A Review of the Literature on Increasing the Representation of Women Undergraduates in STEM Disciplines through Civic Engagement Pedagogies

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Introduction

Despite recognition of the importance of student diversity in enhancing undergraduate STEM education (e.g., Augustine 2005), gender gaps persist in quantitative fields such as physical sciences and engineering (AAUW 1998; Brickhouse 2001; Brotman and Moore, 2008; Campbell et al. 2002; Fadigan and Hammrich 2004; Gilbert and Calvert 2003; Herzig 2004; National Science Board, 2010; Scantlebury and Baker 2007). When individuals of diverse perspectives come together in a group, innovative initiatives tend to be born because varying interests and experiences lead to an amalgam of ideas (e.g., Barber 1995; Frehill et al. 2006; National Research Council 1991; Valian 2005). Therefore, it is important to better understand the contributing factors to this gender imbalance and explore potential avenues that could work toward increasing the representation of women in the field.

This review highlights research that attempts to explain gender differences in recruitment, performance, and achievement in the STEM fields and discusses how differing pedagogies can affect participation within programs in the United States. An interesting additional analysis could compare U.S. STEM curriculum and pedagogy as it relates to successfully recruiting and retaining women to approaches taken in other countries. The general focus is on gender preferences in science courses and variations in confidence levels between males and females with respect to science performance at the classroom level. The review includes examination of scholarship that summarizes effective pedagogical processes and environments in secondary and postsecondary STEM education for females. Finally, this review suggests a potential path towards the diversification of STEM disciplines by describing programs that have successfully spurred an interest among women through the implementation of pedagogical techniques characterized by civic engagement.

Current State of the STEM Gender Gap

There has been a strong push by the federal government to increase the STEM workforce since the Russians launched Sputnik in 1957. The United States has maintained the desire to remain at the forefront of the world in discovery and innovation (Geiger 2004). In 1983, the National Commission

on Excellence in Education published *A Nation at Risk: The Imperative for Educational Reform* in which public school teaching and learning was assessed. The report indicated that the generation of students moving through the public school systems were both scientifically and technologically illiterate (NCEE 1983). Efforts directed toward improving science education have been made since this scathing assessment. For example, the Improving America's Schools Act of 1994 made funds available to provide equipment and materials for hands-on science and math instruction in K–12 settings. Funding also increased in 2006 and 2007 in three separate education-based policy programs that provided additional resources for technology education and improved STEM teacher preparedness (American Competitiveness Initiative 2006; America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act 2007; Carl D. Perkins Career and Technical Education Act 2006). More recently, President Obama indicated plans to expand the Educate to Innovate campaign in K–12 science and math education. As such, there has been an emphasis from the federal government on increasing the exposure to quality STEM education during a student's secondary school experiences through various funding and mandating strategies. Though these legislative acts target all students, the National Science Foundation has supported efforts to address gender differences in STEM fields since 1993.

Results suggest positive gains have been realized, as postsecondary enrollment in the STEM fields for all undergraduates has steadily escalated over the past fifteen years. In addition, the number of bachelor's degrees in these disciplines reached a new peak in 2007 (NSB 2010). There has also been a profound increase in the proportion of women entering STEM disciplines. This proportion has increased from 1993–2007—females have accounted for 58 percent of all bachelor's degrees since 2000 and have earned approximately half of all STEM degrees over the same time period. However, gender disparities in bachelor's degree attainment continue to exist in certain STEM disciplines, specifically in physical sciences and engineering. For example, women earned at least half of all bachelor's degrees in psychology (77 percent), biological sciences (60 percent), social sciences (54 percent), agricultural sciences (50 percent), and chemistry (50 percent). In contrast, men earned 81 percent of engineering degrees, 81 percent of computer sciences degrees, and 79 percent of physics degrees in 2007. Similar gender preferences across STEM disciplines are evident for graduate degrees, as women earned only 31 percent of physical science, 26 percent of mathematics/computer sciences, and 23 percent of engineering doctorates while accounting for over half of social/behavioral sciences, medical/life sciences, and non-STEM doctorates (National Science Board 2010). Understanding the causes of this disparity in certain disciplines is important so that viable solutions can be developed to achieve a more balanced gender composition in all STEM fields. As subsequent sections in this review suggest, implementing innovative pedagogical strategies at the classroom level that have a firm grounding in research on gender learning theory may partly address the issue.

K–12 Achievement in STEM

Comparisons in STEM achievement between males and females could possibly help inform decisions on how to decrease the gender gap. If females have markedly lower achievements than males in STEM fields upon high school graduation, for example, remediation programs could be offered at the college level to promote recruitment and retention in these disciplines. In a study of male and female students in the eighth grade, Catsombis (1995) compared gender differences in both science achievements and attitudes. She found that on average females achieved equivalently to males, and some showed a greater likelihood of enrolling in higher level classes than their male counterparts. However, females also had less positive attitudes about science and less frequently aspired to a career in science.

Similarly, Campbell et al. (2002) compared STEM achievements and attitudes by gender throughout both the K–12 sequence and within postsecondary settings. Males and females scored similarly on tests in the fourth grade, but males tended to develop physical science and technology-related interests, whereas females tended to track toward life sciences at this early age. Eighth graders showed little differences in science and math test scores by gender, but females were more likely to begin algebra coursework by this stage of their educations despite having lower confidence than males in their own math abilities. In addition, twice as many males as females were interested in quantitative or science disciplines by this grade level. High school seniors also showed no differences across gender in achievement, as both males and females were as likely to take advanced coursework. Females were less likely than males to express a desire to major in computer/

information science, science, engineering, or math, and this was later realized through their selection of college programs. Considering racial demographics, the gap in achievement between white students and minority students tended to widen at each successive grade level observation point, but interest in science and math subjects did not vary between these demographic groups. Therefore, the researchers found that, in aggregate, women graduate from high school with comparable knowledge and skills to men in the STEM fields. Furthermore, once women declare a major in one of these fields, they persist at a rate proportional to men. Minority students, on the other hand, are more likely to transfer out of STEM majors prior to degree attainment because, on average, they enter college without the academic preparedness required of these disciplines. As such, institutions of higher education face varying sets of issues in enrolling students into STEM fields dependent upon the student demographic characteristics. For all women, recruitment is a major barrier to enrollment, but institutions also struggle with retention for minority women. Therefore, researchers should take into account the interaction of gender and race in studying students enrolling in STEM fields (Campbell and Storo 1994), and practitioners should recognize the multifaceted nature of the problem.

Differences Across Academic Disciplines

Because research shows no gender differences in STEM achievement, it stands to reason that there are other discipline-specific characteristics that lead to gender imbalances. Work by Brint et al. (2008) identified different cultures of student engagement across broad disciplines. Using the National Survey of Student Engagement (NSEE), they identified five dimensions of effective academic engagement, including active or collaborative learning, student-faculty contact, level of academic challenge, enriching educational experiences, and supportive campus environment. A factor analysis of the engagement items yielded two different cultures that separated according to academic discipline:

1. A humanities/social sciences culture characterized by high student/faculty interaction, discussion and questioning by students in classes, the connection of ideas across courses, and students who go above and beyond the required workload.

2. A science/engineering culture dominated by high quantitative and computer skills, high levels of collaboration with peers, a focus on problem solving, and a pervasive interest in obtaining high-paying and prestigious jobs.

This finding of multiple engagement cultures across fields is not very surprising since there is a variation in the roots of content and views of knowledge across disciplines. The authors clearly assert that students are recruited into a field and undergo a socialization in which they discover and adopt the attributes that are recognized within the field. They cite the field's paradigmatic development as an indicator of the culture, with low paradigmatic fields (humanities and social sciences) encouraging flexibility and discussion, and high paradigmatic fields (science and engineering) promoting more structure. The science/engineering culture of engagement is characterized by specific skill sets in which students work together to solve problems incrementally because, historically, there has been little room for extra discussion on how to approach problems. On the other hand, the humanities/social sciences engagement culture of increased discussion and active class participation is expected, as students and teachers struggle over several possibilities rather than the "one correct answer." Since faculty members at universities have been trained according to certain paradigms, they tend to propagate the corresponding culture of engagement with students through their own teaching (Brint et al., 2008). Similar work by Sheila Tobias (1990) identifies how different cultures of engagement of the disciplines may either attract or repel students from enrolling in a major.

Nelson Laird et al. (2008) compared deep approaches to learning (including higher-order, integrative, and reflective learning) across combinations of Biglan's disciplinary categories, a classification system that describes disciplines across the following dimensions: applied–theoretical, hard–soft, life–non-life. Similarly, they found that the extent to which deep learning techniques are put into practice varies by discipline, with soft, pure, and life fields using deep approaches more frequently than hard, applied, non-life fields. This latter group represents disciplines in which women are currently underrepresented. Like Brint et al. (2008), they attributed differences in the use of engagement techniques to the degree of consensus, or paradigm development, within various fields. Since different disciplines have unique cultures of engagement,

females and males may select a field of study that is a better match for their personal engagement style.

Even within STEM fields, there are differences in the representation of women across disciplines. In engineering, for example, studies show differences in female representation among disciplines (e.g., mechanical, industrial). Research on nine southeastern universities showed that industrial engineering, chemical engineering, and civil engineering have a higher percentage of women enrolled than the other engineering disciplines (Borrego et al. 2005). Similarly, Jenkins and Keim (2005) found that female students in one university preferred biomedical engineering, civil engineering, and chemical engineering and were not as well represented in mechanical and computer engineering. However, these studies stop short of explaining *why* there are differences. Following the logic of Brint et al. (2004), perhaps certain disciplines within the STEM fields have cultures of engagement that are more attractive to females as they search for a home discipline.

There is a wide body of literature on how students select a major field of study. The decision is an important indicator of career choice, earnings, and professional satisfaction. Many factors have been shown to contribute to this choice, including gender (e.g., Jacobs 1986, 1995), race (e.g., Thomas 1985), ethnicity (e.g., Simpson 2001), and labor market returns (e.g., Cebula and Lopes 1982; Davies and Guppy 1997). While there is an extensive literature on the influences that a student's background has on access to and success in higher education, there is a void in how it influences his or her academic plan (Goyette and Mullen 2006). Considering gender issues, the choice of a major is a logical starting point for analyzing differences between males and females in career choice and earnings (Barres 2006; Daymont and Andrisoni 1984).

Zafar's (2009) academic major choice model was applied to students at the Weinberg College of Arts and Sciences at Northwestern University. Students select a major according to expected outcomes during college, anticipated outcomes after college, and individual characteristics, including gender. In efforts to test their major choice model, they surveyed students to gain an understanding of their thought processes during this important academic decision. Gender comparisons on self confidence, self efficacy, and ability showed no differences between males and females in factoring into the declaration of a major in science or engineering. Rather, a difference across genders in the likelihood of enjoying the coursework of science or engineering was the most important determining

factor. Therefore, using the findings from this major choice study as supporting evidence, incorporating pedagogical techniques in science and engineering that have successfully attracted females to other disciplinary cultures may be a successful tactic for recruitment.

Another determining factor in decisions about major fields of study is related to sexual stereotyping (e.g., Metz and Samuelsen 2000). Differences exist across disciplines in the degree to which sexual stereotyping occurs. Society has a pervasive view that science and engineering professions are "male-dominated" thereby causing negative attitudes toward these disciplines among women; this phenomenon is an example of sexual stereotyping. Relative to men, women tend to have less overall interest and perceive fewer educational and career benefits by pursuing these areas (NRC 2006). Despite an overall weak understanding of what engineers actually do by the general public (e.g., Cunningham et al. 2005; Cunningham and Knight 2004; NAE 2008), the sexual stereotyping of the "white male" engineering profession still begins at a young age and is carried throughout life, making it discouraging for women to enroll in programs once they reach college (Metz and Samuelsen 2000). Perhaps the field has sustained this stigma within the general public because it has always been dominated by white males, but the literature has not resolved the cause of the perception. This stereotype threat has been shown to negatively influence performance, as women must cope with feelings of isolation within STEM fields. In a study of females assigned to either a stereotype threat condition or no condition while taking a math test, women under the threat condition reported higher negative feelings with respect to math during the exam. The control group also performed better overall than the group under threatening conditions (Cadinu et al. 2005). In similar research, Kiefer and Seka-quaptewa (2007) observed students in a college-level calculus course under various sexual stereotype conditions. Women under the treatment performed worse on the course's first exam and had a reduced desire to pursue a math-related career relative to women who experienced low stereotyping. Claude Steele's (2003) work also showed that sexual stereotyping explained why women who were equally prepared for challenging math courses underperformed relative to classmates of the same intellectual level. Finally, research by Krendl et al. (2008) focused on how cognitive structures vary under different conditions of sexual stereotype threat. Using magnetic resonance imaging to determine which neural structures

explained the underperformance on math tasks in certain females, they found that certain neural networks are activated during mathematical learning. If a female is in a threat condition, rather than activating this neural network, she instead activates a neural network that controls social and emotional processing. Thus, women who are in a threat situation may not perform as well because the threat causes a preoccupation of the cognitive process.

In summary, clear differences exist between disciplines in the ways that they present themselves to students and thus their attractiveness to women. The different academic cultures of science and engineering versus humanities and social sciences may indicate that women are more attracted to a certain type of engagement in the classroom. Even within STEM, women tend to gravitate toward the soft, pure, life fields (NSB 2010). Academic major choice theory with respect to STEM suggests that women may be underrepresented because they are simply uninspired by potential coursework, suggesting that shifts in pedagogical techniques could potentially influence recruitment. Finally, differences in sexual stereotyping between disciplines also may steer females to enroll in certain fields and avoid others.

STEM-Specific Difficulties in Recruitment and Current Recruitment Techniques

Many studies, especially at the K–12 level, have attempted to determine why it is difficult to recruit women into STEM fields. Reviews of the literature group explanations into broad categories, including precursors, interests, confidence, peer interactions, teacher interactions, and performance (e.g., Bachman et al. 2009). Parents have a large influence on their sons and daughters and act to maintain gender-based norms in society (Bhanot and Javanovic 2005; Buchmann and Dalton 2002). According to these norms, the STEM fields as a potential career destination for their students has a more masculine than feminine connotation (Nosek et al. 2002; Tiedemann 2000). Another potential reason for gender differences is related to variations in subject interests. On average, males prefer structured, goal-oriented subjects (Abu El-Haj 2003), and STEM courses have traditionally been (Donald, 2002) and largely still are (Lattuca and Stark, 2009) arranged in a sequence-driven, hierarchical manner based on continuously building information from a foundation of concepts, though

some recent, select efforts have experimented with more innovative curricula (e.g., Beichner et al. 2007).

There is some evidence that men and women in STEM fields have differing levels of self-confidence (e.g., Schunk and Pajares 2002). Despite entering college with achievement and confidence levels similar to men, women in STEM fields tend to lose that confidence upon matriculation, potentially because of feelings of isolation when they are underrepresented in certain disciplines (Seymour 1995; Whitt et al. 2003). Interactions with male peers who believe women enrolled in STEM fields can either be smart or attractive, but not both, can also be harmful to a their confidence and retention within the field (Seymour 1995). If a female is perceived to be smarter than her male counterparts, she will often be omitted from study groups and lose access to an encouraging peer network (Stake and Nickens 2005).

Considerable efforts already have been made to combat some of these barriers and recruit female students to STEM (e.g., Plumb and Reis 2007). These include professional development programs for K–12 teachers, hosting summer camps targeting underrepresented groups, and developing outreach instructional materials for secondary school settings. Individual institutions of higher education have made substantial efforts to address the chilly climate amongst peers through undergraduate mentoring programs intended for women (e.g., Campbell and Skoog 2004) and STEM learning communities for women (e.g., Kahveci 2006). For example, Kahveci (2006) studied the recruitment effectiveness of a living-learning community for women in science, math, and engineering. In this community, students lived together, formed mandatory study groups, participated in organized activities, and held colloquium, lectures, advising, etc. The declaration of a major for undecided students within the learning community was compared to the major choices of undecided students in an honors chemistry class. Learning community members were more likely than the honors chemistry course undecided students to officially declare a STEM major. In addition, the retention rate of STEM majors within the program was higher than the rate for students in the honors course. Therefore, building a sense of community and engaging students within the living-learning program resulted in positive outcomes for women students and effectively addressed some of the STEM gender difficulties previously outlined.

Successful Pedagogical Techniques for Women in STEM

Busch-Vishniac and Jarosz (2004) suggest that shifting some emphasis from recruitment and climate issues to both curricular content and instructional methods may yield increases in the enrollment of women in STEM. Research shows that women and men respond differently to the way in which content is packaged and taught (Baxter-Magolda 1989; De Courten-Myers 1999; Jacobs and Rossi Becker 1997). Empirical work in both secondary and postsecondary settings supports theories that suggest females are more interested in topics related to their lives, society, and broader concepts than males (Brotman and Moore 2008). Therefore, adjusting course-level practices to align with these findings may cause certain STEM disciplines to become more attractive for females leading them to diversify by gender.

Researchers have found both biological and social variations across genders in effective learning processes (Bachman et al. 2009). The neuroscience literature shows that structural differences between male and female brains may cause varying cognitive functionalities. According to psychometric tests, males tend to consider facts in isolation, while females integrate pieces of information into larger concepts (De Courten-Myers 1999). A cognitive study by Belenky et al. (1986) indicated that females gain knowledge by accessing other experiences. In essence, they generally begin to understand a concept by first relating it to a personal experience. Jacobs and Rossi Becker (1997) also suggest that women excel in math under pedagogies built from intuition and personal experience. Generalization, contextualization, induction, and creativity all generate a greater likelihood that women will learn math concepts. In summary, these cognitive theories indicate that women tend to approach problems and process information contextually from a personal experience.

Several empirical studies have supported these theories through surveys or observations of classrooms in both K–12 and higher education settings. Research by Campbell et al. (2002) showed that hands-on learning for fourth and eighth graders yielded higher achievement in STEM, especially for females in physical science labs. Instead of typical weed-out introductory courses, increasing hands-on activities early in the course sequence promotes the recruitment and retention of women students (O'Callaghan and Enright Jerger 2006). Small group learning has also been shown to enhance achievement, attitudes, and persistence, regardless of whether the

smaller, more engaged group is of mixed genders (Campbell et al. 2002). It facilitates more interaction, greater feelings of acceptance, and more positive expectations, for student participants than the traditional lecture style (Johnson and Johnson 1983), thereby addressing some of the alienation issues sometimes facing women in STEM. Terenzini et al. (2001) compared student learning outcomes between active and traditional learning techniques in engineering schools. They found that students in active learning settings have statistically significant advantages in learning outcomes, specifically in design skills, communication skills, and group skills. Similarly, in a meta-analysis of research on undergraduate education, Springer et al. (1999) found that this collaborative learning style yielded increases in student persistence for STEM fields in particular. In STEM courses, instructors still tend to rely on teacher-centered pedagogies. Students completing a survey in each of their first four semesters of college indicated that science courses typically rely on standard transmission-lecture techniques. Despite having insignificant disparities in ability and performance, deflated persistence for women science students was explained by this teaching method (Dickie et al., 2006). There has been a slow realization among STEM faculty members that instructional methods should be retooled, and interactively designed courses that begin with questions relevant to everyday life have seen more recent success (Seymour 2001).

Utilizing case studies is an example of retooling the curriculum and is an effective pedagogical technique to connect theoretical and practical knowledge (Shulman 1997). For women especially, research shows that contextualizing math and science skills via a practical problem effectually sparks and can sustain a long-term interest in STEM subjects (Halpern et al. 2007). Specifically, stressing the social relevance of science and engineering is a tactic that has proven successful in the recruitment and retention of women. Brotman and Moore (2008) showed evidence throughout the literature that women place a larger importance on conceptual relationships and connections than men, focusing on larger, broader pictures rather than individual details. Similarly, Clewell and Campbell (2002) asserted that effective interventions include using "real life" situations in problem solving and exposing females to role models. Marshall and Dorward (1997) conducted an experiment with undergraduate students to quantitatively determine whether minimal inclusion of biographical information of women scientists had an effect on student perceptions of

women in the field. They introduced the biographical information to certain class sections but not to others and surveyed each class's perceptions before and after the course. Results indicated that perceptions of students who were exposed to women scientists shifted away from the notion that science is a male-dominated endeavor. Perceptions of students in the control group did not change over the course of the semester. As such, this experiment showed that classroom practices can in fact shift students' views of the field and perhaps spark interest to pursue further inquiries.

Several other authors cited successes in the engagement of female students when a science or engineering topic was related to a real-world situation. Zastavker et al. (2006) studied how problem-based learning affected outcomes for first year engineering students. Women in their study cited interdisciplinary teaching, or teaching across topics that mimicked real-world situations, as positive sources of learning. A qualitative study of underachieving high school females noted that students were more likely to engage in activities that were made personally relevant. Implications from this work suggest further research on determining how engagement varies with contexts (Thompson and Windschitl 2005).

Finally, Kardash and Wallace (2001) surveyed 922 undergraduates in an assessment of their perceptions about science. Both males and females had similar academic abilities, appreciation for science, interest in pursuing a science-related career, and beliefs that they were academically prepared. However, they differed in their reactions to the pedagogical techniques employed by professors. Men tended to agree that faculty used cognitively based methods of instruction, but women described the instructional method as being teacher-directed. Consistent with other research, women indicated that faculty did not emphasize broad concepts well enough, did not explain topics in a way that made sense intuitively, and did not link new lessons to previously learned subjects. Most importantly, women did not feel that professors created an engaging classroom environment to allow interaction and collaborative discovery.

The engineering curriculum in freshman-level courses can creatively entice students into the field by addressing social relevance and diversity to allow students to place material into personal and historical contexts. Farrell (2002) described creative examples of classes offered by institutions designed specifically to attract women by showing the social value and relevance of math and science. At Rensselaer Polytechnic Institute, introductory courses are offered as studio classes with only thirty-five students as opposed to the traditional large lectures. Each studio used problem-based learning strategies that engaged students with real-world projects. Tufts University taps into students' hobbies to illustrate fundamentals through courses like "Gourmet Engineer." This class demonstrates heat transfer processes via heating food in an oven and has experienced a 40 percent female to male ratio, twice the national average.

Within the science disciplines, Carlone and Johnson (2007) completed a qualitative study analyzing how several women of color successfully navigated through the education pipeline to become scientists. All of these women began with a personal interest in the topic and suggested that the traditional technique of making efforts to spur interest in the hard sciences may not be the most effective approach. Rather, the recommendation resulting from this research emphasizes the relationship between altruism and science. For African American females, in particular, recruitment efforts may be more successful for disciplines such as health sciences or environmental sciences where there is a clear benefit to society.

Developing a greater sense of engagement and application to society has also happened through service learning courses. Markus et al. (1993) examined the impacts of community engagement on political science students' learning and knowledge acquisition. Students were randomly assigned to course sections that either had a community service component or a traditional framework that acted as the control condition. For the community service sections, students were required to complete twenty hours of service of their choosing during the semester. Reflections through course discussions and short papers also accompanied these experiences. Students in the traditional course followed a typical lecture-discussion model that required a longer term paper assignment. In comparing scores on a common midterm and final examination across sections, students in the community service sections performed .29 of a standard deviation (11 percentile points) better than students in the traditional section. This was evident despite beginning the course with no significant differences in academic ability or student characteristics. Similar findings of improved learning through community service requirements have been found in numerous settings (Astin and Sax 1998; Berson and Younkin, 1998; Eyler 1993, 1995; Eyler et al. 1995; Gray et al. 1996; Ikeda 2000; Pascarella and Terenzini 2005; Strage 2000). In comparison to students enrolled in

traditional-style courses, students in courses with community service requirements indicate that they are better able to apply concepts from the course to new situations (Kendrick 1996; Markus et al. 1993; Miller 1994).

A Technology for Community course in Colorado combines the societal context and community engagement components to generate successful recruitment of women. The program recognizes recruitment success with women if there is a tangible benefit to society (Jessup et al. 2005). Students provide workshops for the greater Boulder community in this computer science course and learn design and problem-solving skills in concert with a humanized classroom setting. Enrollment patterns in the course are 51 percent female, a demographic that normally only accounts for 9–16 percent of the computer science population. Clearly, having the community engagement component of this course increased the attractiveness for females to enroll. As shown, being able to apply knowledge to new contexts is especially attractive for women students, so offering courses with a community engagement component may be an avenue of increasing women's participation in the STEM fields.

A Strategy to Recruit Women into STEM Fields

Courses and programs that have successfully inspired female enrollment in STEM disciplines through societal contextualization of topics can be used as springboards for recruitment. One potential avenue for accomplishing such a focus is to use the lens of civic engagement to introduce the relevance of STEM topics to societal issues. An educational outcome for this lens would be the connection of STEM-related knowledge with choices and action. As the Association of American Colleges and Universities (2007, 39) indicated, "students should be provided with guided opportunities to explore civic, ethical, and intercultural issues in the context of their chosen fields." Employing civic engagement in introductory or general education classrooms to foster a connection between science topics and civic issues may produce new interests and support enrollment in the sciences among women (NRC 1999).

Historically, civic engagement has been a de-emphasized mission of colleges and universities as institutions have shifted from civic institutions to research machines. However, with the recent resurgence of community involvement on campuses, civic engagement has great potential for problem solving and program planning in institutions of higher education (Checkoway 2000). Several benefits could result from incorporating civic engagement into introductory classes or science courses for non-majors that may ultimately result in increased enrollment by women. According to Sax (1996), the strongest predictor of a woman's enrollment in a STEM graduate field is the pre-college interest in making a theoretical contribution to science. Negative predictors include the following: (1) individuals with the "social activist" personality type; (2) women who are concerned with the "social good" of a career choice; and (3) careers that "make a contribution to society." Based upon this research, introducing science topics through civic engagement may attract a wider population of females into these courses that would not have enrolled previously. As Sax (1996) found, these women still may not pursue a graduate degree in the sciences, but they would be exposed to science topics that could potentially spark an interest for future inquiry—this too should be seen as a success for STEM education. Important additional work should further examine career theory and the entry of women into the STEM workforce or further studies in graduate school.

A second benefit of introducing civic engagement into science courses is the potential for producing a more responsible citizenry from these fields. Students majoring in biology, chemistry, and engineering are the least inclined college graduates to participate politically (Hillygus 2005). Introducing civic engagement into coursework may change that behavior. Prior research on learning preferences for women in STEM fields has driven this notion of incorporating civic engagement into science coursework. The end result may yield dual benefits: (1) a more active citizenry of science students, and (2) a curriculum that is more conducive to female student success, interest, and enrollment in undergraduate science classes.

Science Education for New Civic Engagements and Responsibilities (SENCER) is a national effort to teach science through the framework of complex civic issues and their consequences. These classes can provide a vehicle for studying the relationship between classroom processes and increasing women's confidence and interest in science. Overarching SENCER goals include the following: (1) increase student learning and interest through engagement in STEM courses; (2) help students make connections between material presented in STEM courses to their other studies; and (3) strengthen students' understanding of science and their capacity for responsible work and citizenship (SENCER 2006).

SENCER courses place the teaching of science content within the broader context of educating students to become aware of complex and unresolved civic issues. As research suggests, faculty who participate in these courses have found that when students are engaged with learning that is both intellectually challenging and directly connected to "real world" problems, they become interested in or maintain their interest in STEM fields. The courses have clear learning objectives that can be linked to students' goals for personal and career development and include opportunities to communicate results and use new knowledge for action. In addition, courses apply strategies that emphasize active, inquiry-based learning, and many connect studies to community-based issues and groups. All of these pedagogical techniques are consistent with research on the preferred learning styles of female students. As such, implementing frameworks like SENCER may be an effective model for recruiting additional women into the STEM disciplines.

Weston et al. (2006) completed an extensive, independent multi-year evaluation of the SENCER framework and found that enrollment in these courses had a positive effect on students' views of science. This analysis of 10,000 students enrolled in over three hundred SENCER courses also had significant findings for female students in particular. Females showed greater increases than males overall, and non-science majors showed greater gains than science majors on many of the confidence and interest items, regardless of gender. Over the length of a course, women tended to close the pre-course gap that existed with men for these items. Furthermore, women exceeded men in their perceptions of their ability to apply scientific information to social concerns after completing a SENCER course.

The majority of students enrolled in SENCER courses are females who have taken few science courses (Middlecamp et al. 2006). Since these students exhibit gains in both confidence and interest after taking part in the courses, generating interest in STEM among females through civic engagement may be promising. As this review conveys, research shows that females tend to prefer active and collaborative learning environments in which new material is contextualized into real-world situations. Pedagogies that implement civic engagement frameworks in the classroom align with these preferences and represent a strategy for recruiting women into STEM fields.

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