it is a required course for all STEM entering freshmen.

The literature offered consistent information concerning the academic background of females who chose STEM related university majors and the relationship between ability and the decision to study STEM fields. These women were academically prepared and possessed a healthy self-confidence (Lent, Brown & Larkin, 1984). They successfully completed appropriate prerequisites for college level mathematics, science, and physics courses in high school (Brainard & Carlin, 1997; Dick & Rallis, 1991). Females who enrolled in STEM fields were at the top of the mathematics test scores (Mau &And, 1995; Brainard &Carlin, 1997). High-ability females in STEM areas were more likely to be more ambitious in future careers than average females in non-STEM fields and as high in status as gifted males (Lowery, 2004).

Is there a difference between males and females in math ability? Do males have the math gene (Jacobs, 2005)? Although early studies in gender disparities in mathematics performance suggested significant differences in favor of males in the area of quantitative and spatial tasks (Maccoby & Jacklin, 1974), recent research suggests that these differences were much smaller than originally concluded (Linn & Hyde, 1989). The differences were not in ability but rather in math preparation and self-efficacy, which make it necessary to help female students prepare for mathematics beginning in primary schools. Women who enter STEM fields have high self-concepts regarding mathematics and science ability, which appears to form at the secondary school level (Burkham, Lee, & Smerdon, 1997). As Tyson's et al. (2007) study revealed, science and mathematics course-taking habits in secondary schools is one of the most important factors of enrolling in STEM fields at higher levels.

Women who enter STEM fields tend to have strong family encouragement and see themselves as capable of handling high-level mathematics course work (Hazari, Tai, & Saddler, 2007). Dick and Rallis' (1991) survey of engineering students suggested that both males and females in engineering and science careers have had parental or teacher encouragement. Bleeker and Jacobs (2004) suggested that mothers' beliefs about their children's abilities in math and science are formed by gender stereotypes and lead into the succession of their adolescent children's self-perceptions of math aptitude. Social cognitive theory states that an individual's attitude toward science is an important aspect of success in this field. It has been argued extensively that improving student's attitude toward STEM field could improve the rate of enrollment in the field tremendously (Bleeker & Jacobs, 2004).

Critical thinking has often been associated with many science and math curriculum. Whereas people often believe that creativity and critical thinking are innate abilities, God-given talents that not many people possess; most research shows that critical thinking is a learned ability (Barak, 2009). Exposing young girls to technology and science through play and

extracurricular activities prepares women for future engineering classes (Gouldner, 1985). Other scientists relate gender differences in science and mathematics performance to gender differences in spatial abilities, but meta-analyses of gender differences in spatial abilities do not offer any evidence for this hypothesis (Linn &Hyde, 1989). To explain the gender disparities in STEM fields some researchers believe that the traditionally male-oriented extracurricular activities such as playing with mechanical devices, experimenting, or spending hours with computers makes males comfortable with technology (Jackson, Fleury, Girvin, & Gerard, 1995). One prevailing consensus in the literature is the existence of gender disparity in critical thinking favoring males, understanding that critical thinking is not an innate ability but rather learned ability. With better efforts, starting in primary schools, this discrepancy can be eliminated.

One noticeable ignored factor in almost all studies was the students' socioeconomic status as a main indicator of enrollment in STEM fields. Those studies that included socioeconomic status as well as social background as a studied factor found that these students shared a specific socioeconomic as well as social background (e.g., Berman, 1972; McKenna, & Ferrero, 1991). These students were age 19 or younger, were from families with incomes in the top 25%, and had mothers working in STEM professions (Felder, Felder, & Dietz, 1998).

SECTION TWO: Profiling Females Remaining in STEM Fields

The second research question focused on attempting to profiles females who persist in STEM majors at the university level. The decision to persist in the field is similar in principle to those motivating factors that led to enrollment of these females. Females who entered universities with the intention of pursuing a degree in STEM fields were highly filtered achievers who started off with high levels of self-confidence in their academic abilities in math and science (Doolen & Long, 2007). However, the number of females who remained in STEM majors dropped over the course of the first year (Brainard & Carlin, 1997; Doolen & Long, 2007).

A large number of empirical studies were devoted to answering why females leave STEM field. One common theme among existing studies is the excessive rate of attrition among female students in STEM fields in comparison to male students. This phenomenon is commonly referred to as a *leaky pipeline*. The pipeline leaks students at various stages beginning losing STEM interest in middle school and continues by not pursuing the field at university, and later losing interest at post-secondary education levels by changing majors before graduation, and finally, leaving STEM fields after graduating with a STEM degree (Doolen&Long, 2007). There is also not much evidence contributing this high attrition rate to cognitive factors (Seymour, 2002).

One of the frequently mentioned factors in female retention in STEM fields is self-efficacy (Lent et al., 1984; Brainard & Carlin, 1997, Nunez, 2009; Marra, Rodgers, Shen, & Bogue, 2009). Female students who complete a STEM degree are confident in their academic abilities (Brainard & Carlin, 1998).

Females who complete degrees in STEM fields are unambiguous about their academic and career choices (Vogt, Hocevar, & Hagedorn, 2007). They also argued that these women do not view STEM as a stereotypical male career path. On the other hand, females who drop out of STEM fields may find it hard to integrate math and science careers with their sex-role.

SECTION THREE: Circumstance Related to STEM Fields Propensity

The last research question focused on investigating the environmental factors related to enrollment and retention of female students in STEM fields at university level. Once a female student enters a STEM field, her treatment in the classroom may determine her motivation to continue in the field (Zeldin & Pajares, 2000).

Discrimination, intentionally or unintentionally, increases the rate of attrition for females in STEM fields during the first year of college (Kahveci et al., 2006). Leaper and Brown's (2008) study revealed that girls who experienced more academic sexism exhibited lower self-efficacy in math. They further argued that during high school male peers were a frequent source of the academic discrimination followed by teachers and female peers. Guzzetti and Williams' (1996) analysis of discrimination showed that although teachers may be oblivious of gender inequities, students of both sexes are very aware of the existence of such inequities. In summary, the rate of retention increases when the female students' environment is more accepting and does not exhibit any discrimination.

Professors' pedagogical styles can either create an inviting environment for females or discourage them from persisting in the field (Hazari et al., 2007). While university faculty traditionally explain undergraduate attrition from STEM majors as weeding out, students blame their discouragement from STEM majors on the professors who are cold and impersonal (Seymour & Hewitt, 1997). These findings agree with Brainard and Carlin's (1997) findings that, while highly competent female students often drop out, only males of low ability drop out of math and science courses. Professors can increase female interest and therefore female retention in STEM fields by requiring more collaborating group projects in their classes. Collaboration can encourage females to participate more freely and get excited about learning.

Females need a psychological sense of integration in the educational community (Hurtado & Carter, 1997). The stigma attached to STEM fields as nerdy and lonely subjects and eventually a lonely career path tend to discourage girls from choosing these courses at school and later on at college (Sullivan, 2007). Seymour and Hewitt stated, "Some aspects of the learning environments in which many females feel most comfortable—particularly those which are interactive, cooperative, experiential, and learner-focused—are also congenial to many young men." (1997, p. 314)

Other environmental factors include the professors' attitudes toward female students. Zeldin and Pajares' (2000) study revealed an improvement in females' self-efficacy in engineering programs when the faculty exhibited supportive behavior. Females tend to criticize STEM professors for being rigid, distant, and arrogant (Seymour & Hewitt, 1997). Many researchers associate these characteristics with females' low self-confidence and low self-efficacy in engineering classes (Vogt, Hocevar, & Hagedorn, 2007). Triandis (1971) suggests that the students' interactions and direct experiences with their educational environment affect their attitudes toward their fields of study. Professors who create a mutual feeling of equality in the classroom can increase female acceptance in male dominated fields (Seymour, 1995). Students' positive interactions with faculty and their peers can produce a sense of belonging, improve their self-efficacy, and increase their rate of retention (Hurtado & Carter, 1997).

Positive interactions with male classmates can also increase female retention in STEM fields. Since females are in the minority in STEM courses, it is important for females to be accepted and respected by male classmates. This approval makes females who persist in STEM fields feel accepted by their male peers (Seymour & Hewitt, 1997; Vogt et al., 2007).

Support programs for females in STEM.

Technical work places, STEM classroom environments, and laboratories related to STEM classes in general are unfriendly environments for females (Margolis & Fisher, 2002). Therefore, it is essential for colleges to create a supportive environment for female students in STEM fields (Kahveci et al., 2006). Research shows that supportive academic as well as environmental programs enhance female moral and increase their access to science and engineering education (Dyer, 2004).

Females in Science, Engineering, and Mathematics (PWISEM) is one example of supportive programs. PWISEM was established in 2001 at a research university in southeastern United States. This program targeted female undergraduates in STEM majors, particularly first-year students, to foster participation and enhance retention (Kahveci et al., 2006). The programs documented successes in preparing females for STEM studies and future STEM careers.

Women in Science and Engineering (WISE) is another successful program for decreasing women's rate of attrition from STEM fields in university by encouraging collaborative atmosphere, academic support, professional mentoring, peer mentoring, and advising for females in STEM fields. Pace, Witucki, and Blumreich (2008) study of WISE revealed an increase in the rate of retention for female students who participated in the program.

Another example of a successful program is Women in Natural Sciences (WINS) for high school students. The goal of the program is to build an interest in science by creating a close mentoring relationship with WINS' staff and to introduce female students to the science field through frequent visits to museums. WINS' findings revealed an increase in the female student rate of enrollment in STEM fields at university level in comparison to their peers who did not attend such a program (Fadigan & Hammrich, 2004).

Discussion

The literature suggests that females who enroll in STEM fields at university level are academically prepared, have strong family support, are trained to be critical thinkers, and share a common social and socioeconomic background. Females who remain in STEM fields at university level do not experience academic sexism, their professors' pedagogical styles create an inviting environment for both genders, and do not view STEM career path as nerdy and lonely. The environmental factors related to females retention are professors' attitude toward female students, positive classmate interaction with female students, and existence of support programs for female at university level.

Although various efforts exist to increase enrollment and retention rates for females in STEM fields, few attempts have been made to provide supporting programs and to create a warm, inviting, and positive environment for females to thrive in the STEM field at university level. Understanding the factors necessary for females' success in STEM fields can help universities plan and prepare for the incoming freshmen and those who are already in the program.

Future research on comparing and evaluating the existing supportive programs could help universities plan and provide successful support programs for their female students.

Longitudinal studies regarding the success of these programs would help college administrators in providing or mandating such supportive environments or programs within higher level educational settings.

Limitations

As comprehensive as this study was, it does not include all factors involved in all the reviewed articles Another limitation was the search process itself since peer-reviewed publications that employ a scientific process are limited in their scope and perspective, thereby excluding unconventional and unpublished approaches to the problem. Therefore, some insightful opinions that could help researchers gain an understanding of females' low enrollment and high attrition rates in STEM fields have been ignored.

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