Rodgers, K.A.(2009). Retention of Underrepresented College Students in STEM. In B. Bogue & E. Cady (Eds.) Applying Research to Practice (ARP) Resources. Retrieved <Month Day, Year> from http://www.engr.psu.edu/AWE/ARPresources.aspx

Information Sheet:
Retention of Underrepresented College Students in STEM

By: Kelly A. Rodgers, Ph.D., University of Texas at San Antonio

May and Chubin (2003) pointed to seven key factors that contribute to the success and consequent retention of minority students pursuing undergraduate and graduate degrees in STEM: pre-college preparation, recruitment programs, admissions policies, financial assistance, academic intervention programs, and graduate school preparation and admission. Arguably, these factors, while important in STEM specifically, may be deemed crucial elements for minority students in general, regardless of academic major. In fact, the literature on minority student retention as a whole has promoted each of these factors in some form or another (e.g., Fenske, Porter, & DuBrock, 2000; Rivera-Mosquera et al., 2005; Swail, Redd, & Perna, 2003). It is important to note, however, that retention concerns have not had a blanket effect across all STEM fields and ethnic groups. For example, fields like biology and chemistry have achieved and in some cases, exceeded relative gender equality in degrees conferred. In 2006, women received 59.7 percent of the bachelor's degrees awarded in biological and agricultural sciences, and 42 percent of those awarded in physical science fields such as chemistry and physics. However, women received only 19.5 percent of bachelor's degrees awarded in engineering (National Science Foundation, 2008).

In general, graduation rates are not proportionate to the general population across all ethnic groups. In 2004, Asian students represented approximately 11.8 percent of bachelor's degrees awarded in engineering, despite representing only 3.7 percent of the United States population. Conversely, African American, Hispanic, and Native American students garnered 5 percent, 6.9 percent and .5 percent of engineering degrees while representing 12 percent, 11.5 percent and .79 percent, respectively, of the total U.S. population (National Science Foundation, 2006). Thus, it is important to be sensitive to cultural practices and beliefs that may contribute to students' potential to be retained in STEM programs. For example, the overrepresentation of Asians in STEM fields might be explained as the result of their collectivistic, family-oriented culture, where in excelling in a chosen program of study, regardless of the cost, ultimately serves a group goal by portraying the family in a positive way. For African American and Hispanic students, negative views of their cultural backgrounds or family settings may interfere with students' ability to focus and feel positively about their academic abilities.

When gender and minority status are compounded, the scales are especially unbalanced. Bachelor's degrees awarded to African American, Hispanic, and Native American *women* represented 13, 10.9, and .01 percent, respectively, of the total number of bachelor's degrees awarded to women in 2004. However, among women awarded bachelor's degrees in science and engineering, the figures for African American and Hispanic women are 10.7 and 8.1 percent. Only Native American women had a higher representation in science and engineering than overall, garnering .8 percent of all of the bachelor's degrees awarded to women in science and engineering.

The aim of this paper is to understand retention of underrepresented students such as women and those

A Product of SWE-AWE (www.AWEonline.org) and NAE CASEE (www.nae.edu/casee-equity)
NSF Grant #01210642 and #0533520

from particular ethnic backgrounds in STEM disciplines by understanding these students' thought processes and experiences as they navigate their programs. To do this, a brief overview of recent work on college student retention is given, with special attention given to the applicability of that literature to women and minorities in STEM. Then, students' attitudes towards their STEM programs, their self-efficacy beliefs in their ability to complete their graduate or undergraduate program, and the relationship between their self-efficacy and motivation to do so are discussed. This discussion is followed by policy implications and concludes with directions for further research.

Models of Retention

Drawing from the work of Van Gennep's (1960) idea of three stages that exist in the *rites of passage*, Vincent Tinto (1988) proposed three parallel stages of student departure from college: separation, transition, and incorporation. The overarching idea behind Tinto's application of VanGennep's stages to retention at the college level was that retention was most likely to occur when students were able to transition successfully from their past associations (e.g., family home, high school, and neighborhood family networks) to full integration into a new social role or situation (college). Tinto (1975) acknowledged that the task of fully separating from past associations would be harder for students with a home environment significantly different from the college atmosphere, yet insisted that such separation was necessary for full integration into the campus climate, and consequently, for students' retention in that climate. In 1993, Tinto argued that it might not only be impossible to expect full separation from the students' home lives, but that retaining such home ties may actually aid, rather than hinder, integration and consequent retention at the college level, especially for minority students entering a predominantly White college atmosphere.

Underlying Tinto's (1975) original stage or status-based retention theory were psychological mechanisms that made each stage possible. For example, the final stage in the process, incorporation, involves a complete relinquishing of past associations and a full involvement in the new environment. Such a switch suggests a shift in identity. It was the goal of Bean and Eaton (2000) to revise Tinto's (1975) model, explicitly indicating the psychological processes inherent in that model. Noting the failure of Bean and Eaton (2000) to consider the role that culture and racialized experiences may play in the retention of minority students, particularly those attending predominantly White institutions (PWIs), Rodgers and Summers (2008) proposed and tested revisions to Bean and Eaton's (2000) model (Figure 1). The authors suggested that, due to unique cultural experiences, the retention process (or those constructs deemed important for retention) likely looked different for minority student populations.

As suggested by Rodgers and Summers (2008), it is important to question our assumptions regarding the elements that are deemed necessary for success and retention of students in programs and general academic spaces in which they are the minority due to race, ethnicity, or gender. In the following sections, several psychological processes deemed important in the retention process and their implications for the retention of women and other underrepresented students in STEM disciplines will be discussed. Specifically, this overview focuses on students' attitudes, self-efficacy and motivation, and the relationship of each to retention outcomes.

Attitudes

One of the most significant adjustments that Rodgers and Summers (2008) made to Bean and Eaton's (2000) model was positioning attitudes toward the institution (or in the present discussion, toward the major) as a precursor to, rather than an outcome of, psychological processes. The authors contend that in order to positively influence students' psychological processes (e.g., self-efficacy, motivation), institutions must first positively affect students' attitudes, particularly students operating in an environment in which they are the minority. Bean and Eaton proposed that students' attitudes were the result of a reciprocal commitment between student and institution: institutional commitment to the student and students' feelings of commitment to the institution. Institutions demonstrate their commitment to students via visible faculty and academic support, and by demonstrating a respect for things students of particular ethnic or gender groups find important. For example, university support of cultural events like concerts, speakers and special student groups. Reciprocally, students' commitment to the institution can be the result of perceptions of campus climate and feelings of belongingness.

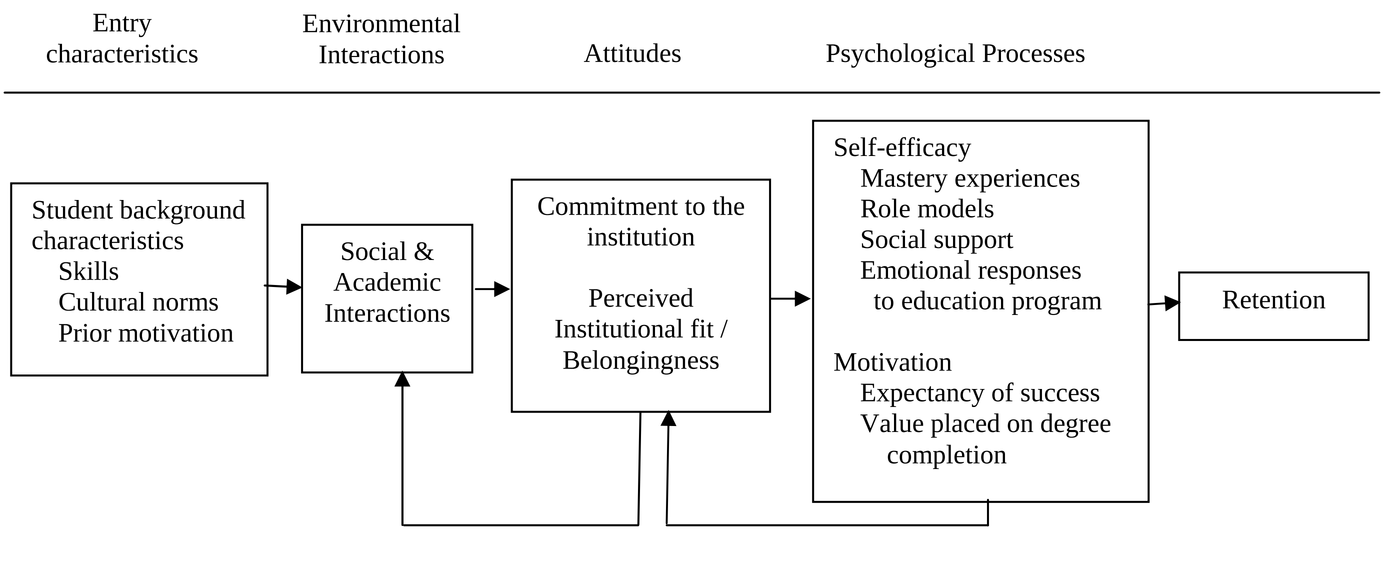

Figure 1. Retention Model (adapted from Bean & Eaton, 2000; Rodgers & Summers, 2008).

Campus & STEM Climate

Cabrera, Nora, Terenzini, Pascarella, and Hagedorn (1999) describe retention models that emphasize a reciprocal commitment between students and their universities as demonstrating a *Student-Institution Fit* perspective. This perspective is useful in explaining the institutional maladjustment of some minority students. According to the authors, when students perceive the campus climate to be intolerant of a particular subculture (ethnic, gender, sexuality-based, etc.), this creates a barrier between student members of that subculture and institutional resources deemed useful and necessary for academic success and satisfaction. When they encounter problems, students become less likely to seek academic support from faculty and peers. They are less willing to be involved with campus activities that might serve to increase their feelings of social and academic integration (Tinto, 1975), thereby decreasing the likelihood that they will remain at the institution.

Hurtado, Griffin, Arellano, and Cuellar (2008) describe the *psychological* climate as only one component of the total campus climate. The authors differentiate it from the *structural* climate, which refers mainly to the physical representation (in the context of the present discussion) of women and underrepresented students in STEM programs at undergraduate and graduate levels. Thus, in fields such as the physical sciences that have reached equity in attracting and retaining traditionally underrepresented students, students may continue to enroll in these programs while not necessarily perceiving the psychological climate to be welcoming, but due, in part, on the visibility of other underrepresented students.

NSF Grant #01210642 and #0533520

The diverse sample ofundergraduate male and female students in de Pillis and de Pillis' (2008) study of gender-based undertones in engineering school mission statements expressed that there were clear masculinized sentiments inherent in the mission statements that evoked a sense of intolerance for traits and behaviors generally associated with women, such as being soft spoken, eager to soothe feelings, or likable. Instead, participants inferred a preference for students who might be described as "forceful" or "dominant," characteristics often associated with men. The African American, Hispanic, and Native American female graduate students in Johnson's (2007) study also pointed to a science culture in which one must be visible and vocal to be successful. . This is in opposition to the socialization of many women, wherein women are sometimes expected to be seen and not heard. These criteria were strengthened for women of color, despite Hanson's (2004) contention that, due to cultural beliefs regarding womanhood and the family structure, African American women in particular should be ideal candidates for survival in a STEM program.

Belongingness

The women in Johnson's (2007) study of science professors' discouragement cited the oft-used lecture-style courses as a serious barrier to their feelings of belongingness. Indeed, lecture style classes have long been discussed in terms of the significant challenges that they propose for all students while proposing a bevy of solutions (e. g. Jones, 2007; Cooper & Robinson, 2000; Saville, Zinn, Neef, Van Norman & Ferreri, 2006). . However, the format may be especially damaging for women and members of ethnic minority groups. The accessibility of faculty relationships in many STEM fields is crucial for women, especially those from underrepresented ethnic groups. Faculty relationships have been shown to be effective in influencing academic achievement and persistence, particularly for students in academic spaces where they are the minority (see Cabrera, et al., 1999; Cokley & Chapman, 2008; Hurtado & Ponjuan, 2005).

In her qualitative examination of the dynamics of graduate students in a research methods course, Diangelo (2006) observed a lack of participation on the part of several Asian and Asian American female students. This result was especially curious because in this particular class on a predominantly White campus, Asian students were in the majority; yet most of the participation was aimed at and included the few White male students, and to a lesser extent, White females. A woman in Robinson and McIlwee's (1991) study explained her decision to leave her engineering position for a position in marketing partially as the result of feelings of alienation by male students:

> [In the lab] it was hard, I had to fight all the time. Marketing was more natural for me. I seemed to be much more accepted…. [In the lab] I wouldn't get the feedback from the other guys, so I was constantly feeling like I wasn't as good… (p. 412)

In the graduate research methods course, Diangelo (2006) also observed that the professor engaged the White male students more and was noticeably dismissive of the contributions of female students and completely overlooked non-White students.

Blickenstaff (2005) also cites pedagogical style as a possible deterrent of women and underrepresented students from pursuing or being retained in STEM fields. However, this deterrent extends beyond pedagogical implications. The women in Johnson's study (2007) expressed that the aggressive and competitive pedagogical style that tends to favor White males not only put the women at an academic disadvantage, but also left them feeling alienated and unable to forge relationships with professors. This is a crucial element of success in STEM programs, because close relationships with faculty are necessary for

A Product of SWE-AWE (www.AWEonline.org) and NAE CASEE (www.nae.edu/casee-equity)
NSF Grant #01210642 and #0533520

letters of recommendation to graduate and professional schools and additional opportunities to participate in grant research. As a result, women and students from cultural backgrounds that eschew this aggressive and competitive approach to education end up in danger of being left out, resulting in feelings of exclusion and lack of belongingness within the program.

.

Psychological Aspects of Retention

Rodgers and Summers (2008) proposed the inclusion of several psychological constructs in any discussion of minority college student retention. Among them, the authors addressed the role of self-efficacy and motivation in the retention process. Both will be discussed in the following sections.

Self-efficacy

Bandura (1977) described self-efficacy as "the beliefs in one's capacity to organize and execute the courses of action required to produce given attainments" (p. 3). That is, self-efficacy refers to one's belief that he or she can deal with a specific task or situation and reach a particular goal. This discussion of self-efficacy will specifically address students' beliefs in the likelihood that they can complete an undergraduate or graduate degree in a STEM discipline. Pajares (1996) states that self-efficacy affects the choices that one makes, how hard one works at a task, and how long one perseveres when the task is problematic and difficult. One's self-efficacy regarding a task or situation also has implications for the affective domain. Bandura (1977) indicated four sources from which we assess the likelihood that we can successfully reach a given attainment: 1) mastery experiences, 2) social persuasion, 3) vicarious experiences, and 4) emotional and physiological states. (For more on Self-Efficacy, see the ARP series by Rittmayer (2008).

Mastery experiences refer to the opportunities that one has had in accomplishing similar tasks or goals. It also encompasses the discrete knowledge that one possesses that is deemed necessary for completion of the attainment. This includes not only having an appropriate background in key academic areas, but also having experienced a measure of academic success. In fact, the findings of Besterfield-Sacre, Moreno, Shuman, and Atman (2001) and Arnette (2004) suggests that simple preparation in math and science fields is insufficient for the positive mastery experience that is important for high self-efficacy in the completion of degrees in STEM fields.

Instead, these authors indicate that another of Bandura's sources, *social persuasion*, may more fully explain the gap that exists between the ability of STEM disciplines to attract and retain women and other underrepresented students. Social persuasion refers to the influence that others have in a particular context. In the academic context it describes, for example, faculty encouraging and offering students support. Parents, friends, and significant others can also serve as effective social persuaders in that they may provide the social support necessary for students to thrive in an academic environment where they are underrepresented and sometimes overlooked. The literature on the importance of social support, particularly for the academic success of ethnic minority and female students in college and STEM disciplines, is extensive. Much of the literature focuses on the support, or lack thereof, that ethnic and gender minority students perceive in their relationships with faculty (e.g., Aluede, Imahe, & Imahe, 2002; Bradburn, 1995; Solarzano, Ceja, & Yosso, 2000; Zeldin & Pajares, 2000).

Solarzano, Ceja, and Yosso (2000) examined the concept of racial microagressions (covert incidences of racially-charged experiences) and the effect these microaggressions had on relationships undergraduate students had with classmates and faculty. The authors found that such incidences created a barrier of discomfort between minority students and many White faculty to the extent that students did not deem faculty to be supportive or approachable when problems and concerns with the course arose. Students also indicated these poor relationships with faculty, combined with microaggressions, instilled feelings of self-doubt about their academic abilities. Similarly, in their study of women in STEM disciplines, Zeldin and Pajares (2000) found that faculty support was linked to women's positive self-efficacy in STEM fields.

Bandura's third source of efficacy expectations, *vicarious experiences*, points to the importance of relevant role models for women and underrepresented students pursuing careers in STEM disciplines. Among the possible relevant models are female and ethnic minority STEM professionals, both in the university classroom and in other spaces in which students might operate (e.g., labs, internship companies, career mentor programs). In examining the relationship between faculty models and students' major choice, Rask and Bailey (2002) found a correlation between the number of women who pursue careers in STEM disciplines and the number of female faculty in these disciplines.

The major contribution of relevant models in STEM is the creation of possible selves for women and underrepresented students (Packard & Nguyen, 2003). High school girls of varying ethnic backgrounds in Packard and Nguyen's (2003) study of the factors influencing students' intended career path indicated that mentoring relationships with women in STEM were influential in their perceived possible selves, making it easier for them to envision themselves pursuing studies in similar areas. Similar results regarding the importance of female mentors and role models have been found in a plethora of studies (e.g., Bettinger & Long, 2005; Cohoon, 2002; Downing, Crosby, & Blake-Beard, 2005) as well as in work addressing role modeling and mentoring for students from underrepresented ethnic groups (Gasbarra & Johnson, 2007; Habrowski & Maton, 2009). Contact with relevant role models can play a role in influencing students' motivation to pursue and complete a course of study that leads to a STEM-related career.

The most oft utilized mentoring model is the expert-protégé model, wherein students interact with faculty and others serving in a mentoring capacity on a one-on-one basis. However, other mentoring models that stem from gender and cultural norms may be used in conjunction with the expert-protégé model to enhance the functionality of the mentoring relationships. For example, in their study of academic persistence of Native American college students, Jackson, Smith, and Hill (2003) found that family support, faculty warmth, and "structured" social support (peer groups, other faculty) were instrumental in students' persistence. These various modes of mentoring indicate the effectiveness of a community style of mentoring for Native American students, as well as for women and students from ethnic backgrounds that emphasize group goals and responsibility over individual expectations (e.g., Gloria & Rodriguez, 2005; Sanchez, Esparza, & Colon, 2008).

Steele and Aronson (1995) proposed the idea of stereotype threat, which is described by Marra, Rodgers, Shen, and Bogue (2009) as "debilitating performance anxiety for individuals who are members of a group for which there is a negative stereotype related to the task" (see also Singletary, Ruggs & Hebl, 2009) Stereotype threat effectively illustrates Bandura's (1977) idea of emotional and*physiological states* as significantly affecting one's self-efficacy. Although originally conceptualized to offer partial explanation of the lower test performance of African Americans compared to students of other racial and ethnic groups, stereotype threat has also been tested and found to be a significant contributor to the academic performance of women and students from underrepresented ethnic backgrounds in STEM disciplines (Bergeron, Block, & Echtenkamp, 2006; Kellow & Jones, 2008; Kiefer & Sekaquaptewa, 2007; Ryan & Ryan, 2005). Thus, the anxiety associated with women's fears that they might confirm the negative stereotypes associated with female achievement in STEM actually hinders their performance on academic tasks. The African American and Hispanic men and women interviewed in Hurtado, Cabrera, Lin, Arellano, and Espinosa's (2008) study of the experiences of underrepresented minority undergraduate students in science expressed concern regarding how their abilities were perceived, both as the result of their participation in minority-focused research programs and the assumptions others made based on their enrollment at minority-serving institutions. For more on stereotype threat, see the ARP series by Singletary, Ruggs & Hebl (2009).

Motivation

In 1983, Eccles, Adler, Futterman, Goff, Kaczala, Meece, and Midley proposed that motivation was the result of an interaction between expectancy for success and task value; symbolically, Motivation = Expectancy x Value. This model is useful when thinking about what influences women and underrepresented students to seek and complete STEM-based college degrees.

Cox and Whaley (2004) state that *expectancy for success* has two components: beliefs about the self and one's perception of the likelihood for success. Rodgers (2008) places the authors' description within an academic realm, describing these components as referring to academic self-concept ("beliefs about the self") and task-specific self-efficacy ("what individuals view as their probability for success at a specific task"). The present discussion will particularly address students' global sense of themselves as mathematicians, scientists, engineers, etc., and what they believe to be their chances of completing a STEM degree at either the undergraduate or graduate level. The previous section addressed students' self-efficacy in STEM and its effects on program involvement and retention, so duplication of that discussion will be avoided here with the focus placed on students' self-concept in STEM.

In his self-concept implementation theory, Super (1953) proposed that in choosing a career path, individuals attempt to coordinate their own self-image with one that is associated with a possible career choice. So, in the context of Eccles et al.'s (1983) model, students' derive their perceptions of themselves as mathematicians, scientists, engineers, etc., at least in part, from the images of existing professionals in those fields.

The Black female high school students who participated in Parsons' (1997) examination of the images Black females held of scientists generally (11 out of 20 participants) described a typical scientist as "an unattractive, funny-looking, middle-aged White man" (p. 757). Such perceptions of scientists may influence female and ethnic minority students' conceptualization of their possible selves, which can negatively affect their perceptions of the likelihood they can succeed in fields dominated by professionals unlike themselves. Their viewpoint also suggests an inherent belief that only "middle-aged White" men complete degrees in science. Such thinking points to external attributions (Weiner, 1979) and creates a convenient "out" when students encounter hurdles during their programs. That is, perceptions of STEM professionals as non-female and non-minority may promote reasoning such as, "My struggles are not due to my lack of effort and commitment to completing my degree but to the likelihood that this degree is not really for people like me."

Lent et al. (2005) applied the tenets of social cognitive theory (Bandura, 1989), which envelops expectancy for success, to a sample of African American engineering students attending two historically Black colleges (HBCU) and one predominantly White institution (PWI). Students attending HBCUs expressed higher self-efficacy, more positive outcome expectations, technical interests, and perceived more social support than did those students attending the predominantly White institution. The authors explain this finding as possibly indicative of an emphasis on same-race mentoring and role-modeling at HBCUs compared to PWIs, suggesting that HBCUs, particularly in STEM fields, may offer African American students an advantage. Seymour (1995) suggested similar experiences among students of different ethnic groups in varying academic environments. For example, in a sample of Latino/a undergraduate students from various disciplines, Gloria, Castellanos, Lopez, and Rosales (2005) found that social support and university comfort were the stronger predictors of non-persistence than student self-beliefs. Gloria and Rodriguez (2000) emphasized the particular importance of Hispanic/Latino mentors for Hispanic/Latino students' academic success and persistence, pointing to the community orientation of many Hispanic cultures.

Eccles et al. (1983) identified four components of *task value*: cost, interest value, utility value, and attainment value. Cost refers to what one must give up in order to pursue a goal or task. Interest value refers to the extrinsic or intrinsic rewards or incentives that one receives as the result of participating in a task (Cox & Whaley, 2004). Utility value and attainment value describe students' perceptions of the usefulness of a task and what one has to gain by completing the task, respectively.

The cost dimension of task value is of particular interest when discussing retention of women and underrepresented students in STEM. The literature on the retention of underrepresented students in college in general has largely pointed to issues related to perceived costs of developing a bicultural identity that allows students to become integrated into the campus (usually predominantly White) culture while also maintaining an identity associated with their particular ethnic group (e.g., Furr & Elling, 2002; Rendon, Jalomo, & Nora, 2001; Rodgers & Summers, 2008; Tinto, 1993; Torres, 2003). Fordham and Ogbu's (1986) conceptualization of "acting White" has been fairly prominent in discussions of Hispanic and African American students' supposed resistance to academic domains in general. This conceptualization has been examined at the college level (e.g., Harper, 2006; Smedley, Myers, & Harrell, 1993) to explain academic achievement, integration, and ultimate retention of these students. Fordham and Ogbu's (1983) theory of "acting White" proposes that some students of color, primarily Black and Hispanic, resist academic achievement because they associate it with acting White. Acting White assumes that academic achievement or pursuing a college education comes at the cost of relinquishing one's ethnic identity. This theory of anti-intellectualism has been challenged. Cokley (2003) cites three studies (Cokley, 2001; Fordham, 1986; Graham, 1997) that he believes are supportive of not only a peaceful coexistence of African American students' academic and ethnic identities, but that also demonstrate higher levels of racial identity are actually conducive for academic achievement.

Narrowing the view from the general college level to retention patterns specifically within STEM disciplines, the impact of *cost* as a contributor to overall motivation and ultimately to retention adopts a different look. Here, it is necessary to consider the characteristics of programs in STEM disciplines, where underrepresented students may perceive costs of participation, including a loss of identity as they attempt to adopt the value system of predominantly male and European fields STEM disciplines are often viewed as competitive; success often depends on standing out from one's peers, sometimes in an aggressive manner. This aggressive characterization is of particular note. Seymour (1995) points to the competitive nature of some STEM disciplines, such as engineering, as one explanation for the loss of women from related programs and careers. Similarly, Gneezy, Niederle, and Rustichini (2003) suggest that as the competitive nature of an environment increases, women's performance decreases while men's performance increases. Despite indicating few barriers to persistence in the first year, by senior year, the female engineering students in Brainard and Carlin's (1998) study indicated feelings of intimidation as being a barrier to their persistence and comfort in their programs. In their examination of the career choices and mobility of a sample of male and female engineers, Robinson and McIlwee (1991) assert that the "culture of engineering" favors men more than women, and the stronger the competitive component of this culture, the more women suffer in their continuing pursuit and success in engineering careers. Indeed, results indicate that the pursuit of a STEM career may come at the cost of relinquishing, at least in part, a more "feminine" approach to academic and career success that emphasizes social interaction and support among classmates and colleagues. A similar assumption can be made about the fit between the "engineering culture" and students from ethnic backgrounds that emphasize collectivistic rather than individualistic goals (Triandis, 1989). African American, Hispanic, Native American, and Asian cultures are among those considered to emphasize group efforts. For more on motivation in STEM, see the ARP series by Beier and Rittmayer (2008) and Rittmayer (2008).

Implications for Policy

The discussion in the previous sections point to several ways in which STEM programs, particularly at the college level, can increase the satisfaction and consequent retention of women and ethnic minority students. Some of these retention methods include:

- Continuation of recruitment efforts directed at female faculty and faculty of color (see Anderson, 1995; Gilmartin, Denson, Li, Bryant, & Aschbacher, 2007; Rutherford, 2008; Sonnert, Fox, & Adkins, 2007; Suresh, 2006).
- Visible and accessible academic support resources (tutoring, lab groups, etc.).
- Structured programs that offer a variety of mentoring opportunities, both one-on-one as well as community-style mentoring that involves students' social systems (faculty, professional mentors, family, etc.; Gloria & Rodriguez, 2005; Sanchez, Esparza, & Colon, 2008).
- Additional financial support, especially important for first generation undergraduate or graduate students (Perna, Lundy-Wagner, Drezner, Gasman, Yoon, et al., 2007).
- Analysis of pedagogical practices that may not be conducive for the learning for women and other underrepresented students (Schull & Weiner, 2002; Uekawa et al., 2007).
- Summer math and science enrichment courses at the undergraduate level to help prepare students for possible success in STEM fields (Tyson, Lee, Borman, & Hanson, 2007).
- Attention to language barriers, especially for American-born students learning English as a second language.
- Culturally-inclusive curricula. For example, seeking to use engineering concepts to solve problems that exist in central American countries, necessitating both students and faculty acquire background knowledge about the target country before solving the problem.

Existing support programs should also receive frequent assessment and revision when necessary.

Directions for Future Research

As we continue to encourage women and students from minority backgrounds to seek careers in STEM disciplines, we need to evolve our methods of examining their experiences and successes in order to meet the needs of this growing, but still small, population in STEM. Due to the small number of women and particularly underrepresented students in STEM, much of the research focused on these populations has been qualitative (e.g., Chinn, 1999; Diangelo, 2006; Johnson, 2007; Robinson & McIlwee, 1991). Such qualitative investigations are useful in that they serve to paint a vivid picture of how women and ethnic minority students experience their STEM programs and thus provide a window into students' experiences and concerns that quantitative research does not allow. However, qualitative research has limitations. Qualitative research lacks generalizability, which limits our ability to look for trends and nuances that may paint a clearer picture of retention needs of special STEM populations.

For example, new quantitative research may investigate self-efficacy or campus climates as they relate to

A Product of SWE-AWE (www.AWEonline.org) and NAE CASEE (www.nae.edu/casee-equity)
NSF Grant #01210642 and #0533520

specific universities, and even as they may relate to particular STEM disciplines (e.g., math versus science versus different engineering specialties). With the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) instrument (Marra, Schuurman, Moore, & Bogue, 2005), Marra and her colleagues are using a multi-institutional approach to garner sufficient quantitative data to investigate a variety of social cognitive factors involved in women and minorities' engineering success and retention. However, many of the researchers gathering quantitative data about STEM students have not utilized instruments geared solely towards students in the sciences. Most have involved popular but not STEM-specific instruments, such as the Multidimensional Multiattributional Causality Scale (Lefcourt, von Baeyer, Ware, & Cox, 1979) to measure attributions of female engineering students (Nauta, Epperson, & Waggoner, 1999). Lent, Brown and Larkin's (1986) self-efficacy for academic milestones measure has also been used to assess self-efficacy among women and students attending historically Black institutions (Lent et al., 2005). The *Journal of Engineering Education Special Report* (2006) identified the need for engineering-specific measures, particularly quantitative measures, as one of the most important elements necessary for the continued progress of engineering (and more largely, STEM) education.

Indeed, the research base would benefit from more research, qualitative or quantitative, on women and ethnically underrepresented students in engineering and other STEM disciplines in general. Specifically, future research on the retention of women and underrepresented students in STEM disciplines should cover several areas:

- Why is the retention of STEM students attending HBCUs higher than predominantly White institutions? How do admissions standards, pedagogy, and climate differ? What is their secret and how can PWIs simulate it?
- What effects do different pedagogical practices/approaches have on persistence? How might STEM pedagogy be adjusted so that it becomes more gender-neutral?
- When women and minorities leave STEM, do they leave school altogether or switch to another discipline? What guides these decisions?
- How effective is inclusiveness training for STEM faculty?
- What makes STEM disciplines such as biology more successful at attracting and retaining women of varying cultural backgrounds than physical sciences in which women are still underrepresented and engineering?
- How might we use what we know about the success of women of varying ethnic backgrounds in STEM, particularly engineering and physical sciences, to design a retention model that can guide retention and academic program development?
- What part does social encouragement from family, faculty, friends, and significant others play in the persistence of women in general and women from underrepresented ethnic backgrounds?

Through these and other investigations, we can continue the ever-evolving process of understanding what guides, excites, and retains women and underrepresented students in STEM disciplines.

References

Aluede, O. O., Imahe, C., & Imahe, J. (2002). University female students' motives in enrolling for non-traditional degrees. *Australian Journal of Career Development, 11*(2), 45–48.

Anderson, V. (1995). Identifying special advising needs of women engineering students. *Journal of College Student Development, 36*, 322–329.

Arnette, R. (2004). *Perspectives: The gender gap in math and science*. Retrieved from http://sciencecareers.sciencemag.org/career_development/previous_issues/articles/2800/perspectives_the_gender_gap_in_math_and_science/parent/158

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review, 84*, 191–215.

Bandura, A. (1989). Social Cognitive Theory. In R. Vasta (Ed.), *Annals of child development, 6*, 1–60. Greenwich, CT: Jai Press.

Bean, J. P., & Eaton, S. B. (2000). A psychological model of college student retention. In J. M. Braxton (Ed.), *Reworking the student departure puzzle* (pp. 48–61). Nashville, TN: Vanderbilt University Press.

Beier, M. E., & Rittmayer, A. D. (2008). Motivational factors in STEM: Interest and academic self-concept. *Applying Research to Practice Resource.* National Academy of Engineering Center for the Advancement of Scholarship on Engineering Education Assessing Women and Men in Engineering (AWE) Project. Retrieved September 14, 2009 from http://www.engr.psu.edu/awe/secured/director/assessment/Literature_Overview/PDF_overviews/ARP_SelfConcept_Overview_122208.pdf

Besterfield-Sacre, M. B., Moreno, M, Shuman, L. J., & Atman, C. J. (2001). Gender and ethnicity differences in freshman engineering student attitudes: A cross-institutional study. *Journal of Engineering Education, 90*, 477–490.

Bergeron, D. M., C. J. Block, & B. A. Echtenkamp. (2006). Disabling the able: Stereotype threat and women's work performance. *Human Performance, 19*, 133–158.

Bettinger, E. P., & Long, B. T. (2005). Do faculty serve as role models? The impact of instructor gender on female students. *American Economic Review, 95*, 152–157.

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education, 17*, 369–386.

Bradburn, E. M. (1995). Engineering gender roles: A self-efficacy model of occupational choice and persistence. *Dissertation Abstracts International Section A: The Humanities and Social Sciences, 55*(7), 2146A.

Brainard, S., & L.Carlin. (1998) A six-year longitudinal study of undergraduate women in engineering and science*. Journal of Engineering Education, 87,* 369–375.

Cabrera, A. F., Nora, A., Terenzini, P. T., Pascarella, E., & Hagedorn, L. S. (1999). Campus racial climate and the adjustment of students to college: A comparison between White students and African-American students. *Journal of Higher Education, 70*, 134–160.

Chinn, P. W. U. (1999). Multiple worlds/mismatched meanings: Barriers to minority women engineers. *Journal of Research in Science Teaching, 36*, 621–636.

Cohoon, J. M. (2002). Recruiting and retaining women in undergraduate computing majors. *ACM SIGCSE Bulletin, 34*(2), 48–52.

Cokley, K. O. (2003). What do we know about the motivation of African American students? Challenging the "Anti-Intellectual" myth. *Harvard Educational Review, 73*, 524–558.

Cokley, K., & Chapman, C. (2008). The roles of ethnic identity, anti-white attitudes and academic self-concept in African American student achievement. *Social Psychology of Education, 11*, 349–365.

Cooper, J. L., & Robinson, P. (2000). The argument for making large classes seem small. *New Directions for Teaching and Learning, 8,* 5-16.

Cox, A. E., & Whaley, D. E. (2004). The influence of task value, expectancies for success, and identity on athletes' achievement behaviors*. Journal of Applied Sport Psychology, 16*, 103–117.

Cronin, C., & Roger, A. (1999). Theorizing progress: Women in science, engineering and technology in higher education. *Journal of Research in Science Teaching, 36*, 637–661.

Diangelo, R. J. (2006). The production of Whiteness in education: Asian international students in a college classroom. *Teachers College Record, 108*, 1983–2000.

de Pillis, E., & de Pillis, L. (2008). Are engineering schools masculine and authoritarian? The mission statements say yes. *Journal of Diversity in Higher Education, 1*, 33–44.

Downing, R. A., Crosby, F. J., & Blake-Beard, S. (2005). The perceived importance of developmental relationships on women undergraduates' pursuit of science. *Psychology of Women Quarterly, 29*, 419–426.

Eccles, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., et al. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motives: Psychological and sociological approaches* (pp. 75–146). San Francisco: W. H. Freeman.

Fenske, R. H., Porter, J. D., & DuBrock, C. P. (2000). Tracking financial aid and persistence of women, minority, and needy students in science, engineering, and mathematics. *Research in Higher Education, 41*, 67–94.

Fordham, S., & Ogbu, J. (1986). Black students' school success: Coping with the "burden of acting White." *Urban Review, 18*, 176–206.

Fuligni, A. J. (2001). Family obligation and the academic motivation of adolescents from Asian, Latin American, and European backgrounds. *New Directions for Child and Adolescent Development, 94,* 61–75.

Furr, S. R., & Elling, T. W. (2002). African-American students in a predominately White university: Factors associated with retention. *College Student Journal, 36*, 188–202.

Gasbarra, P., & Johnson, J. (2008). *Out before the game begins: Hispanic leaders talk about what's needed to bring more Hispanic youngsters into science, technology and math professions.* A Public Agenda Report Prepared for American's Competitiveness: Hispanic Participation in Technology Careers Summit, May 5-6, 2008, Palisades, NY. Retrieved September 14, 2009 from http://www.ibm.com/ibm/ibmgives/downloads/ Out_Before_the_Game_Begins_April_16_2008.pdf

Gilmartin, S., Denson, N., Li, E., Bryant, A., & Aschbacher, P. (2007). Gender ratios in high school science departments: The effect of percent female faculty on multiple dimensions of students' science identities. *Journal of Research in Science Teaching, 44*, 980–1009.

Hanson, S. L. (2004). African American women in science: Experiences from high school through the post-secondary years and beyond. *NWSA Journal, 16*(1), 96–115.

Harper, S. R. (2006). Peer support for African American male college achievement: Beyond internalized racism and the burden of "acting White." *Journal of Men's Studies, 14,* 337–358.

Hurtado, S. H., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2008). The science of diversifying science: Underrepresented minority experiences in structured research programs. Paper presented at the Annual Meeting of the Association for Institutional Researcher, Seattle, WA.

Hurtado, S. H., & Ponjuan, L. (2005). Latino educational outcomes and the campus climate. *Journal of Hispanic Higher Education, 4*, 235–251.

Gloria, A. M., Castellanos, J., Lopez, A. G., & Rosales, R. (2005). An examination of academic nonpersistence decisions of Latino undegraduates. *Hispanic Journal of Behavioral Sciences, 27*, 202–223.

Gloria, A. M., & Rodriguez, E. R. (2000). Counseling Latino university students: Psychosocial cultural issues for consideration. *Journal Counseling and Development, 78*, 145–154.

Gneezy, U., Niederle, M., & Rustichini, A. (2003). Performance in competitive environments: Gender differences. *Quarterly Journal of Economics, 118*, 1049–1074.

Johnson, A. C. (2007). Unintended consequences: How science professors discourage women of color. *Science Education, 91*, 805–821.

Jones, S. E. (2007). Reflections on the lecture: Outmoded medium or instrument of inspiration? *Journal of Further and Higher Education, 31*, 397-406.

Kellow, J. T., & Jones, B. D. (2008). The effects of stereotypes on the achievement gap: Reexamining the academic performance of African American high school students. *Journal of Black Psychology, 34*, 94–120.

Kiefer, A. M., & Sekaquaptewa, D. (2007). Implicit stereotypes and women's math performance: How implicit gender-math stereotypes influence women's susceptibility to stereotype threat. *Journal of Experimental Social Psychology*, *43*, 825–832.

Lent, R. W., Brown, S. D., & Larkin, K. C. (1986). Self-efficacy in the prediction of academic performance and perceived career options. *Journal of Counseling Psychology, 33*, 265–269.

Lent, R. W., Brown, S. D., Sheu, H., Schmidt, J., Brenner, B. R., Gloster, C. S., et al. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students Historically Black Universities. *Journal of Counseling Psychology, 52*, 84–92.

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009). Self-efficacy of women engineering students – Three years of data at U.S. institutions. *Journal of Engineering Education*, *98*, 27-38.

Marra, R. M, Schuurman, R., Moore, C., & Bogue, B. (2005). Women engineering students' self efficacy beliefs – The longitudinal picture. *Proceedings of the Annual Meeting of the American Society for Engineering Education Annual Conference and Exposition*. Portland, OR.

May, G. S., & Chubin, D. E. (2003). A retrospective on undergraduate engineering success for underrepresented minority students. *Journal of Engineering Education, 92*, 27–39.

National Science Foundation, Division of Science Resources Statistics. (2008). *Science and Engineering Degrees: 1966–2006*. Detailed Statistical Tables NSF 08-321. Arlington, VA. Retrieved August 27, 2009, from http://www.nsf.gov/statistics/nsf08321/

National Science Foundation, Division of Science Resources Statistics. (2006). *S&E Degrees, by Race/Ethnicity of Recipients: 1995: 2004*. NSF 07-308. Susan T. Hill and Maurya M. Green, project officers. Arlington, VA.

Nauta, M. M., Epperson, D. L., & Waggoner, K. M. (1999). Perceived causes of success and failure: Are women's attributions related to persistence in engineering majors? *Journal of Research in Science Teaching, 36*, 663–676.

Packard, B. W., & Nguyen, D. (2003). Science career-related possible selves of adolescent girls: A longitudinal study. *Journal of Career Development, 29*, 251–263.

Pajares, F. (1996). Self-efficacy beliefs and mathematical problem-solving of gifted students. *Contemporary Educational Psychology, 21*, 325–344.

Parsons, E. C. (1997). Black high school females' images of the scientist: Expression of culture. *Journal of Research in Science Teaching, 34*, 745–768.

Rask, K. N., & Bailey, E. M. (2002). Are faculty role models? Evidence from major choice in an undergraduate institution. *Journal of Economic Education, 33*, 99–124.

Rendon, L. I., Jalomo, R. E., & Nora, A. (2000). Theoretical considerations in the study of minority student retention in higher education. In J. M. Braxton (Ed.), *Reworking the Student Departure Puzzle* (pp. 127–156). Nashville, TN: Vanderbilt University Press.

Rittmayer, A. D. (2008). Self-efficacy in STEM. *Applying Research to Practice Resource.* National Academy of Engineering Center for the Advancement of Scholarship on Engineering Education Assessing Women and Men in Engineering (AWE) Project. Retrieved from http://www.engr.psu.edu/awe/secured/director/assessment/Literature_Overview/PDF_overviews/ARP_SelfEfficacy_Overview_122208.pdf

Rivera-Mosquera, E., Philips, J. C., Castelino, P., Martin, J. K., & Dobran, E. S. M. (2007). Design and implementation of a grassroots precollege program for Latino youth. *Counseling Psychologist, 35*, 821–839.

Robinson, J. G., & McIlwee, J. S. (1991). Men, women and the culture of engineering. *Sociological Quarterly, 32*, 403–421.

Rodgers, K. A. (2008). Racial identity, centrality and giftedness: An expectancy-value application of motivation in gifted African American students. *Roeper Review, 30*, 111–120.

Rodgers, K. A., & Summers, J. J. (2008). African American students at predominantly White institution: Towards a revised retention model. *Educational Psychology Review, 20*, 171–190.

Rutherford, A. (2008). A century of change: Gender, religion, and science at Mount Holyoke. *Psychology of Women Quarterly, 32*, 343–344.

Ryan, K. E., & Ryan, A. M. (2005). Psychological processes underlying stereotype threat and standardized math test performance. *Educational Psychologist, 40*, 53–63.

Sanchez, B., Esparza, P., & Colon, Y. (2008). Natural mentoring under the microscope: An investigation of mentoring relationships and Latino adolescents' academic performance. *Journal of Community Psychology, 36*, 468–482.

Saville, B. K., Zinn, T. E., Neef, N. A., Van Norman, R., Ferreri, S. J. (2006). A comparison of interteaching and lecture in the college classroom. *Journal of Applied Behavior Analysis, 39*, 49-61.

Shull, P. J., & Weiner, M. (2002). Thinking *inside* the box: Self-efficacy of women in engineering. *International Journal of Engineering Education, 18*, 438–446.

Singletary, S. L. (2009). Stereotype threat: Causes, effects, and remedies. *Applying Research to Practice Resource.* National Academy of Engineering Center for the Advancement of Scholarship on Engineering Education Assessing Women and Men in Engineering (AWE) Project. Retrieved September 14, 2009 from http://www.engr.psu.edu/awe/secured/director/assessment/Literature_Overview/PDF_overviews/ARP_StereotypeThreat_Overview_31909.pdf

Seymour, E. (1995). The loss of women from science, mathematics, and engineering undergraduate majors: An explanatory account. *Science Education, 79*, 437–473.

Smedley, B. D., Myers, H. F., & Harrell, S. P. (1993). Minority-status stresses and the college adjustment of ethnic minority freshmen. *Journal of Higher Education, 64*, 434–452.

Solorzano, D., Ceja, M., & Yosso, T. (2000). Critical race theory, racial microaggressions and campus racial climate: The experiences of African American college students. *Journal of Negro Education, 69*, 60–73.

Sonnert, G., Fox, M. F., & Adkins, K. (2007). Undergraduate women in science and engineering: Effects of faculty, fields, and institutions over time. *Social Science Quarterly, 88*, 1333–1356.

Special Report. (2006). The research agenda for the new discipline of engineering education. *Journal of Engineering Education, 95*, 259–261.

Steele, C. M, & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*, 797–811.

Super, D. E. (1953). A theory of vocational development. *American Psychologist, 8*, 185–190.

Suresh, R. (2006). The relationship between barrier courses and persistence in engineering. *Journal of College Student Retention: Research, Theory and Practice, 8*, 215–239.

Swail, W. S., Redd, K. E., & Perna, L. W. (2003). Retaining minority students in higher education: A framework for success. *ASHE-ERIC Higher Education Report, 30*(2), 43–73.

Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research, 45*, 89–123.

Tinto, V. (1988). Stages of student departure: Reflection on the longitudinal character of student leaving. *Journal of Higher Education, 59*, 438–455.

Tinto, V. (1993). *Leaving college: Rethinking the causes and cures of student attrition.* Chicago: University of Chicago Press.

Torres, V. (2003). Influences on ethnic identity development of Latino college students in the first two years of college. *Journal of College Student Development, 44*, 532–547.

Triandis, H. C. (1989). The self and social behavior in differing cultural contexts. *Psychological Review, 96*, 506–520.

Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, technology, engineering and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment. *Journal of Education for Students Placed at Risk, 12*, 243–270.

Uekawa, K., Borman, K., & Lee, R. (2007). Student engagement in U. S. urban high school mathematics and science classrooms: Findings on social organization, race and ethnicity. *Urban Review, 39*, 1–43.

University of Texas at Austin Women in Engineering Program. (2008). Retrieved November 14, 2008, from http://www.engr.utexas.edu/wep/

VanGennep, A. (1960). *The rites of passage* (trans. M. Vizedon and G. Caffee). Chicago: University of Chicago Press.

Weiner, B. (1979). A theory of motivation for some classroom experiences. *Journal of Educational Psychology, 71*, 3–25.

Zeldin, A., & Pajares, F. (2000). Against the odds: Self-efficacy beliefs of women in mathematics, scientific, and technical careers. *American Educational Research Journal, 37*, 215–246.

A Product of SWE-AWE (www.AWEonline.org) and NAE CASEE (www.nae.edu/casee-equity)
NSF Grant #01210642 and #0533520