



## Literature Overview: Motivational factors in STEM: Interest and Self- Concept



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The achievement gap between men and women in science, technology, engineering, and mathematics (STEM) disciplines in college and graduate study is narrowing, with more women pursuing degrees in STEM. However, the representation of women in STEM-related careers, especially in engineering, is disproportionately low (Halpern et al., 2007). Motivational theories have been relatively unstudied in relation to gender differences in STEM. These theories consider goal choice, intensity of effort, and persistence related to goal attainment. Expectancy-value models of motivation have been used to understand educational choices related to education in STEM (Eccles, 1994; Eccles & Wigfield, 2002). These models consider the values an individual places on different types of activities and the expectations that effort will lead to valued rewards. Two important components of these theories are (a) interest, which is a determinant of the valence components of expectancy-value models, and (b) self-concept, which is a determinant of both interest and expectation of success for a task.

Research shows that gender differences in interest and self-concept (typically assessed with self-report measures) significantly affect the choice to pursue STEM related studies and careers, as well as performance in STEM (Halpern et al., 2007; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Seymour & Hewitt, 1997). The purpose of this literature review is to examine research on gender differences in STEM-related interest and self-concept, to consider the implications of this research, and to provide practitioners with useful information on how to influence interest and self-concept in STEM.

### Interest and Self-Concept Definitions

*Interest judgments* are defined as relatively stable preferences that are focused on objects, activities, or experiences (Hidi, 1990; Schiefele, Krapp, & Winteler, 1992). Greater congruence between one's interests and one's environment leads to greater satisfaction, performance, and persistence in activities (i.e., Achter, Lubinski, Benbow, & Eftekhari-Sanjani, 1999; Ackerman, Bowen, Beier, & Kanfer, 2001; Eccles & Wigfield, 2002; Köller, Baumert, & Schnabel, 2001; Leuwerke, Robbins, Sawyer, & Hovland, 2004; Schaefers, Epperson, & Nauta, 1997; Schiefele et al., 1992). Academic interests direct effort toward learning in a domain (Ackerman, 1996) and are correlated with a multitude of academic and occupational outcomes including course selection, achievement, and persistence in a given field of study or career. In fact, academic interest in a specific domain (e.g., physics, math, English) is correlated with achievement in that domain. For example, students who are interested in computers typically earn better grades and enroll in more computer science classes than students who do not share this interest (Schiefele et al., 1992). Furthermore, loss of interest in STEM fields was the most frequently cited reason that college students gave for switching out of STEM majors (Seymour, 1995).

*Self-concept.* Self-concept is defined as self-perceptions that fundamentally influence behavior (Rosenberg, 1979; Shavelson, Hubner, & Stanton, 1976). Like interest, self-concept is an important indicator of educational choice and achievement (e.g., it predicts course selection and success in secondary and post-secondary education; Eccles, 1994; Guay, LaRose, & Boivin, 2004). Moreover, academic self-concept predicts academic achievement and performance beyond prior achievement and interest (e.g., Bandura, 1997; Marsh et al., 2005).

*Self-concept versus self-efficacy.* Although both self-concept and self-efficacy (a motivational construct also related to academic achievement; Bandura, 1997) involve a judgment of competence within a domain, academic self-concept and self-efficacy are two distinct constructs. Academic self-concept refers to a person's perceptions and knowledge about the self in an academic achievement situation (e.g., I solve math problems easily). Self-concept judgments often include an affective judgment related to how much an individual likes the domain (e.g., I enjoy my science classes; Bong & Skaalvik, 2003). In contrast, self-efficacy is defined as a judgment about one's ability to organize and execute the courses of action necessary to attain a specific goal (e.g., I can successfully solve algebraic equations involving fractions; Bandura, 1997). Self-concept and self-efficacy are related in that individuals will have more self-efficacy for tasks they consider central to their self-concept and for tasks that they enjoy (e.g., Jane will be more confident in her ability to solve algebra problems if she enjoys math and thinks of herself as someone who is good at math; Bong & Skaalvik, 2003).

### **Development of Interest and Self-Concept**

Interest and self-concept are thought to develop through a reciprocal relation with achievement, which can be described in three overall steps. First, achievement in a domain positively influences the development of self-concept in that domain (e.g., I did well in a chemistry class and conclude that I am good at chemistry). This self-concept will, in turn, positively influence interest in that domain (e.g., I'm good at chemistry so I'm interested in taking more chemistry courses). Increased interest will lead to the pursuit of more achievement experiences in the domain, and the cycle will continue (Guay, Marsh, & Boivin, 2003; Marsh et al., 2005; Nagy, Trautwein, Baumert, Köller, & Garrett, 2006).

In addition to interest and achievement, other factors that have been identified as important in the development of self-concept (Skaalvik & Skaalvik, 2002) are:

- (a) Causal attributions: whether students attribute success or failure to their own action, or to external factors or chance. For example, if Mary does well in physics, and attributes her success to her aptitude and hard work, her physics self-concept is more likely to be positively affected than if she were to attribute her success to having an easy instructor.
- (b) Reflected appraisal: how students think others perceive them including peers, family, and role models. For example, Jane is more likely to develop an engineering self-concept if she perceives that her parents think she has an engineer's skill set and temperament.
- (c) External and internal frames of reference. External frames of reference involve comparing one's own abilities with the abilities of peers (e.g., I am a little better at science than Jim). Internal frames of reference involve comparing different abilities within one person. Internal judgments are made independent of judgments based on external frames (e.g., I am better at math than English). Internal and external frames simultaneously influence the development of self-concept. For example, Jane may be a poor math student relative to her peer group (external), but may have a relatively high math self-concept because she perceives that she is better at math than English (internal).

There is empirical support for the importance of external comparisons for the development of STEM-related interest. Specifically, when students perceived that they did not “fit in” with their classmates in STEM courses, interest in the topic was negatively affected (Lee, 1998). Because both boys’ and girls’ interests are influenced by the extent to which they relate to others already in the discipline, the increased presence of female students in the sciences (e.g., with about half of the degrees in some STEM disciplines earned by women) should have a positive influence on girls’ interest in STEM.

### **Gender and Interest in STEM**

Gender differences in academic interests reflect gender stereotypes. Boys indicate more interest in natural science and mathematics relative to other domains; girls are likely to endorse language arts and humanities as interesting (Ackerman et al., 2001; also see review and meta-analysis by Schiefele et al., 1992). These findings are pervasive even when comparing interests of the most gifted male and female students. A study tracking middle school students with exceptional math or verbal abilities found that, 10 years later, women were significantly more likely than men to indicate an interest in humanities and social sciences, whereas men were more likely to indicate an interest in mathematics (Lubinski, Webb, Morelock, & Benbow, 2001).

Gender differences in vocational interests are also pervasive, and echo those found in academic domains. Women are more likely to express interest in people-oriented careers (social professions, such as nurse or teacher), and men are more likely to express interest in careers such as engineer or computer programmer (Holland, 1996; Lippa, 1998, 2005). These gender differences in vocational interests are reflected in the actual number of men versus women in these different occupations: there are proportionally more male engineers and proportionally more female teachers and social workers (Lackland & DeLisi, 2001).

### **Gender and Self-Concept in STEM**

Similar to interests, research shows that there are gender differences in STEM self-concept. Boys show greater self-concept and interest in STEM domains relative to girls (Achter, Lubinski, Benbow, & Eftekhari-Sanjani, 1999; Ackerman et al., 2001; Simpkins, Davis-Kean, & Eccles, 2006; Watt, 2006). Within STEM fields, there are also gender differences in self-concept. Girls and women are more likely to have self-concepts aligned with biology and the study of medicine, and boys and men are more likely to have self-concepts aligned with engineering, math, and physics (Lee, 1998). These differences fall along gender stereotypic lines: boys and men express interest for physical and computer sciences, and girls and women express interest in more “people oriented” STEM fields, such as biology and medicine.

Research also shows that STEM self-concept is more stable through middle to high school for boys than it is for girls (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002). One possible explanation for this finding is that girls and women have a tendency to excel across academic domains regardless of interest level. Indeed, research shows that girls and women are likely to have roughly equal verbal and math abilities, whereas men are likely to have higher math abilities than verbal abilities (Halpern et al., 2007). Although a balanced ability profile may be an advantage for many tasks, the breadth of women’s abilities relative to men’s will potentially negatively affect their self-concept and interest in STEM disciplines (due to internal frames of reference; e.g., I am better at English than science). Alternatively men’s more narrow ability profile, when aligned with STEM-related fields, will serve to strengthen their interest and self-concept in STEM. Closer examination of the frames of reference that influence the development of self-concept is provided below.

*External frames of reference.* Academic self-concept is influenced by a students’ relative standing compared to others in the same class or school. Specifically, self-concept is negatively related to the

average achievement of others. This effect has been termed the “Big Fish Little Pond Effect” (BFLPE; Marsh, 1990) and has been found in numerous studies of different types of school systems and cultures (see Marsh, Kong, & Hau, 2001, and Marsh & Hau, 2003, for a review). As an example, consider two students with the same level of achievement in two different schools: one school with a high average ability level and another with a low average ability level. The student in the high-achieving school may be below average in ability relative to others in her school, whereas the student in the low-achieving school may be above average. The BFLPE predicts, and research has shown, that being in the high-achieving school would negatively influence the student’s academic-self concept, whereas being in the low-achieving school would positively influence it.

Studies on BFLPE have not explicitly examined gender differences, but this effect is potentially important for explaining gender differences in STEM self-concept. For example, research shows that girls may be more negatively influenced by poor grades in middle and high school than boys (Simpkins et al., 2006). In practice, this research finding means that girls’ self-concepts may be more negatively affected relative to boys by the lower grades all students might receive when coursework becomes more difficult (e.g., in advanced STEM tracks in high school).

Furthermore, the loss of women from STEM fields in college might be explained by changes in self-concept due to women’s sensitivity to grades and BFLPE. For example, first year college students may experience being academically average compared to their peers for the very first time in their lives. The “weed out” culture (where only the strongest survive) in many introductory STEM courses in college may impact women’s self-concept more negatively than men’s (Seymour, 1995).

The decline of STEM self-concept may be exacerbated if women have positive social and educational experiences in disciplines outside of STEM. Given that women have more balanced ability profiles than men, positive experiences outside of STEM (such as achievement or finding social connections with others in non-STEM disciplines) may be more likely for women than it is for men. For reasons elaborated below, these positive experiences will potentially shift women’s self-concept toward a non-STEM discipline. Indeed, finding an academic aptitude or interest outside of STEM was the second most common reason women in college gave for switching out of STEM behind losing interest in STEM fields (Seymour, 1995).

*Internal frames of reference.* Although individuals’ academic achievement in different areas is usually highly correlated, domain-specific self-concepts are not (Marsh, 1990). This suggests that students develop domain-specific self-concepts based on internal judgments about their relative abilities across domains. Furthermore, these relationships suggest (and empirical research supports, Marsh & Hau, 2004) that within a person, achievement in one domain negatively affects self-concept in another. In an international study of school achievement and self-concept in math and verbal domains, Marsh and Hau found that, within people, achievement in the domain of mathematics negatively affected verbal self-concept. Similarly, achievement in verbal domains negatively affected math self-concept.

## **Interventions to Increase Interest and Self-Concept in STEM**

*Classroom Management and Quality of Instruction.* Research shows that student perceptions of classroom management are positively related to interest in the course. Math courses perceived by students to be structured and well-organized led to student interest, autonomy, and competence (Kunter, Baumert, & Köller, 2007; Seymour & Hewitt, 1997). These findings suggest that a relatively straightforward intervention to increase student interest in STEM would be to ensure that instructors receive adequate training, not only to develop content expertise, but also to structure their lessons and manage their classrooms effectively.

Structure and class management may be especially important in STEM disciplines because the complexity of the material requires the students to focus their attention to achieve, and achievement is important in the development of self-concept and interest.

Research has also shown that instructors can greatly influence self-concept and interest by fostering an open and interactive learning environment. A study of university engineering students found that both men and women experienced greater self-concept and interest when engineering instructors fostered an environment where students felt safe to ask questions and interact versus environments where interaction was not the norm and where students felt intimidated to ask questions (Vogt, 2008). Students in open environments may get to know their instructors and peers, who may become influential role models. Moreover, open learning environments are likely to foster more realistic judgments about relative ability. For example, if I know others have questions similar to mine, I might judge my skills more favorably than if I think I am the only one with questions.

*Involvement in Research.* Achievement in a domain is an important determinant of domain-specific interest and self-concept. As such, providing students with achievement experiences in STEM will influence STEM related interest and self-concept. Qualitative research on the effect of undergraduate research experiences in STEM suggests that this is indeed the case (Hunter, Laursen, & Seymour, 2006). Interviews with both faculty member sponsors and undergraduates involved in STEM research revealed that involvement in research was instrumental in getting students to start thinking like scientists and thinking of themselves as scientists (i.e., developing a scientist self-concept; Hunter et al., 2006). This involvement provided students with confidence that they could conduct independent research and succeed in the profession, thereby increasing self-concept and interest in the field.

*Interest in Material and Classroom Composition.* Häussler and Hoffmann (2002) designed an intervention to increase self-concept and interest in physics for German girls in middle school. The intervention used new material thought to be interesting across gender and manipulated the composition of the classes such that some classes were half the size of others, and some were composed of same-sex students. Although overall interest in physics declined for all students throughout the year, the decline was much steeper for those students (both boys and girls) enrolled in the larger coed classes. Those students in the smaller classes did not report as steep a decline in interest over the year. Moreover, those in the same-sex classes experienced the lowest decline in interest.

These results suggest that interventions designed to engage students can influence the development of self-concept and interest in STEM. Additionally, these authors found that same-sex environments had an overall positive influence on girls' development of interest in science, perhaps because both boys and girls were more likely to feel they "fit in" with their peer students. However, the study's authors caution that same-sex environments may not be as effective without educational interventions that focus on increasing interest in science (Häussler & Hoffmann, 2002).

*Interventions Outside of the Classroom.* Jayaratne, Thomas, and Trautmann (2003) assessed the effects of a science immersion camp for girls in middle school that provided achievement experiences in science (laboratory work) and exposure to role models (women working in STEM). Participants in the program were compared with a control group of applicants who did not participate, measuring self-concept and interest both immediately after the camp and again at the end of high school (five to six years later). Immediately after the camp there were no differences observed in science self-concept or interest for girls who participated in the program and those who did not. However, at the end of high school, women who

participated in the program reported higher science self-concept and interest in science activities than women who were not participants in the science immersion camp. This suggests that those who participated in the camp were perhaps more likely than non-campers to seek out additional STEM experiences after camp leading to increased interest and self-concept in STEM throughout high school.

*External Frames of Reference.* BFLPE suggests that the academic self-concept of high-achieving students will be negatively affected when they are “tracked” into high-achieving cohorts, or take relatively demanding courses with other high-achieving students. This effect also suggests that the academic self-concept of low-achieving students will be positively affected when they are placed in low-achieving cohorts, or select easier courses in high school. Recent research has compared the effects of the BFLPE and academic “tracking” on self-concept (Trautwein, Ludtke, Marsh, Köller, & Baumert, 2006). Results demonstrated that the boost in self-concept from being put in the highest track was not greater than the decrement in self-concept this group experienced due to BFLPE. Similarly, the negative effect of self-concept related to being placed in the lowest performing cohort did not offset the increase in self-concept experienced by the lowest performing cohort due to the BFLPE. Although this research highlights the importance of peer groups for the development of self-concept, the differences in the amount each track learned at the end of the term was not examined. Furthermore, it does not shed light on the potential issues associated with developing a self-concept that is inaccurate in terms of actual ability. Research shows that a self-concept that is unwarranted relative to ability level (e.g., Jack has developed a solid science self-concept in a low performing cohort) may lead to eventual disappointment when the individual goes from a “small pond” to a larger one (Forsyth, Lawrence, Burnette, & Baumeister, 2007; Pintrich, 2003).

### **Implications and Recommendations for Practitioners**

Research on interventions suggests that practitioners can influence the development of STEM interest and self-concept. Some implications and recommendations for influencing the development of interest and self-concept in STEM are discussed below.

- Achievement in a domain is essential for the development of both interest and self-concept in that domain. Accordingly, practitioners should incorporate achievement opportunities in STEM, especially for girls and women (e.g., encouraging students to participate in laboratory research, incorporating hands-on laboratory experiences into classroom activities).
- Student achievement in STEM that is recognized and rewarded will foster interest and self-concept in STEM.
- The development of interest and self-concept in STEM is a function of perceptions of influential others such as parents and role models. These influential figures can let children know that they are perceived to have the skills and temperament necessary for STEM.
- A well-managed classroom, where STEM material is targeted toward the interests of both girls and boys, will potentially increase achievement, self-concept, and interest in STEM.
- Classrooms where students feel free to ask questions and interact with instructors will foster interest and self-concept in STEM. In-class activities that require interaction between instructors and students will help foster open learning environments.
- Classroom environments where students feel they “fit” will also increase self-concept and interest in STEM. Providing forums where students develop relationships with one another (e.g., small group work) may serve to increase sense of belongingness while, at the same time, providing students additional peer support.

Research on internal and external frames of reference paints a potentially confusing picture of how to bolster self-concept. Because self-concept is negatively influenced by the achievement of peers, should practitioners recommend that high achieving students not enroll in difficult courses with other talented students? Likewise, because achievement in one area negatively influences self-concept in another, should practitioners interested in bolstering STEM self-concept discourage achievement in any area other than STEM? These solutions seem neither logical nor warranted. Rather, awareness of the influence of external and internal comparisons on self-concept leads to the following recommendations:

- Bolster the STEM self-concept of students taking difficult courses (or in a high achieving track) by discouraging competition in the classroom.
- Inform students about when they have achieved in STEM and encourage perspective-taking to discouraged students (e.g., reminding students of the complexity and difficulty of the material).
- A solid STEM self-concept may also make achievement outside of STEM less likely to affect STEM self-concept negatively. For example, students who perceive that others see them as a scientist (i.e., reflected appraisal) may be less likely to abandon science when they excel in another area. Providing opportunities to solidify students' STEM self-concepts through science clubs, extracurricular research, or other such activities will make achievement in areas outside of STEM less threatening to the STEM self-concept.

### Areas for Future Research

The past decade has seen a proliferation of research recognizing the importance of both interest and self-concept in the choices to pursue certain goals (e.g., educational or occupational) and achievement toward reaching those goals. Much of this research has focused on the development of interest and self-concept. Simultaneously, there has been a proliferation of research on both motivational and ability related gender differences in STEM. Combining these streams of research raises a number of questions for future exploration:

- How does the development of self-concept differ for boys and girls? Although we may understand the trajectories of self-concept for many domains, we do not understand whether or not self-concept and interest develop differently for boys versus girls. For example, do boys or girls weigh judgments made through external and internal frames differently? Are girls and boys differentially influenced by people they consider to be important? Findings in this area would permit the development of tailored interventions aimed at increasing academic self-concept and interest for both boys and girls.
- How do educational transitions influence interest and self-concept? Although much research in the past five years has focused on external frames of reference and BFLPE, this research has not specifically examined the effects of an educational transition on self-concept and interest. For example, do students who are high achievers at relatively average high schools experience a decline in self-concept when transitioning to a more competitive college or is self-concept relatively well preserved through transitions? Do educational transitions affect men and women differently? Examination of these questions would help tailor interventions to occur when student interest and self-concept are most vulnerable.

In sum, interest and self-concept are especially important in STEM disciplines – gender differences are found, favoring men, for both STEM-related self-concept and interest. Future research will likely further inform practitioners about how to positively influence STEM related interest and self-concept across genders and cultures.

(For a practice-oriented guide on this topic or other ARP Resources, go to: <http://www.AWEonline.org/ARPResources.aspx>)

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