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A Review of Psychosocial Factors Associated with Undergraduate Engagement and Retention in STEM

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Abstract

Low retention rates of undergraduate students in science, technology, engineering, and math (STEM) fields is a persistent problem in the United States (U.S.), with the U.S. lagging behind many countries in producing a sufficient number of STEM graduates. A better understanding of the barriers that result in students dropping out of STEM fields is essential for increasing engagement and retention of STEM undergraduate students. In this regard, a growing body of research demonstrates that psychosocial factors such as STEM self-efficacy, sense of belonging, intelligence beliefs, and grit are associated with STEM outcomes such as engagement and retention. In this review paper we examine how these key psychosocial variables (STEM self-efficacy, sense of belonging, intelligence beliefs, and grit) impact engagement and retention of undergraduate STEM students. An introduction to each of these factors is given, major work in the field is discussed, and typical instruments used to assess or measure these factors are described. It is hoped that this review may form the foundation of larger studies seeking to understand how nurturing and supporting these psychosocial factors may help support retention of undergraduate STEM students, particularly from those student populations underrepresented in the STEM fields.

Introduction

Low retention rates of undergraduate students in science, technology, engineering, and math (STEM) fields is a persistent problem in the United States (U.S.). The U.S. lags behind many countries in producing a sufficient number of STEM graduates. For example, the U.S. awarded roughly 800,000 science and engineering undergraduate degrees compared to the EU's 1 million degrees and China's 1.7 million degrees in 2016 (NSB, 2020). By 2025, the U.S. is projected to be short 2 million STEM workers (National Science Foundation, 2018). A better understanding of the barriers that result in students disconnecting or dropping out of STEM fields is essential for increasing engagement and retention of STEM undergraduate students.

There is a growing demand for skilled STEM workers in both the United States and around the world. However, despite this growing need for a skilled STEM workforce, there is a high attrition rate among STEM undergraduate students, with 48% of students leaving their STEM fields (Chen, 2013). Leaving a STEM field may involve either changing to a non-STEM major or leaving college altogether. Students may decide to leave a STEM field for a variety of reasons. A burgeoning area of research has narrowed in on better understanding how various social and psychological (psychosocial) factors may affect students and their desire to stay within or exit STEM fields. For example, past research has identified specific stereotypes about STEM as contributing to retention issues (Shin et al., 2016). More specifically, stereotypes that frame STEM skill as an innate talent (as opposed to a learned skill) are associated with students leaving STEM (Bages & Martinot, 2011; Dweck, 2006; Hong & Lin-Siegler, 2012; Leslie et al., 2015; Shin et al., 2016). This stereotype builds from a common perception that being skilled in STEM is innate or an inborn trait. As such, this belief can imply that success in STEM should "come

easy" and if it does not come easy, it implicitly implies that student is not cut out for a rigorous career in STEM (Shin et al., 2016). Thus, if a student struggles in STEM, the student may perceive their difficulties as indicative of their incompatibility with STEM, as the material "should be easy" if STEM capacity is perceived to be innate.

In this review paper, we explore how certain key psychosocial variables can impact STEM student engagement and retention. By synthesizing past empirical research, we will demonstrate why understanding and measuring psychosocial variables is an important piece of information when the goal is to increase student engagement and retention. We focus on four psychosocial variables shown in experimental and/or correlational research to have an impact on STEM outcomes. These four psychosocial variables are: 1) STEM self-efficacy, 2) sense of belonging, 3) intelligence beliefs, 4) and grit, all of which have been shown to impact engagement and retention of undergraduate STEM students (Good et al., 2012; Leslie et al., 2015; Lytle & Shin, 2020).

STEM Self-Efficacy

Self-efficacy is the psychological belief that one has the ability to successfully accomplish a given task (Bandura, 1997). Decades of research illustrate that self-efficacy can enhance accomplishments and personal well-being and has emerged as an important predictor of academic outcomes such as motivation and goal orientations (Multon et al., 1991; Usher et al., 2019; Zimmerman, 2000). Within the realm of STEM, if a student believes they can succeed in their STEM classes, this refers to their sense of STEM self-efficacy. STEM self-efficacy has been identified as a contributor of reluctance to pursue a STEM educational path or career (Borgen & Betz, 2008; van Aalderen-Smeets, van der Molen, Xenidou, 2018). According to Bandura (1997), a strong sense of self-efficacy can enhance accomplishments and personal well-being in a multitude of different ways. This premise aligns with the research as self-efficacy has emerged as an important predictor of academic outcomes such as motivation, major satisfaction, and goal orientations (Chen & Tutwiller, 2017; Komarraju, Swanson, & Nadler, 2014). Among STEM students, self-efficacy predicts engagement, recruitment, and retention of STEM students (Lent et al., 2003; Wang, 2013).

STEM self-efficacy is often measured using a modified 5-item scale originally created by Midgley et al. (2000) as a measure of academic self-efficacy. Participants answer on a 1 (*Strongly Disagree*) to 7 (*Strongly Agree*) scale with sample items that include: "I can do almost all the work in my STEM classes if I don't give up" and "I am certain I can figure out how to do the most difficult class work in STEM." This scale has been used in recent empirical work characterizing how psychosocial variables influences STEM outcomes (Lytle & Shin, 2020; Shin et al., 2016).

Sense of Belonging

For decades, psychologists have viewed the sense of belonging as a key to human motivation (Baumeister & Leary, 1995). A sense of belonging refers to the idea that one fits in and belongs and may be applied to variety of settings and situations. Having a sense of belonging is associated with a host of positive outcomes such as perceiving that one's life is meaningful. This

fundamental human motivation is another key predictor of academic engagement. As such, much of the research has focused on undergraduate students' sense of belonging at their university (Apriceno et al., 2020; Hoffman et al., 2002).

Specific to STEM, a substantial body of empirical research examines how sense of belonging impacts key outcomes such as engagement and retention (Rosenthal et al., 2011; Yeager et al., 2016). For example, a sense of belonging predicts intentions to pursue a STEM discipline (Good et al., 2012), whereas a lack of belonging has been associated with students' decision to leave STEM. In an experiment designed to address retention among underrepresented first year undergraduates, Yeager and colleagues (2016) utilized a social belonging intervention. The intervention was designed to

> "dispel the misperception that only certain students (e.g., disadvantaged students) experience difficulty and question their belonging in college. It conveys that almost everyone worries at first. Further, the intervention shows how students can overcome these challenges with time" (Yeager et al, 2016).

As a result of this intervention, full-time enrollment rates and grade point averages increased (Yeager et al., 2016). In an experiment investigating the relationship between sense of belonging and gender bias in STEM, U.S. women (as compared to U.S. men) reported less belonging and lower aspirations to participate in STEM when exposed to STEM gender bias. Interestingly, these gender differences disappeared when participants were told that STEM promotes gender equality (Moss-Racusin et al., 2018). In another study, exposure to role models had a positive impact on sense of belonging among STEM students (Shin et al., 2016). As a whole, sense of belonging is a key predictor of STEM outcomes such as engagement and retention.

Sense of belonging is often measured using an established 12-item measure (Mendoza-Denton et al., 2002), in which participants rated their comfort on a scale from 1 (*I do not feel comfortable*) to 10 (*I feel comfortable*). Example items include "How comfortable do you feel at your university?" and "How do you feel about your peers and classmates?" A more specific STEM sense of belonging measure (Good et al., 2012) includes sample items such as "I feel that I belong to the STEM community" and "I consider myself a member of the STEM world" on a 1 to 7 scale.

Intelligence Beliefs

Individuals hold different theories about intelligence beliefs; whereas some view intelligence as unchangeable or fixed (entity theory), others view intelligence as malleable, something that can change and develop over time (incremental theory; Dweck, 1999; Yeager & Dweck, 2012). Decades of research illustrate that individuals with a fixed view of intelligence (entity theory) tend to view academic setbacks as indicative of a lack of intelligence, whereas individuals with a growth mindset (incremental beliefs) are more likely to view academic setbacks as a challenge and an opportunity to improve (Blackwell et al., 2007; Dweck, 2013; Good et al., 2012).

One's intelligence beliefs have important implications for academic performance. For example, promoting a growth mindset among STEM students was associated with lower rates of dropout

among STEM undergraduate students. An increase in incremental beliefs was linked with lower rates of dropping out of STEM among students in a biology course (Dai and Cromley, 2014). Similarly, among undergraduate students in an algebra course, those who endorsed greater incremental beliefs at the start of the semester reported more help seeking behavior at the end of the semester. This increase in help seeking behavior suggests that endorsement of incremental beliefs may promote resilience (Shively & Ryan, 2013). In another study greater endorsement of incremental beliefs influenced key predictors of STEM interest and engagement among first-year undergraduate STEM students (Lytle & Shin, 2020).

Growing research suggests that a student's own beliefs about intelligence, perceptions of the degree of other student's malleable or fixed intelligence, student perceptions of their educators' beliefs, and their educators' actual intelligence beliefs all play a role in STEM outcomes. For example, ninth-grade students described women's intelligence as less malleable than men's intelligence. Believing that women's intelligence is less malleable had implications for how student's perceived effort among students, such that women who worked hard were perceived as having a lower ability of success (Verniers & Martinot, 2015). Students who perceive that their educators endorse more fixed mindset beliefs both anticipate and actually experience greater psychological vulnerability. This psychological vulnerability translates into a host of immediate negative outcomes (e.g., less belonging in class, greater negative affect) and long-term effects such as less class engagement and lower grades (Muenks et al., 2020). Yeager and colleagues (2019) found that educators' endorsement of a growth mindset impacted student outcomes. As the research on intelligence beliefs continues to expand beyond the realm of the individual's belief, this psychosocial variable is an important one to consider and examine when interested in better understanding student outcomes.

Intelligence beliefs are often measured with an 8-item measure developed by Dweck (2000). Sample items include "To be honest, you can't really change how intelligent you are" and "You have a certain amount of intelligence, and you really can't do much to change it" on a 1 (*Strongly Disagree*) to 6 (*Strongly Agree*) scale.

Grit

Grit is perseverance and passion for long-term goals (Duckworth et al., 2007). As one of the newer concepts detailed in this review paper, grit has generated enthusiasm among researchers interested in examining predictors of academic achievements. In their original research, Duckworth and colleagues (2007) reported that grit accounted for 4% of the variance in educational outcomes among diverse groups such as undergraduates from elite universities and National Spelling Bee contestants. Above and beyond some of the traditional predictors of educational outcomes such as IQ, self-control, and conscientiousness, grit emerged as a stronger predictor of outcomes (Duckworth et al., 2007; Duckworth & Gross, 2014). This growing body of research suggests that grit represents a unique construct and taps into something not captured by other traditional predictors of academic success (Duckworth et al., 2009).

In recent years, grit has also emerged as a predictor of STEM outcomes with a focus on interventions that promote a growth mindset among both students and educators. For example, individuals high in grit were able to maintain interest in their courses and consistent interest in

STEM (Hunter, 2020). In a study assessing data from 12,000 undergraduates across many different institutions of higher education in the United States, grit was significantly associated with both GPA and engagement (Fosnacht et al., 2019).

A shortened 8-item measure grit scale, developed Duckworth and Quinn (2009), includes sample items such as "I am a hard worker" and "I often set a goal but later choose to pursue a different one" (reverse scored) on a 1 (*Very much like me*) to 5 (*Not at all like me*) scale.

Discussion

STEM knowledge and skills are in growing demand in the United States and across the world. However, it has been predicted that the U.S. will fall short, by more than 1 million individuals, of the needed STEM workers by 2024 (Varas, 2016). To meet the demands of the 21st century, a better understanding of how to recruit, engage, and retain students in STEM is essential.

As an example, the four psychosocial variables (STEM self-efficacy, sense of belonging, intelligence beliefs, and grit) highlighted in this review paper illustrate how important social and psychological factors are in tackling the problems of engaging and retaining STEM students. Other proposed approaches, such as tracking and fostering the development of adaptive expertise in undergraduate students which is believed to help students apply the content knowledge learned in their classes in practice, have also been proposed as a means to support undergraduate STEM student resilience in their studies (Fisher & Peterson 2001, Fisher & De Rosa, 2021). What appears to be clear is that a better understanding of how psychosocial factors influence student retention will enable the development of carefully designed and targeted interventions, both inside and outside of the classroom, to support these psychosocial factors and the resilience of STEM students in pursuing their undergraduate studies.

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