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ABSTRACT

The under-representation of women in physical science, technology, engineering, and mathematics (PSTEM) career fields is a persistent problem. This paper summarizes an extensive review of the literature pertaining to the many issues that surround this problem. The review revealed a wide range of viewpoints and a broad spectrum of research methodologies used to analyze the multiple factors associated with the under-representation of women in PSTEM career fields. It used four frameworks to examine the issue: social psychological framework: internal conflict models; environmental and economic framework: external conflict models; comprehensive framework: integrated models; and critical feminist framework: alternate assumptions models. Overall, regarding internal conflicts, confidence issues were found to be a barrier, and goal-orientation an asset. Regarding external conflicts, negative environments were offset by positive social support networks. Regarding integrated models, good preparation and good advising were necessary, but not sufficient, to sustain commitment. Regarding the feminist perspective, women avoid intervention strategies that label them as defective or try to fit them to the mold or a male-dominated paradigm. (Contains 83 references.) (SM)

What does the Literature Say about the Persistence of Women with Career Goals in Physical Science, Technology, Engineering, and Mathematics?

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Abstract

The under-representation of women in Science, Math, and Engineering (PSTEM) career fields is a pernicious and persistent problem. Why is it that among undergraduates 59% of men and only 48 % of women persist in PSTEM careers? Why is it that 46% of men and only 27% of women persist in a mathematics or statistics major? Why is it that women comprise 30% of students entering PSTEM graduate programs, but women represent only 15% of those completing their programs? Why is it that after two decades of research there is still no definitive answer to any of these questions? More importantly, why is it that, in this same timeframe, women have achieved parity with men in all undergraduate and most graduate career fields with the exception of the math-intensive physical science fields? In this paper, the author has summarized an extensive review of the literature pertaining to the multifarious issues surrounding these distressing and persistent questions.

The review revealed a wide-range of viewpoints, and a broad spectrum of research methodologies that have been used in analyzing the multitude of factors associated with the under-representation of women in PSTEM career fields. The author has used four frameworks to focus this vast panorama of designs: (a) Social-Psychological Framework: Internal Conflict Models; (b) Environmental and Economic Framework: External Conflict Models; (c) Comprehensive Framework: Integrated Models; and (d) Critical Feminist Framework: Alternate-Assumptions Models. The author has evaluated the collective implications of these four strands of research and synthesized a unique strategy for developing a profile of the conditions that encourage the persistence of women in PSTEM career fields.

What does the Literature Say about the Persistence of Women with Career Goals in Physical Science, Technology, Engineering, and Mathematics?

Women have made tremendous strides in achieving parity with men in the attainment of degrees in higher education. From 1970 to 2002, women increased from 43% to 57% of all bachelor's degrees; from 40% to 59% of all master's degrees; and most amazing of all, from 12% to 54% of all doctoral degrees (NCES, 2003). Yet, despite the fact that women have overtaken men in the attainment of bachelor and master's degrees, the surge has been disproportionate by career field. The range of participation by women in specific career fields is marked by wide variances.

Female graduates predominate in fields like psychology, education, biological sciences, and liberal and fine arts where they comprise a majority at each of the three levels of higher education. However, they are scarce in the physical science, technology, engineering, and mathematics (PSTEM) career fields where they comprise the smallest minorities. In mathematics, women earn 46% of bachelor's degrees; 42% of master's degrees; and only 29% of doctoral degrees (NCES, 2003). In physical science women earn 42% of bachelor's degrees; 38% of master's degrees; and only 28% of doctoral degrees (NCES, 2003). In technology and engineering fields, women attain fewer than 20% of the master's and doctoral degrees degrees (Cage, 1999; NCES, 2003). Over the last decade, women have actually lost ground in many of these math intensive career fields (Commission on the Advancement of Women and Minorities in Science, 2000; Ivie & Stowe, 2001; Johnsrud, 1995; Seymour & Hewitt, 1997; Wilson & Boldizar, 1990)

These statistics are coupled with some alarming trends in female persistence rates reported by Seymour and Hewitt (1997). Among undergraduates 59% of men and only 48

% of women persisted in PSTEM careers. About 46% of men and only 27% of women persisted in a mathematics or statistics major. Women comprised 30% of students entering PSTEM graduate programs, but women represented only 15% of those completing their programs (National Science Foundation, 2002). After two decades of research there is still no definitive explanation for these observed patterns. More importantly, while women have achieved parity with men in all undergraduate and most graduate career fields, they have not experienced similar gains in the math-intensive physical science fields (Commission on the Advancement of Women and Minorities in Science, 2000). In this paper, the author undertakes an extensive review of the literature pertaining to the multifarious issues surrounding these distressing and persistent phenomena.

This author found in a review of the extant literature that a wide range of frameworks, and a broad spectrum of research methodologies have been used to study the problem of female PSTEM persistence. The literature pertaining to the under-representation of women in PSTEM career fields encompasses a vast panorama of diverse factors. In order to bring focus to a plethora of issues, the studies cited in this paper were categorized according to one of four frameworks: (a) Social-Psychological Framework: Internal Conflict Models; (b) Environmental and Economic Framework: External Conflict Models; (c) Comprehensive Framework: Integrated Input–Environment–Output Models; and (d) Critical Feminist Framework: Alternate-Assumptions Models.

Social-Psychological Framework: Internal Conflicts

The Social-Psychological Framework focuses upon internal conflicts that arise from the *gender factor*. The gender factor alone accounts for a significant number of false positives among women in many studies. Women who have an expressed interest in a PSTEM career are far more likely than men to abandon the pursuit of that career, even when they have demonstrated a superior aptitude (Adair, 1991; Lee, 1987; Schaefers, Epperson, & Nauta, 1997). The issues pertaining to gender are central, rather than peripheral in the study of female persistence in PSTEM careers. Yet, the gender factor remains a conundrum (Linn & Kessel, 1995; National Science Foundation, 1999; Seymour & Hewitt, 1997; Unger & Crawford, 1992).

The Social-Psychological Internal Conflict Models fall into three subsets: Psychology of Gender Models, Psychology of Career Development Models, and Social-Psychological Models. Psychology of Gender Models grapple with the *nature versus nurture* conundrum as well as with problems in *measuring gender differences*.

Psychology of gender models. Psychology of gender models predicate, either an inherent difference in the physiological-psychology of the genders, or a contextual difference in the social-psychology of the genders. Jensen (1995) based recommendations for education upon a physiological view of cognitive psychology. Observed gender differences in stage development prompted this observation: "The differences [in brain development] between males and females are so prevalent that same-sex teaching methods might need to be reconsidered" (Jensen, 1995, p. 285).

Frieze, Parsons, Johnson, Ruble, and Zellman (1978) viewed the gender factor as one of sex-role socialization. They predicated that negative external factors limit female internal expectancies. They found that sex-role bias, and sex-discrimination had a tendency to erode female confidence. Kondrick (2002) found that PSTEM career women frequently spoke of the internal struggle to gain confidence in a male-dominated system.

Problems in measuring gender differences have also been studied. Tavris (1992) asserted that differences between the genders are actually statistically small. Yet, in comparing those differences, men have been assigned the standard of *normal*. Women therefore have been labeled as *abnormal*. Rhode (1990) emphasized that this fundamental flaw in the standard of comparison has obliterated the unique attributes that women bring to PSTEM careers.

Alternatives to the male normative standard of measurement have also been advocated. Unger and Crawford (1992) explored the implications of a reversal of standards. They constructed the argument that language frames the perception of reality: *Field-dependent* women become *field-insensitive* men; women who *underestimate* their math ability, becomes men who *overestimate* their math ability; women who are *not competitive enough*, become men who are *not co-operative enough*. Kondrick (2002) advocated an approach to female PSTEM persistence studies that eliminates the issue of gender bias. The author constructed a model that compared the experiences of PSTEM career women to the beliefs of PSTEM career women in order to investigate the factors that encourage the persistence of women in PSTEM career fields.

Psychology of career development models. Psychology of career development models predicate that women have a unique persistence standard and career calculus which has not been reflected in unisex career models. Fiorentine and Cole (1992) found that a portion of female pre-med students dropped out of their program while less talented male counterparts remained. Women expressed a more flexible career calculus than men. Women switched majors without perceiving that switch as a failure in their ultimate career goal, or in their attainment of status. Women allowed themselves to switch career pathways when the possibility of failure existed. Men allowed themselves to switch career pathways only when no possibility of success remained.

Osipow and Fitzgerald (1996) questioned whether or not a unisex career model is even possible. They found that models which predicted persistence in math and science career pathways had an accuracy rate of 90% for men and only 34% for women. They postulated that these rates suggested that the models omitted factors that have a unique importance to women. Kondrick (2002) interviewed PSTEM career women who identified some affective variables that were not included in these models. PSTEM career women expressed the importance of supportive family, friends, professional organizations, and mentors in achieving their career objectives.

Social-psychological models. Social-psychological models predicate that the interaction between women and their social environment mediates internal conflicts encountered by women in pursuit of PSTEM Career goals. This framework has been employed is a large variety of studies. Some of the factors that have been investigated are: cultural conflict, degree intention, dual-career demands, emotions and learning, fear of success, internal belief systems, learning styles, marital status, role-conflict, self-concept, self-efficacy theory, and service-motivation.

Cultural conflicts have been found to be negatively correlated with female PSTEM persistence. Kalata (1996) has proposed that Generation-X simply doesn't want to pay the price of a PSTEM career which requires more hours of study, and more hours in the laboratory than most other career choices (Christou, 1994; Khoon et al., 1997). Nora, Cabrera, Hagedorn, and Pascarella analyzed the factors that operate on student perceptions, commitments, and persistence. They found that these cognitive, affective, and environmental factors operated differently across race and gender. When other factors are controlled, black males persisted at rates equal to or greater than white males. However, the reverse was true for black females, who had the lowest persistence rates, even when other factors were controlled. Kondrick (2002) found that among PSTEM career women, 85% classified themselves as Caucasian, and 84% attended a predominately white middle to upper class high school; 52% believed that cultural/ethnic influences in the family are important to persistence; and 76% believed that the socio-economic/cultural influences of the school environment are important to persistence.

The ultimate goals underlying a degree intention have been found to be positively correlated with female PSTEM persistence. Garber (1977) found that women switched out of PSTEM career majors when they discovered an incompatibility between their ultimate goals and the reality of the PSTEM career pathway. Kondrick (2002) found that 75% of PSTEM career women had an unwaivering commitment to their PSTEM career goals; 82% believed that steadfastness is an important factor in persistence.

The link between emotions and learning and their effect upon persistence has been found to be a complicated web. Schaer, Pancake, Aull, & Curtis (1990) found little difference between the level of enjoyment that men and women experienced in any given subject. Yet, gender rather than enjoyment was a better predictor of persistence. Taylor (1994) found that the link between personality development and learning is pivotal. Mature women, non-traditional students, needed a particularly supportive environment that affirms relationship and encourages autonomy. Ingleton (1995) confirmed that emotions are powerful motivators for both genders. However, women were especially susceptible to the effects of both affirmation and shame. LeDoux (1996) concluded that pride and shame, being secondary emotions, were uniquely constructed by individuals within the context of their cultural and social environments. Kondrick (2002) found that PSTEM career women credited enjoyment or love of their studies as one of the primary motivators in their persistence.

Parental influence and socio-economic status of the home environment have been found to have a profound effect upon the development of internal belief systems. Fair (1995) found that a positive attitude toward math studies, math self efficacy, expectation for math success, math related career goals, and an appreciation for the value of math began at home. Kondrick (2002) found that 48% of PSTEM career women surveyed had at least one parent who was engaged in a PSTEM career field during their pre-collegiate years; 79% believed that parental influence is an important factor in the choice of a PSTEM career goal. The majority of these women (63%) were raised in a middleclass or higher income household; 70% believed that the socio-economic status of the home environment is an important factor in the choice of a PSTEM career goal.

Gendered difference in preferred learning styles have been proposed as a factor contributing to the attrition of PSTEM career candidates. Magolda (1992) found that women tended to be more community oriented in their preferred learning style. Belenky, Clinchy, Goldberger, & Belenky (1986) proposed that women have a unique way of knowing, learning, and understanding. They postulated that for women, their gender-unique way of interpreting truth and constructing a scientific method may be inherently incompatible with the established male model. Richardson & King (1991) found that for men and women, "intellectual development proceeds through parallel but distinct developmental schemes" (p. 378). They asserted that only qualitative research methods would be able to allow the distinct voices of women to be heard. Kondrick (2002) adopted this philosophy in a mixed method study of PSTEM career women. It was found that affective variables relating to community support, and intrinsic motivation that were expressly important to women in their pursuit of a PSTEM career goal were largely ignored in the extant literature.

Married status has been found to be negatively correlated with persistence. Mercer (1989) found that married students took longer to graduate. Hagedorn (1993) found that married students were more likely to switch out of PSTEM career pathways. Kondrick (2002) found that PSTEM career women believed that the spousal factor could be a positive or a negative factor depending upon the mate. Among these PSTEM career women 98% were not married for the greater part of their undergraduate years; 89% did not have to divide their time and energies between graduate school and spousal commitments. The degree to which they believed this freedom from a spousal relationship is important to persistence was 20%, and 21% respectively.

Dual-career demands have been found to be negatively correlated with female PSTEM persistence. McCrohan (1996) found that women were more likely to suffer from the stress of balancing school, work, and child care. Chater & Hatch (1991) also found that colleges and universities were largely insensitive to the dual-career needs of these women, and further marginalized them as casual students. Haddad (1996) found that couples tended to divide family responsibilities in a manner that shifts more of burden upon women. Tweedell (1997) found that women were most likely to abandon their career objectives due to family responsibilities at home or unsatisfactory social relationships at school. Kondrick (2002) found that PSTEM career women believed that child care and elder care were more problematic than a spousal commitment. Among these PSTEM career women as graduate students 82% were free from childcare, and 52% were free from the care of other dependent adults. The degree to which they believed this freedom from social commitments is important to persistence was 59%, and 65% respectively.

The perception of role conflict has been found to be negatively correlated with female PSTEM persistence. Pfost and Fiore (1990) found that women were not as likely to choose or persist in career fields that they were socialized to believe were gender-inappropriate. Lewin (1948) coined the term *tokenism* to describe the isolation that students would experience in any career field in which they were perceived as a minority. A closely associated factor, *fear of success*, has also been found to contribute to the attrition of PSTEM career candidates. Pfost & Fiore (1990) found that women were likely to avoid career choices that were considered gender inappropriate for fear of lessening their romantic appeal. Kondrick (2002) found that 71% of PSTEM career women did not suffer from role conflict as an adolescent; 82% believed that freedom from such conflicts it is important to persistence.

Self-concept has been found to be positively correlated with female PSTEM persistence. Langan-Fox (1991) investigated the link between self-concept and career motivation. The author found that women have an inherently different set of overarching career goals. Their motivators were predominately intrinsic. Moore (1988) found that women choose plausible career options that took into account the needs of others. Taylor, Friot, and Swetnam (1997) found that the level of confidence women experienced was related to their gendered concept of themselves. Women who recognized gender bias were able to choose to reject the message that the larger culture was sending them. Kondrick (2002) found that 71% of PSTEM career women believed that they had high self-esteem and personal confidence throughout their education; 98% believed that such self-efficacy it is important to persistence.

Self-efficacy in regards to math-intensive career choices has been to be positively correlated with female PSTEM persistence. Post-Kammer & Smith (1985) found self-efficacy to vary by gender and career field. Drafter and engineer were the two math intensive career fields for which middle school girls lacked confidence in their ability to pursue as a career. Crawford (1995) found that girls lost self-efficacy throughout their high school years. Baughman (1997) found career self-efficacy was a strong predictor of first quarter college persistence in a PSTEM career pathway. Kondrick (2002) found that 76% of PSTEM career women had chosen a PSTEM career goal before they entered college; 77% believed that an early PSTEM career choice it is important to persistence.

Service-motivation has been found to be particularly important to women in making their career choices. One of the primary reasons that women gave for switching into a non-SME career was the prospect of greater social service in non-PSTEM career fields such as education, medicine, business, and social studies (Sax, 1992; Seymour & Hewitt, 1997; Wolffensperger, 1993). Miech and Elder (1996) found, however, that women, especially idealists, who leave PSTEM career fields for careers in perceived service oriented fields like education are often disillusioned in their expectations. Kondrick (2002) did find that the service-motivation was cited by only a small number of PSTEM career women as a prime factor in their persistence. Yet PSTEM career women were frequently found to be engaged in service-oriented projects that were not the primary focus of their careers. They were especially active in mentoring activities at all levels of the education system.

Environmental-Economic Framework: External Barriers

The Environmental-Economic Framework focuses upon external conflicts that arise from negative gender-bias. Both the overt and covert sex-bias encountered by women at all levels of the education system limits access and lowers persistence rates of women in PSTEM career pathways. The Environmental-Economic External Conflict Models fall into two subsets: Environmental Barrier Models, and Economic Barrier Models. These environmental and human capital models argue, that even in the absence of internal conflicts, from the chilly classroom to the lukewarm reception of labor markets women have a higher bar to vault than their male cohorts who aspire to a PSTEM career goal.

Environmental barriers. Environmental barrier models predicate sex bias in the education system that discourages women who pursue an SME career. They include the chilly classroom climate, institutionalized sexism, inadequate mentoring or role models, pre-collegiate inequities in preparation, poor-teaching, tokenism, and role entrapment. The Strategic Study Group on the Status of Women (1987) was one of the early studies that documented negative gender-bias in PSTEM classrooms. Cage (1993) found that women faired better in PSTEM classrooms at private or smaller private or liberal arts universities that at larger research institutions. Kondrick (2002) found that only 26% of the PSTEM career women attended the smaller schools; yet 68% believed that the type of institution (liberal arts, or research, etc.) attended is important to persistence.

Johnson, Goldberg, and Sedlacek (1995) reported that the most frigid climes for women were found in engineering schools. They found that focus groups warmed the climate by providing support, and focus for women in a hostile education environment. Seymour and Hewitt (1997) and Kondrick (2002) found that women were sometimes more, rather than less determined when confronted with overt sexism. Kondrick (2002) found that 76% of PSTEM career women experienced a friendly classroom environment and 77% found their instructors to be friendly and available for assistance outside of the classroom; 98% and 93%, respectively, believed these factors to be important to persistence.

Rogers (1989) found that even when no overt hostility existed, women who were outnumbered by their male cohorts experienced increased performance anxiety through the effects of role entrapment. Yet, they found that these women were highly motivated to persist despite the pressure and isolation that resulted from being in a minority in their program. Sax (1996) found that tokenism, the result of stereo-typing of minority members of a culture, had an adverse effect upon self-esteem and student satisfaction. Kondrick (2002) found that 70% of PSTEM career women were in programs where they were in the minority; only 26% believed that parity was important to persistence.

Institutionalized sexism has been found to operate through biased admissions procedures (Sperling,1991), gender biased standardized tests that discriminate against women (Chater & Hatch, 1991), and the marginalization of women in graduate programs (Erickson, 1996). Jones (1997) found that after a decade of exposure, *de facto* institutionalized sexism was still not recognized by members of the majority culture where it existed. Kondrick found that among PSTEM career women 74% reported a graduate school climate free from overt sexism, and 67% found a female friendly environment in the classroom; 88% and 83%, respectively, believed that these factors are important to persistence in a graduate program.

Mentors and role models have been found to be one of the most positive environmental factors in female PSTEM persistence. Loftin (1993) found that individual instructors with a midwifery approach to education had a profound positive effect upon all students. Robst, (1996) found that female role models were more important to women in PSTEM careers than to women in other higher education programs. Kondrick found that among PSTEM career women, 55% had a mentor or role model throughout their career; 88% believed that having good emotional support is important to persistence.

By contrast, poor teaching has been decried as one of the most negative environmental factors in female PSTEM persistence. Seymour and Hewitt (1997) found poor teaching to be the biggest complaint of both persisters and non-persisters in PSTEM programs. Armstrong (1996) found that, although both persisters and non-persiters complained about poor teaching, discontent was most intense among non-persisters. Kondrick (2002) found that among PSTEM career women, 79% rated their classroom and laboratory instructors as good teachers; 98% believed that good classroom instruction is important to persistence.

Lack of adequate pre-collegiate preparation in math and science has been found to be the single largest factor that accounts for failure to persist. However, Jagacinski, LeBold, and Salvendy (1988) discovered in an early study that pre-collegiate preparedness did not have the same predictive power across genders. The discovery of false positives, women who, according the models, should have persisted but did not, was the first alert that the female PSTEM persistence problem was systemic (Campbell & McCabe, 1982; Lee, 1987; Pricken, 1989). Kondrick (2002) found that among the PSTEM career women studied, in high school 96% had completed three years of science classes, 92% had completed at least three years of math classes, 96% had a high GPA in these classes, and 92% scored high on math and science portions of their college entrance exams; 91%, 90%, 97%, and 83%, respectively, believed that such a solid foundation is important to persistence.

Economic barriers. Economic barrier models predicate sex bias in financial aid programs, and labor markets that discourage women who pursue an SME career. They include the variable effects of financial aid packaging, investment theory regarding the hidden costs of college attendance, the effects of risk-aversion on human capital investment, imperfect markets, inadequate career counseling, and gender differentials in pre-college resources. These economic factors explicate many of the disparities in access to higher education for women. Reisburg (1998) found that financial resources more than intellectual resources determined who attended college. Among low income students who did not attend college, 60% cited lack of funding as the major reason. Baker and Vélez (1996) found that women were more likely to have to postpone career plans and were therefore more likely to suffer from hardships common to non-traditional students. Kondrick (2002) found that among PSTEM career womensurveyed, 95% attended college full-time during their undergraduate years, only 27% worked off campus during the school term, and 92% were of traditional cohort age when they received their bachelor degree; 81%, 63%, and 23%, respectively, believed that adequate financial resources in undergraduate school is important to persistence.

Williams(1997) reported that the shift in financial aid programs away from grants and toward loans, disproportionately impacted lower income students who were more risk-averse and more likely to be female. Mortenson (1989) analyzed this shift in funding from the perspective of investment theory. Students were found to be sensitive to the hidden costs of attending college. Lower income students were found to be less willing to surrender immediate earnings while attending college; less willing to mortgage their futures to secure student loans; and less likely to anticipate a net gain from a college education. The burdens of these hidden costs were found to weigh more heavily on female and minority students who were disproportionately represented among low-income students. Johnsrud (1995) found that women graduate students were more likely than men to have been be self-supporting, and less likely to have received prestigious graduate assistantships. Kondrick (2002) found that among PSTEM career women 63% believed that they had adequate financial resources in graduate school; 88% believed that such security is important to persistence.

Bogan (1993) analyzed risk aversion from the perspective of investment in human capital. The author found that the pattern in financial aid packaging represented a shortsighted under-investment in education. Seymour and Hewitt (1997r) reported that one of the four issues of non-perssiters not shared by persisters was the concern about job-options and lack of adequate material rewards for their investment.

Women have lost earning power over the last five years (Henry, 2002). Women reportedly earned about 75 cents on the dollar as compared to men (National Center for Education Statistics, 1997). Christou (1994) argued that in a perfect market, women would merit equal pay for equal credentials. Imperfects markets that lack parity have had a chilling effect on the PSTEM career aspiration of women. Christou enumerated the barriers: (a) PSTEM career costs are higher for PSTEM majors, (b) women are at greater risk of acquiring indebtedness in the current market system, and (c) women have a lower expectation of reward for that risk. The author predicted that women will continue to avoid risk as long as the market perpetuates gender inequity.

With such high risks, and uneven rewards women have had a special need for sound investment advice and therefore, good career counseling. Rayman (1995) and Seymour and Hewitt (1997) discovered that both persisters and non-persisters were concerned about the quality of career counseling that they received. Kondrick (2002) found that PSTEM career women were more distressed by poor career counseling than poor teaching. Just 54% of the PSTEM career women believed that they received purposeful, structured advisement at the undergraduate level, and 51% believed that they received good advice in the selection of a graduate program; 93%, and 92% respectively believed that such reliable advice is important to persistence.

Comprehensive Framework: Integrated Models.

The Comprehensive Framework focuses upon the integration of internal and external factors into a single model. Those combined effects include both direct and interaction effects. Astin and Green (1987) pioneered the Input–Environment–Outcome (I-E-O) model in an extensive study of the twenty-year trends of college freshmen. Astin and Astin (1991) continued to study the effects of the college environment upon the race and gender inequities that were found in the science pipeline. The rest of the Comprehensive or Integrated Models have been organized by educational level: high school, undergraduate, and graduate school.

High school level studies. Hanson (1996) conducted a comprehensive longitudinal study of the combined effects of gender, family resources, school resources, and personal resources upon the achievement, access, and attitudes of adolescent girls. Surprisingly, this study concluded that

> Gender differences in science achievement (as measured by standardized exams) occur *before* [italics added] differences in math achievement. They are already present in seventh grade and continue into tenth grade. By tenth grade boys score higher than girls on both science and math exams. (p. 24)

Another revelation was that, "Relative to males, the females have a higher self-concept and more progressive sex-role attitudes" (p. 53). Yet, "Young women who stay in science may actually have lower self-concepts than women who do not, and they have unexpectedly high family orientation and low work orientation" (p.91).

In general, the study concluded that, for girls, the move into and out of the PSTEM career trajectory was characterized as follows: Early access promoted continued access to PSTEM opportunities. However, early access did not necessarily guarantee continued achievement or positive attitude toward PSTEM careers. Early positive attitude toward PSTEM careers promoted continued achievement. However, an early positive attitude did not necessarily guarantee continued access to PSTEM opportunities. Early achievement promoted continued achievement and access to PSTEM opportunities. The effect of early achievement on attitudes was not stated in the Hanson study.

Kondrick (2002) reported on the experiences and beliefs of PSTEM career women concerning the importance to persistence of twelve of factors at the high school level. These have been reported above with the exception of two factors. Among the

PSTEM career women surveyed, 78% reported that they had high school math and science teachers who encouraged girls as well as boys; 96 % believed that such encouragement is important to persistence. In regards to access to technology, 53% reported that they had ample access either at home or at school; 78% believed that ready access to technology is important to persistence.

Undergraduate level studies. The overwhelming majority of PSTEM persistence studies targeted the undergraduate population. A number of early studies attempted to unravel the main and interaction effects of internal and external environments upon persistence of undergraduates in PSTEM careers (Campbell and McCabe, 1982; Lee, 1987; Pricken; 1989; Wilson & Bodizar, 1990; Adair, 1991;Astin & Astin; 1991; Horvath, Bodin, & Wright, 1992; Sax, 1992; Wolffensperger, 1993). The main thrust of these studies was to find what, beyond a good high school preparation, would predict the persistence in the PSTEM career pipeline. The gender anomaly surfaced repeatedly in these studies. DeBohr (1981) posited that,

> Something in the environment may be operating differently for male and female students. In light of these findings it is recommended that prediction studies of college performance continue to consider the factors within the college environment that interact with traditional predictors of academic success. (p. 494)

Later studies continued to search for the silver bullet, the definitive reason that undergraduate students rarely switch into, but frequently switch out of PSTEM career pathways (Hull-Toye, 1995; Civian and Schley, 1996; Brawer, 1997; Grahm, 1997; Schaefers, Epperson & Nauta, 1997; Cage, 1999). The gender factor continued to be the most persistent enigma in every PSTEM persistence model. Seymour and Hewitt (1997) conducted three years of exhaustive interviews with PSTEM switchers and non-switchers. They found the definitve factor in PSTEM persistence to be illusive. They concluded that the complaints of switchers and non-switchers differed more in quantity than in quality. Most of those complaints have been addressed in the previous sections above concerning Internal and External conflicts. Seymour and Hewitt did, however, target poor teaching, not as a silver bullet, but as a chief concern of switchers and non-switchers alike.

Kondrick (2002) reported on the experiences and beliefs of PSTEM career women concerning the importance to persistence of twelve of factors at the undergraduate level. These have been reported above with the exception of one factor among the PSTEM career women survey, 92% reported that they had declared an SME major during their first four undergraduate semesters; 58% believed that it was important to have a definite PSTEM career goal upon entering college. The importance of a good high school background was also affirmed by PSTEM career women as cited in previous sections of this review (Kondrick, 2002). However, the CAUMSET report (Commission on the Advancement of Women and Minorities in Science, 2000) and data from the National Science Foundation (1999) has also confirmed that although girls are completing more science and math preparatory courses, they are still underrepresented in Science and Technology majors.

Graduate level studies. Johnsrud (1995) found that gender inequities pervaded all levels of PSTEM graduate education. Women were found to be a minority in their disciplines, they took longer to graduate, and dropped out at rates higher than men.

Rayman and Brett (1995) constructed a causal model of the effects of internal social-psychological variables and external institutional-cultural factors upon science career persistence after graduation. They found that affective variables, such as good career counseling, and family encouragement were as important as high school preparedness and type of institutional environment to the retention of female graduate students.

Kondrick (2002) reported on the experiences and beliefs of PSTEM career women concerning the importance to persistence of twelve of factors at the graduate school level. These have been reported above with the exception of one factor. The PSTEM career women surveyed reported having a nurturing chair or major advisor in their graduate program; 79% believed that such supportive relationships are important to persistence.

Critical Feminist Framework: Changing the Assumptions

The Critical Feminist Framework focuses upon the need for changing the assumptions in gendered research models. Kondrick (2002) stated that, "The internal spaces, the external spaces, and the cyberspaces of western culture have been dominated by male-centric iconoclasts. Science culture has been no exception" (p. 106). Harding (1989) recognized this condition of gendered society. This author posed two critical questions regarding the core assumptions of an *objective scientific* view:

> Who benefits from insisting on rigid separations between the natural and social sciences, and between 'pure science' and its technologies and applications? [and] What would it mean to create a science *for women*, and one that is *for women around the globe*? (p.705)

Ross (1991) found that PSTEM career women were not equally rewarded for their investment in their educations. The gender disparity was found to be worst in academe itself. Sissel (1993) reported that less than ten percent of the literature reviewed reflected gender issues, and only a tiny fraction of those articles were framed in a critical feminist voice. The issues dealt more with the failure of women to achieve than with the task of articulating the special concerns of women.

Bonder (1996) remarked on the changing assumptions of women in regard to education. The author observed that at one time the consensus among women leaders was "centered mainly on the need to integrate women into the educational order . . . [now] one can 'hear' the claim that women have the right to revise and transform models, institutions, and 'accepted practices'" (p. 89).

Despite of these advances, Erickson (1996) lamented that imperfect markets continued to deny financial parity to women who had achieved numerical parity in their disciplines. The author explicated the disparity between male-centric and feminist-centric assumptions:

> Critical theory interprets power relations in terms of race, class, gender, and the role education systems play in reproducing the status quo. Feminist theory defines power in terms of community and connectedness as defined as interdependence of thought and belief. (p.15)

Conclusion

Kondrick (2002) synthesized a profile of the factors that encourage the persistence of women in PSTEM career pathways. Twelve variables from each of the three education levels were selected from those cited in extant literature above. A cohort of 205 PSTEM career women responded to a questionnaire which contained the 36 sets of parallel questions. The theory part was designed to measure the importance of each of the 36 variables to a woman's ability to persist in an SME career goal. The history part was designed to measure the aptness of each of the 36 variables in describing their own experiences in the SME career pipeline.

The model distilled 14 variables that fit more than 50% of the women, and were believed important by more than 50% of the women, and were statistically independent measures. A high GPA in math and science classes, high scores on college entrance exams, adequate high school science courses, no role conflict, and an early PSTEM career choice were the factors at the high school level. Attending school full-time, a friendly classroom climate, and good career advice were the three factors at the undergraduate level. Steadfast career goal, adequate finances, nurturing chair or major advisor, mentors, freedom from childcare, and good advising were the factors at the graduate level.

The perspective of PSTEM career women upon the factors that encouraged persistence is encapsulated in the following conclusions. As regards to Internal conflicts, confidence issues are a barrier and goal-orientation is an asset. As regards External Conflicts, negative environments are offset by positive social-support networks. As regards Integrated Models, good preparation, and good advising are necessary, but not sufficient to sustain commitment. And in regard to the Feminist Perspective, women avoid intervention strategies that label them as defective, or that try to fit them to the mold of a male-dominated paradigm.

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