Increasing College Students' Interest and Engagement in STEM:

A Comparison of Strategies for Challenging STEM Stereotypes

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Abstract of the Dissertation

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Increasing science, technology, engineering, and mathematics (STEM) graduates has become an important part of the education agenda in the U.S. in recent years. Stereotypes about STEM (i.e., belief that STEM abilities are innate, and that European American men are best suited for STEM) have been identified as one of the critical factors that may contribute to low recruitment and retention of STEM students. Drawing from the literatures on biological essentialism and role models, this study compared different strategies for challenging STEM stereotypes among undergraduate students in STEM and non-STEM fields. STEM stereotypes were challenged directly with research articles that provided non-biological explanations for STEM success and interest (a strategy used in the essentialism research) and indirectly with biographies of successful STEM role models who are underrepresented in their field and who succeeded through hard work (a strategy used in the role model research). Contrary to the predictions, exposure to the role model biographies, research articles, or combination of both did not have statistically significant effects on participants' reported STEM interest and academic intentions. Possible explanations for the lack of significant findings as well as suggestions for developing effective interventions to promote STEM engagement among students are discussed.

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Introduction

Science, technology, engineering, and mathematics (STEM) fields have become vital to the nation's innovation, economic growth, and competitiveness. Despite the significant need for a skilled STEM workforce, the supply of U.S. STEM students does not and will not meet the projections of growth in these industries. According to the National Center for Education Statistics, only 28 percent of students choose a bachelor's degree in STEM, with only 2 and 3 percent of students choosing fields in mathematics and physical sciences, respectively (Chen, 2013), rates that are well-below what is necessary to meet the demands of a growing STEM need. An additional critical concern is the high attrition rate among STEM students, with 48 percent of bachelor's degree students leaving STEM fields by changing to a non-STEM major or exiting college altogether (Chen, 2013). According to the President's Council of Advisors on Science and Technology (PCAST), a 10% increase in the retention rate of STEM students would result in meeting 75% of the 1 million additional needed STEM graduates (PCAST, 2012).

The lack of STEM students in the education pipeline is further exacerbated by the persistent underrepresentation of women and historically underrepresented racial/ethnic groups such as African Americans and Latinos in many STEM fields. For example, women make up less than 20% of bachelor's degree graduates in computer science, physics, and engineering, and African American and Latino students each make up less than 10% of bachelor's degree graduates in these fields (NSF, 2015). The representation of both groups represents significant underrepresentation compared to their prevalence in the general population.

To address the STEM workforce shortage, it is important to examine factors that both encourage students to consider pursuing STEM fields *and* sustain interest among existing STEM students, with additional attention given to the large untapped talent pool of female, African

American, and Latino students. Stereotypes about STEM have been identified as one of the critical factors that may contribute to low recruitment and retention of STEM students (Good, Rattan, & Dweck, 2012; Hong & Lin-Siegler, 2012; Leslie, Cimpian, Meyer, & Freeland, 2015). For example, the belief that innate abilities are required for STEM success discourages some students, particularly those who are viewed as lacking innate STEM abilities such as women and African American and Latino students, from pursuing STEM degrees (Leslie et al., 2015). Further, the lack of gender and racial diversity of STEM professionals at high levels of achievement may also signal to women and underrepresented race/ethnic groups that STEM fields are most well-suited for European American men (e.g., McGee & Martin, 2011; Stout, Dasgupta, Hungsinger, & McManus, 2011).

Investigating strategies that challenge the stereotypes about STEM abilities and STEM professionals that affect students' interest and persistence in STEM, including underrepresented students, seems to be a fruitful avenue for producing more STEM graduates. In this study, I focused on two commonly held stereotypes about STEM success: the belief that STEM abilities are innate and the belief that certain groups (European American men) are best suited for STEM, and systematically tested strategies for challenging those stereotypes in an experimental intervention study.

STEM Stereotype: STEM Abilities are Innate

In the United States, there is a prevalent belief that STEM abilities are innate talents that have a biological basis, especially in fields such as math, physics, engineering, and computer science (Bartholomew, Darragh, Ell, & Saunders, 2011; Leslie et al., 2015). Take for example, Albert Einstein, who is known as one of the greatest physicists of all time. Researchers have been studying Einstein's brain for years to seek biological explanations for his extraordinary accomplishments (Falk, Lepore, & Noe, 2012), and yet the significant contributions of Einstein's personal, psychological characteristics such as his dedication to hard work and persistence in the face of challenges, which are critical factors associated with obtaining expertise and success (Ericsson, Krampe, & Tesch-Romer, 1993) are often overlooked or not discussed.

The belief that STEM abilities are biologically based or innate can have negative effects on students' engagement and performance in STEM (e.g., Bages & Martinot, 2011; Dweck, 2006; Hong & Lin-Siegler, 2012; Leslie et al., 2015). For instance, priming fifth grade students to perceive an advanced math student's success as a result of being gifted, rather than through hard work, decreased students' subsequent math performance (Bages & Martinot, 2011). This belief that innate abilities are required for STEM success can discourage *any* student from considering pursuing and persisting in a STEM field if one believes that s/he does not possess the "gene" for STEM. Any challenges students face in STEM courses may signal to them that they aren't naturally gifted in STEM and therefore shouldn't pursue a STEM career. Further, some students may believe that they don't have the "STEM gene" if they have to work hard and put a lot of effort into their work since hard work can be perceived as an indication of a lack of innate talent (e.g., Cho & Schwarz, 2008; Mendick, 2005; Tsay & Banaji, 2011). Together, the belief about STEM abilities being innate can discourage students from pursuing a STEM career as well as discourage those already in STEM from persisting in the field.

Although the stereotype of STEM abilities being innate can affect any student, certain groups of students (e.g., female, African American, and Latino) may be more vulnerable to the effects of this stereotype than others, given that they are historically stereotyped as lacking innate talents in STEM (e.g., Dar-Nimrod & Heine, 2006; Good, Aronson, & Harder, 2008; Good et al., 2012; Spencer, Steele, & Quinn, 1999; Steele, 1997). Leslie and her colleagues (2015) found that the underrepresentation of female and African American students are most severe in fields where innate talents are most valued and viewed as critical to success (e.g., math, physics, computer science, and engineering). Similarly, among undergraduate women taking college calculus, those who perceived negative gender stereotyping in their math environment reported lower sense of belonging in math. This was only true if they perceived that their math environment endorsed the belief that math intelligence is innate and fixed (Good et al., 2012), thus supporting the hypothesis that stereotypes about innate STEM abilities can be a barrier for individuals who do not fit into this stereotype.

STEM Stereotype: Only European American Men belong in STEM

Another stereotype that is particularly detrimental to female, African American, and Latino students is the stereotype that one particular group (i.e., European American men) belongs in STEM. Successful STEM professionals are often depicted as European American men (Barman, 1997; Bodzin & Gehringer, 2001; McGee & Martin, 2011; Thomas, Henley, & Snell, 2006). Equating STEM with European American males threatens female and African American and Latino students' performance and identity in STEM (Eccles, 1987; Good et al., 2012; London, Rosenthal, Levy, & Lobel, 2011; Nosek et al., 2009; Rosenthal, London, Levy, & Lobel, 2011; Settles, 2004; Settles, Jellison, & Pratt-Hyatt, 2009; Spencer et al., 1999; Steele, 1997). For instance, activating the stereotype that STEM is for men by presenting a STEM conference video depicting a low number of female conference attendees decreased women's sense of belonging and interest in participating in the conference (Murphy, Steele, & Gross, 2007). Even subtle cues that are typically associated with male interests in a STEM environment (e.g., a Star Trek poster, comics) activate the stereotype that STEM is for men and reduces women's interest and identification in STEM (Cheryan, Plaut, Davies, & Steele, 2009). These studies suggest that the stereotype that only European American men belong in STEM discourages underrepresented groups from pursuing STEM, thereby hindering STEM recruitment.

Because European American men are perceived to fit the stereotype of a successful STEM professional, female, African American, and Latino students who are negatively stereotyped in STEM may perceive their gender or racial identity to be not compatible with STEM, leading them to disengage from STEM (e.g., London et al., 2011; Settles, 2004; Settles et al., 2009). For example, when students perceive that their identity (e.g., as a woman) is incompatible with their STEM field, they report lower sense of belonging in STEM, less motivation, and greater sense of insecurity in STEM, and ultimately greater expectations of dropping out of STEM (London et al., 2011). Hence, the stereotype that successful STEM professionals are typically European American men may contribute to the attrition of underrepresented STEM students who do not fit the stereotype.

In sum, two prevalent stereotypes about STEM discussed above appear to be barriers for recruiting and retaining students in STEM. The stereotype that STEM abilities are biologically based can be a barrier for any individual student who does not fit the stereotype as well as individuals from negatively stigmatized social groups (female, African American, and Latino students), whereas the stereotype that only European American men possess innate STEM abilities and succeed in STEM can be an additional barrier for female, African American, and Latino students. Taken together, research suggests that one promising way to address recruitment and retention issues in STEM is by challenging these stereotypes.

Understanding the origins of the two STEM stereotypes may provide insight into strategies for challenging the stereotypes that discourage students, including underrepresented students from pursuing and persisting in STEM. Drawing from the literatures on biological essentialism, discrimination, and socialization, the following sections review the origins of these two stereotypes.

Biological Essentialism

Biological essentialism is one of the components of psychological essentialism that explains human behaviors and attributes in terms of biology and genetics (Bastian & Haslam, 2006; Dar-Nimrod & Heine, 2011; Keller, 2005). From the perspective of biological essentialism, individual traits, such as personality have a biological basis that is predetermined. Intelligence is one of the traits that is often perceived in light of biological essentialism (Dar-Nimrod & Heine, 2011). People commonly believe that there is a one-to-one correspondence between genes and intelligence. That is, environmental influences on intelligence are often ignored or de-emphasized with greater emphasis placed on the roles of genes on intelligence. Group differences are also explained in terms of genetics, thus perceiving men and women, and different racial/ethnic groups to be inherently different from each other (Bem, 1993; Dar-Nimrod & Heine 2011, for review). For example, from the essentialist view, women are genetically predetermined to be nurturing and emotional while men are naturally independent and analytical (Gaunt, 2006).

Dar-Nimrod and Heine (2011) state that biological essentialist bias leads people to perceive 1) outcomes as immutable and predetermined, 2) behaviors/traits to be caused by genes, 3) groups that share the same genetic foundations as homogenous, and 4) outcomes as natural and thus leading people to be more accepting of the outcome. The first three arguments made by Dar-Nimrod and Heine (2011) are key in explaining the origins of STEM stereotypes. In the case of STEM fields, the first and second arguments suggest that success in STEM is caused by genetic predispositions that cannot be changed, and thus devaluing the effects of environmental, personal, or psychological factors that may contribute to STEM success. This belief leads to the stereotype that STEM abilities and success have a biological basis, which can diminish the interest of any students who do not believe that they have the required genetic foundations for STEM success.

The third argument made by Dar-Nimrod and Heine (2011) suggests that STEM success is determined by whether a member of a group is believed to be genetically superior in STEM abilities, indicating that groups who do not share the same genetic foundation as the genetically superior group cannot obtain STEM success. This belief leads to the stereotype that only European American men possess natural STEM abilities, and thereby discouraging female, African American, and Latino students from pursuing and persisting in STEM.

Although it has not been studied in the context of STEM, research on biological essentialism suggests that endorsement of biological essentialism is associated with gender and racial stereotyping in the academic and career contexts (e.g., “African Americans are unintelligent”) (Keller, 2005). For instance, women who endorse a biological basis for gender differences are more likely to endorse negative stereotypical feminine traits (e.g., gullible) than those who believe that environmental factors are responsible for gender differences (Coleman & Hong, 2008). This evidence suggests that STEM stereotypes may have originated from the ideology that individual as well as group differences in traits and abilities are biologically based.

Taken together, theoretical and empirical work on biological essentialism provide an explanation for the origins of the stereotype about innate STEM abilities as well as stereotype about European American men in STEM. The literature on discrimination and socialization provides additional explanations for the stereotype about European American men's innate abilities and success in STEM.

Discrimination and Socialization

Women and African Americans have a long history of being the target of discrimination and prejudice (Allport, 1954). It was not until *Brown vs. Board of Education* ruling (1954), that African American students had equal opportunities for education as European American students. However, even after the desegregation of schools, discrimination against African American students still remained. Until the 1960s, African American students pursuing higher education mostly attended predominantly black colleges (Gurin & Epps, 1975). Women were also deprived of equal opportunities for education (Clarke, 1873). For example, Dr. Vera Rubin, a renowned astronomer who was the first to find evidence of the existence of dark matter, was rejected from graduate program in astronomy at Princeton because the institution did not accept women in their astronomy program at the time, and this policy was not abandoned until 1975 (Soter & Tyson, 2011).

As illustrated in the previous paragraph, white privilege or male privilege in the U.S., especially in the educational and organizational contexts, are deeply rooted in history and continue to persist (Nelson, 2005; Whitley & Kite, 2010). The wage gap between European Americans and African Americans/Latinos continues to exist as well as the gender wage gap (Bureau of Labor Statistics, 2014; 2015). Also, considerable gender and racial gaps in Nobel Prize recognition are present in physics and chemistry, with the majority of the Nobel Laureates being European American men (Nobel Foundation, 2015). This evidence suggests that greater educational and occupational opportunities for European American men and greater recognition of their STEM accomplishments may contribute to overrepresentation of this group in STEM fields, thereby promoting the stereotype that European American men are more suitable for STEM.

Socialization also plays a role in emphasizing the positive stereotype about European American men with STEM (Eccles, 1983; 1987; Eccles, Jacobs, & Harold, 1990). Parents and adults in children's environment (e.g., teachers) as well as mass media (e.g., television, movies, books) communicate gender role expectations that shape children's attitudes surrounding gender roles (Eccles et al., 1990). Boys are more encouraged and given more opportunities to engage in stereotypical masculine activities (e.g., building blocks), while girls are encouraged and given more opportunities to engage in stereotypical feminine activities (e.g., playing with dolls). Parents and teachers often hold gender beliefs about STEM, which affect students' attitudes toward and performance in STEM (Gunderson, Ramirez, Levine, & Beilock, 2012 for a review; Yee & Eccles, 1988). For instance, parents who hold stereotypical beliefs about math (i.e., men are more talented than women in math) perceive their sons to have higher math abilities than daughters, which in turn affects children's perception of their math abilities (Tiedemann, 2000). These early experiences of socialization and expectations encourage women to pursue more traditional educational programs and occupations (e.g., nursing), while discouraging them from pursuing non-traditional fields like STEM, thereby contributing to numeric disparity in STEM participation (Eccles, 1994 for a review).

Therefore, historically rooted discrimination against women, African Americans, and Latinos as well as socialization contribute to the numerical dominance of European American men in STEM, which consequently promotes the stereotype that European American men are more suitable for STEM.

In summary, the literatures on biological essentialism, discrimination, and socialization provide explanations for the origins of the two STEM stereotypes that discourage students from pursuing and persisting in STEM. To increase STEM recruitment and retention, it is therefore crucial to challenge the STEM stereotypes that can be a barrier for all students, including female, African American, and Latino students.

Challenging STEM Stereotypes: Informational Approach

The literature on biological essentialism suggests an effective way to challenge these stereotypes by directly providing information that challenges the belief in a one-to-one correspondence between genes and intelligence. Previous studies have primed people to either endorse or reject biological essentialism (Brescoll, Uhlmann, & Newman, 2013; Chao, Hong, & Chiu, 2013; Coleman & Hong, 2008; Dar-Nimrod & Heine, 2006; Kraus & Keltner, 2013; No, Hong, Liao, Lee, Wood, & Chao, 2008; Williams & Eberhardt, 2008). In these studies, biological essentialism was primed by presenting research that provided evidence for the biological basis for social groups and group differences in traits, while anti-essentialism articles presented research that found no or insignificant evidence for the biological basis for group differences and/or presented research that support non-biological influence (i.e., societal, environmental influence) on group differences. Findings suggest that priming the anti-essentialism ideology had positive effects on various gender and racial attitudes (e.g., Chao et al., 2013; Coleman & Hong, 2008). For instance, women who were presented with an article that argued that gender characteristics and differences originate primarily from social factors were less likely to endorse negative feminine traits (e.g., gullible) and faster to reject stereotypical feminine traits as self-descriptive than those presented with an article supporting a biological basis for gender characteristics and differences (Coleman & Hong, 2008).

In the STEM context, Dar-Nimrod and Heine (2006) found that women exposed to anti-essentialism information outperformed women exposed to an article supporting the biological basis for gender differences on a math test. Findings from Dar-Nimrod and Heine (2006) along with other studies from the biological essentialism literature (e.g., Brescoll et al., 2013; Chao et al., 2013; Coleman & Hong, 2008; Kraus & Keltner, 2013; No et al., 2008; Williams & Eberhardt, 2008), suggest that essentialism beliefs can be challenged through a relatively brief presentation of research findings that do not support innate theory and can have positive effects on people's attitudes and beliefs. However, most of the studies on essentialism have focused on attitudes towards and prejudice against various social groups (e.g., race, gender, socioeconomic status), and there is generally a lack of research in the context of STEM. To my knowledge, the Dar-Nimrod and Heine (2006) study is the only study that focuses on STEM issues. However, this study focuses specifically on gender differences in math performance and recruited only female undergraduate students and has not extended to studying STEM interests among all students, which I addressed in this study.

In the current study, I aimed to apply strategies used in the biological essentialism research to challenge the two STEM stereotypes by directly downplaying the role of biology and genetics in the development of STEM abilities, while emphasizing the contributions of the non-biological factors for STEM success (e.g., socialization) using research articles to increase STEM interest among STEM and non-STEM students, including female, African American, and Latino students.

Challenging STEM Stereotypes: Biographical Approach

The literature on role models suggests another effective way to challenge the stereotypes about innate STEM abilities and associating European American men with STEM (Hong & Lin-

Siegler, 2012; Marx & Ko, 2012; Marx & Roman, 2002; McIntyre, Paulson, & Lord, 2003; Rosenthal, Levy, London, Lobel, & Bazile, 2013; Shin, Levy, & London, 2016; Stout et al., 2011; Young, Rudman, Buettner, & McLean, 2013). Role models—successful exemplars who demonstrated recognizable achievements and accomplishments in a field-- have been studied among women and African American and Latino students, who often lack or have limited exposure to role models from their own group in their field (e.g., Bages & Martinot, 2011; Cheryan, Drury, & Vichayapai, 2013; Dasgupta & Asgari, 2004; Klopfenstein, 2005; Marx, Ko, & Friedman, 2009; Marx & Ko, 2012; Marx & Roman, 2002; McIntyre et al., 2003; Stout et al., 2011; Young et al., 2013). These studies aimed to challenge the negative stereotypes associated with underrepresented groups (e.g., women in non-traditional fields) by providing successful exemplars in a field (e.g., female engineer) to undergraduate students in STEM (e.g., Stout et al., 2011), undergraduate students not in the target STEM field (i.e., computer science in Cheryan et al., 2013), and school-aged children (Bages & Martinot, 2011). Findings show that exposure to counter-stereotypic role models (e.g., female engineer) via direct contact (e.g., Stout et al., 2011) or indirect contact, such as through biographies has positive effects on students' academic performance in the stereotyped domain (e.g., math for women; standardized exam for African Americans) as well as interest, attitudes, engagement, and identification in those fields (e.g., Marx et al., 2009; Rosenthal et al., 2013; Shin, Levy, & London, 2016). For instance, exposure to successful female physicians from diverse backgrounds through biographies increased female pre-med students' perceptions of fit between their gender and being in pre-med, sense of belonging in pre-med, and interest in a career in medicine (Rosenthal et al., 2013).

Other studies used role models to challenge the biological explanation for success with elementary school (Bages & Martinot, 2011), junior high school (Good, Aronson, & Inzlicht, 2003), and high school students (Hong & Lin-Siegler, 2012). For example, a study with high school students showed that among students with lower initial interest in science, exposure to biographical information of prominent scientists (e.g., Newton) that discussed how the scientists' personal, social, and intellectual struggles led to their accomplishments, had a positive effect on students' interest in physics lessons. This finding highlights the positive effects of challenging the STEM stereotypes through role models on recruitment of previously marginally interested students into STEM.

A recent study (Shin et al., 2016) extended the research on role models by uniquely challenging both the stereotype about innateness of STEM abilities and the stereotype associating European American men with STEM with undergraduate students in STEM and non-STEM students, as these stereotypes can discourage non-STEM students from considering pursuing STEM and STEM students from persisting in STEM. In this study, participants were exposed to six biographies of successful underrepresented professionals in STEM (e.g., African American professor in biology) whose success was attributed to hard work, persistence, and commitment, thereby emphasizing the non-biological explanations for STEM success. Also, importance of social support, another non-biological explanation for STEM success, which has been identified in the literature as an important facilitator of STEM success especially among underrepresented groups (London et al., 2011; Rosenthal et al., 2011) was emphasized in these biographies. Findings show that both STEM and non-STEM students exposed to such role models reported higher interest in STEM and greater perceived compatibility between their identity as an individual and as a STEM member compared to participants who had no role model exposure.

In addition to promoting STEM interest and identity among students, Shin et al. (2016) found that exposure to underrepresented role model biographies had a significant effect on promoting positive attitudes towards various racial groups (e.g., African Americans) among European American students. In the biographies, accomplishments of the underrepresented role models were highlighted as well as how they overcame the academic and social struggles through hard work and persistence. Therefore, exposure to positive, admirable information about non-European American role models (e.g., African American) promoted positive racial attitudes among European American students toward various racial groups. This is a novel finding in the role model literature that was followed up on in the current work. It is worthwhile to note that this finding is consistent with findings in the broader intergroup relations literature. That is, past research shows that exposure to positive exemplars promotes positive racial attitudes and reduces stereotyping among European Americans (e.g., Columb & Plant, 2011; Dasgupta & Greenwald, 2001; Plant et al., 2009).

Study Overview

Drawing from the literatures on stereotyping, biological essentialism, and role models, I compared various strategies to challenge two commonly held stereotypes about STEM success (the belief that STEM abilities are innate and the belief that European American men are best suited for STEM) as a means to increase and sustain STEM interests among STEM and non-STEM students, including underrepresented groups (i.e., women, African Americans/Latinos). The essentialism manipulations used in previous studies were adopted (e.g., Dar-Nimrod & Heine, 2006), in which participants were presented with research findings that challenge the stereotype that innate abilities are central to STEM success and that European American men have innate STEM abilities. The biographies of successful STEM underrepresented role models used in a previous study were adopted (Shin et al., 2016); these biographies focus on success through hard work and challenge the stereotypes that European American men are best suited for STEM and that STEM abilities are innate. To compare and contrast the biographical approach used in the role model literature and the informational approach used in the essentialism literature, participants were randomly assigned to the following conditions: *Condition 1*: biography only condition; *Condition 2*: information only condition; *Condition 3*: combination condition (biography and information); and *control condition*. Participants in the biography only condition were presented with the biographies of diverse STEM role models who succeeded through hard work, thereby indirectly challenging the two common stereotypes. Participants in the information only condition were presented with research findings that there is no biological basis for STEM talents and that STEM interest and success are due to non-biological factors (e.g., socialization), thereby directly challenging the two STEM stereotypes. Participants in the combination condition were presented with both the biographies and the research findings. Lastly, participants in the control condition were presented with neutral passages about vacuum cleaners.

To examine the effectiveness of the manipulations, this study examined STEM-related academic outcome variables that have been identified in the previous studies as being relevant to recruiting and retaining STEM students, including interest in STEM (Rosenthal et al., 2013, Shin et al., 2016), perceived identity compatibility in STEM (London et al., 2011), STEM self-efficacy (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011), intention to take STEM courses (Good et al., 2012), and expectations of dropping out of STEM (Rosenthal et al., 2011). Although the experimental manipulations focused specifically on STEM issues, discussion of academic experiences and abilities in the experimental passages were expected to have a positive impact on students' general academic sense of belonging as evidenced in previous work (Shin et al., 2016) and thus academic sense of belonging was also examined. Additionally, participants' feelings toward various social groups who are underrepresented in STEM, including African Americans, Latinos, and women in non-traditional fields were measured using the feeling thermometer scale (Wolsko, Park, Judd, & Wittenbrink, 2000).

Hypotheses

Hypothesis 1**:** Given that STEM stereotypes are barriers for recruitment of non-STEM students into STEM and retention of current STEM students, I hypothesized that the three experimental conditions (biography only condition, information only condition, combination condition) would have positive effects on both STEM and non-STEM students' STEM interest, perceived identity compatibility between self and STEM, STEM self-efficacy, intention to take courses in STEM, and academic sense of belonging, as well as lower expectations of dropping out of STEM compared to those in the control condition. This is consistent with past research showing that exposure to positive role models who challenged the STEM stereotypes promoted positive STEM-related and general academic outcomes for both STEM and non-STEM students (Shin et al., 2016).

Hypothesis 2: More specifically, the biography only condition and the information only condition were hypothesized to have similar effects on participants as they both challenged the two STEM stereotypes. However, given that the combination condition challenged the STEM stereotypes both indirectly through biographies and directly through research articles, this condition was hypothesized to have the strongest effect of all conditions.

Hypotheses 3a-b: Given that the role models in the biography only condition and the combination condition were from underrepresented racial/ethnic groups (e.g., women and/or

African American/Latino) and that the research articles in the information only condition and the combination condition provided non-biological explanation for racial and gender differences in STEM representation and performance, these three experimental conditions were hypothesized to have positive effects that are specific to women (Hypothesis 3a) and African American and Latino samples (Hypothesis 3b). Since women, African Americans, and Latinos are stereotyped as not fitting in STEM and may have lower perceived fit between STEM and their stereotyped identity, it was expected that exposure to these manipulations would increase their perceived identity compatibility between STEM and the stereotyped identity (i.e., being a woman, being an African American or Latino), whereas men and European Americans would not benefit from the manipulations as they should already have higher levels of perceived fit in STEM given their historical numeric dominance in STEM fields and positive STEM stereotypes (e.g., London et al., 2011; Settles, 2004; Steele, 1997). Consistent with Hypothesis 2, the combination condition was expected to yield the strongest effect since STEM stereotypes were challenged indirectly with biographies and directly with research articles.

Hypotheses 4a-b: Since the female and racially underrepresented role models were portrayed in a positive way in the biographies and their underrepresentation and achievement gap were explained in the research articles, experimental conditions were hypothesized to promote positive attitudes toward these groups (Hypothesis 4a: African American and Latino; Hypothesis 4b: women in STEM). More specifically, it was hypothesized that the European American sample in the experimental conditions would show more positive attitudes to African Americans and Latinos (Hypothesis 4a) and that men in the experimental conditions would show more positive attitudes towards women in STEM (Hypothesis 4b) than those in the control condition.

Consistent with previous hypotheses regarding differences among the experimental conditions, the combination condition was hypothesized to have the strongest effect.

Target Population

Undergraduate students in both STEM and non-STEM disciplines were recruited for this study. Past research in this area such as the role model study (Shin et al., 2016) in which this study is partly based on, for example, only included a sample from a psychology subject pool, which included mostly non-STEM majors. Studying both STEM and non-STEM college samples is crucial given that producing more qualified STEM workforce requires both recruiting more undergraduate students into STEM and retaining existing STEM students (PCAST, 2012). Therefore, both STEM and non-STEM students are important targets of STEM interventions. Also, the undergraduate years are a critical period where dramatic psychological developments occur, including integration of identities, internalization of beliefs and values as well as intellectual development (Blimling, 2010). According to Chickering's theory of psychosocial development in college students, establishment of identity occurs throughout life but is especially critical during the college years. Further, students make career and vocational plans during college years (Chickering & Reisser, 1993), thus making this period ideal for testing and implementing interventions for increasing and establishing STEM interest and identity.

Studying undergraduate students at all stages of college years from first to fourth year is important given that students decide to pursue a major in STEM not only during the first year in college but at any time point in college (Chen, 2013). For instance, in math and physical sciences, less than 40% of students decide their major during their first year in college and more than 60% of students choose a major field after their first year. In biological/life sciences and computer/information sciences, a little over 50% of students choose their major during their first year in college, while in engineering and technologies, more than 70% of students choose their major during their first year (Chen, 2013). Further, in many universities, including the institution where this study was conducted, students are not required to declare a major in their first year of college and the overlapping course requirements across majors in many universities allow students to easily change majors throughout college. Therefore, it is important to target all undergraduate students.

Method

Participants and Procedure

A total of 1311 (62.9% women; 34.7% men) students from both STEM (37.0%) and non-STEM (59.4%) fields at Stony Brook University were recruited through the psychology subject pool (78.3%) as well as various STEM courses (e.g., math; 21.7%). The sample was diverse in terms of race/ethnicity (37.2% European American, 36.8% Asian, 10.2% Latino/Hispanic, 8.9% African American, 4.4% mixed/other race, .1% Native American/American Indian/Alaskan Native) and year in school (first year: 25%, second year: 32.1%, third year: 21.4%, fourth year: 16.6%, other: 1.9%). Both samples were invited to participate in an online study which involved completing a brief 5-minute pretest survey followed by a presentation of either one of the three experimental passages: biography only condition (which indirectly challenged the STEM stereotypes through role model biographies), information only condition (which directly challenged the STEM stereotypes through research articles), combination condition (which included a combination of information from the two other conditions), or the control passages (neutral passages about vacuum cleaners) and a 10-15 minute posttest survey. The biography only condition included four of the six biographies from Shin et al. (2016), and the information condition included four research articles that were either adapted from previous essentialism research (e.g., Brescoll et al., 2013; Dar-Nimrod & Heine, 2006) or created for this study. The combination condition included four biographies from the biography only condition and four research articles from the information only condition. The control condition included four neutral passages about vacuum cleaners. All the surveys and the passages were presented via *Qualtrics*, a widely used online survey software. The study was described to participants as an online study about reading comprehension to somewhat mask the true purpose of the study.

For participants recruited through the psychology subject pool, a link to the survey website was posted on the subject pool website, SONA, whereas participants recruited from STEM courses received the link in an email invitation. If participants agreed to participate, participants were asked to complete a brief 5-minute pretest survey, which included a measure of STEM interest, non-STEM interest, and academic sense of belonging. Participants were then randomly assigned to one of the three experimental conditions or the control condition, and were asked to read a series of passages. Immediately after the presentation of the passages, a 10-15 minute posttest survey was given, which included manipulation checks (measure of perceived importance of social support for STEM success, importance of hard work for STEM success, and measure of anti-essentialism beliefs for all participants; questions about perceptions of the role models for the biography only condition and the combination condition and a question about credibility of the research articles for the information only condition and the combination condition), as well as major study measures (STEM interest, non-STEM interest, perceived identity compatibility between self and STEM, perceived identity compatibility between self and non-STEM, STEM self-efficacy, intention to take STEM courses, intention to take non-STEM courses, academic sense of belonging, and expectations of dropping out of STEM), additional study measures (perceived identity compatibility between gender and STEM, perceived identity compatibility between gender and non-STEM, perceived identity compatibility between race and STEM, perceived identity compatibility between race and non-STEM, feelings toward different racial groups and women in non-traditional fields), and demographic questionnaire (age, gender, race/ethnicity, major, undergraduate GPA, and SAT) . After the completion of the study, participants were debriefed about the true purpose of the study by receiving debriefing information on *Qualtrics*.

Measures

Pretest and posttest measures.

STEM interest. A 4-item measure of STEM interest (Shin et al., 2016) was used to measure students' interest (e.g., "How interested are you in pursuing a career in STEM?") and excitement for STEM majors and careers (e.g., "How do you feel about a major in STEM?"). Participants responded on a 7-point scale ranging from 1 (*not at all interested/ not at all excited*) to 7 (*highly interested/ highly excited*) (Pretest: $\alpha = .96$; Posttest: $\alpha = .97$).

Non-STEM interest. A 4-item measure of non-STEM interest (Shin et al., 2016) was used to measure participants' interest (e.g., "How interested are you in pursuing a career in non-STEM?") and excitement for non-STEM majors and careers ("How do you feel about a major in non-STEM?"). Participants responded on a 7-point scale ranging from 1 (*not at all interested/ not at all excited*) to 7 (*highly interested/ highly excited*) (Pretest: $\alpha = .95$; Posttest: $\alpha = .96$).

Academic sense of belonging. The academic sense of belonging scale used in Shin et al. (2016), which has been adapted from the Affective Commitment Scale (Allen & Meyer, 1990) was used to measure participants' sense of belonging in their academic environment. Two items measured sense of belonging in one's major (e.g., "I feel a strong sense of belonging to others in my major or field of study"), 2 items measured sense of belonging in one's department/program (e.g., "I feel a strong sense of belonging to my department/program"), and last 2 items measured sense of belonging in one's school (e.g., "I feel a strong sense of belonging to my school"). Participants responded on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) (Pretest: $\alpha = .90$; Posttest: $\alpha = .92$).

Additional posttest measures.

Self/STEM perceived identity compatibility. Modified version of the 1-item pictorial Inclusion of Others in Self (IOS) scale (Aron, Aron, & Smollan, 1992) used for measuring participants' perceived identity compatibility between self and being in STEM (Shin et al., 2016) was used. Participants chose a picture that best illustrated the compatibility between their two identities (self and STEM) from a set of 7 Venn diagrams that vary in the extent to which they overlap. Response ranged from 1 (*indicating less compatibility between self and STEM*) to 7 (*indicating greater compatibility between self and STEM*).

Self/non-STEM perceived identity compatibility. Modified IOS scale (Aron et al., 1992) used in Shin et al. (2016) was used to measure participants' perceived compatibility between self and being in non-STEM. Response ranged from 1 (*indicating less compatibility between self and non-STEM*) to 7 (*indicating greater compatibility between self and non-STEM*).

Gender/STEM perceived identity compatibility. Modified IOS scale (Aron et al., 1992) used for measuring perceived identity compatibility between one's gender and being in STEM (Ahlqvist, London, & Rosenthal, 2013; London et al., 2011; Rosenthal et al., 2013; Shin et al., 2016) was used. Response ranged from 1 (*indicating less compatibility between gender and STEM*) to 7 (*indicating greater compatibility between gender and STEM*).

Gender/non-STEM perceived identity compatibility. Modified IOS scale (Aron et al., 1992) used for measuring gender/STEM perceived identity compatibility (e.g., Shin et al., 2016) was modified to measure perceived identity compatibility between one's gender and being in non-STEM. Response ranged from 1 (*indicating less compatibility between gender and non-STEM*) to 7 (*indicating greater compatibility between gender and non-STEM*).

Race/STEM perceived identity compatibility. Modified IOS scale (Aron et al., 1992) was used to measure perceived identity compatibility between one's race and being in STEM. Response ranged from 1 (*indicating less compatibility between race and STEM*) to 7 (*indicating greater compatibility between race and STEM*).

Race/non-STEM perceived identity compatibility. Modified IOS scale (Aron et al., 1992) was used to measure perceived identity compatibility between one's race and being in non-STEM. Response ranged from 1 (*indicating less compatibility between race and non-STEM*) to 7 (*indicating great compatibility between race and non-STEM*).

STEM efficacy. A 5-item measure of academic self-efficacy (Shin et al., 2016) adapted from Midgley et al. (2000) was modified to measure participants' self-efficacy in STEM classes (e.g., "I am certain I can master the skills taught in STEM classes this year"). Participants responded on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) (α = .96).

Intent to take STEM courses. Intent to Pursue Math Scale (Good et al., 2012) was modified to measure participants' intention of taking STEM courses in the future. Items included, "How likely are you to take a math or statistics class in the future?" and "How likely are you to take a science class in the future?". Participants responded on a 7-point scale ranging from 1 (*very unlikely*) to 7 (*very likely*).

Intent to take non-STEM courses. Intent to Pursue Math Scale (Good et al., 2012) was modified to measure participants' intention of taking non-STEM courses in the future. Items included, "How likely are you to take a business class in the future?" and "How likely are you to take a humanities class (e.g., English, literature, cultural studies) in the future?". Participants responded on a 7-point scale ranging from 1 (*very unlikely*) to 7 (*very likely*).

Expectations of dropping out of STEM. A single item measure of expectations of dropping out of one's major (Rosenthal et al., 2011) was modified to measure STEM participants' expectations of dropping out of STEM ("I may consider dropping out of STEM before graduating"). Participants responded on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Feelings toward various social groups. The feeling thermometer scale (Wolsko et al., 2000) was used to measure participants' feelings toward various social groups, including African Americans, Latino Americans, and women in non-traditional fields (e.g., engineering). Participants responded on a scale ranging from 0° (*cold*/*unfavorable*) to 100° (*warm*/*favorable*). To measure European Americans' feelings towards African Americans and Latino Americans, European Americans' feelings toward each group were subtracted from their feelings toward their own racial group to calculate European Americans' ingroup bias against African Americans or Latino Americans. No such calculation was made to measure participants' feelings toward women in non-traditional fields.

Demographics. Participants reported their age, gender, race/ethnicity, field of study, and past academic achievement (e.g., SAT, undergraduate GPA).

Recognition test. To examine whether participants read the passages and also to fit with the cover story of a reading comprehension study, participants were asked questions about the passages they read. For the biography only condition and the information only condition, three multiple-choice or true/false questions about the passages were asked to examine whether participants read and remembered the passages. A total of six questions from the biography only condition and the information only condition were included in the combination condition. For the biographies in the biography only condition and the combination condition, questions included: “What was the race of the surgeon at Mount Sinai Hospital?”, “What was the undergraduate major of the UX designer at Google?”, and “At which institution did these four individuals obtain their undergraduate degrees?”. For the research articles in the information only condition and the combination condition, questions included: “The first article, ‘Expectations are responsible for gender differences in science abilities, researchers say’ states that using FMRI, DNA analyzers, and messenger RNA blockers, researchers failed to find any gender or racial differences in science abilities. True/False”, “In the third article, ‘Environmental factors are responsible for underrepresentation of women and racial minorities in engineering’ Dr. Patel found that ________affect(s) people’s career decision in engineering”, and “In the last article, ‘No genetic basis for computer or technology related skills’ a nationwide longitudinal study with 10,000 children showed that participation in computer and technology courses and workshops increased children’s knowledge in these areas as well as their interest in pursuing a career in computer or technology related fields. True/False.” For the neutral passages in the control condition, questions included: “According to the passage, which is NOT one of the advantages of handheld vacuum cleaners?”, “According to the passage, one of the disadvantages of ______ vacuum cleaners is the cost of purchase and maintenance” and “According to the passage, while upright vacuum cleaners are suitable for cleaning a variety of surfaces from hardwood floors to carpets, they are not effective in cleaning corners and hard to reach places because of their size. True/False.”

Manipulation checks. Manipulation checks were included to test whether participants’ beliefs about STEM abilities and success were influenced by the experimental manipulations.

Two items assessed participants' beliefs about the importance of social support (e.g., "Success in STEM cannot be achieved without the support of family, friends, classmates, or professors") and 2 items assessed beliefs about the importance of hard work, persistence, and commitment in STEM success (e.g., "STEM success is determined by one's hard work, persistence, and commitment") to examine whether the biographies in the biography only condition and the combination condition influenced participants' beliefs about hard work and social support for STEM success. Responses ranged from 1 (*strongly disagree*) to 7 (*strongly agree*). To examine whether the research articles in the information only condition and the combination condition influenced participants' beliefs about the biological basis for STEM abilities, 4 modified items from the Belief in Genetic Determinism scale (Keller, 2005) were used (e.g., "Genetic predispositions have no influence whatsoever on the development of STEM abilities"). Responses ranged from 1 (*strongly disagree*) to 7 (*strongly agree*) with greater agreement indicating anti-essentialism beliefs. Additional manipulation checks were included to assess participants' perceptions of the role models in the biography only condition and the combination condition. Consistent with past research (e.g., Rosenthal et al., 2013; Shin et al., 2016) participants rated role model biographies' perceived relevance ("How relevant to you did you find the 4 profiles that you read about?"), similarity ("How similar do you think you are to the 4 people you read about?"), and how inspiring the role models were ("How inspiring are the 4 people you read about?"). Additionally, participants rated role models' competence ("How competent do the 4 people you read about seem?"), likeability of the role models ("How likable are these 4 people?"), and obtainability of the role models' success ("How likely do you think that you could accomplish what the 4 people you read about have accomplished?"). Responses ranged from 1 (*not at all relevant/ not at all similar/ not at all inspiring/ not at all competent/ not* *very likable/ not at all likely*) to 10 (*completely relevant/ completely similar/ completely inspiring/ completely competent/ very likable/ completely likely*). An additional manipulation check was included to assess the credibility/believability of the information presented in the research articles ("How credible are the research findings presented in these articles?") with responses ranging from 1 (*not at all credible*) to 7 (*highly credible*).

Results

Recognition Test

On average, participants in all four conditions performed well on the recognition test, answering a majority of the questions correctly (biography only: M = 86.7%, information only: M = 78.8%; combination: M = 81.2%, control: M = 78.8%). Participants who did not complete this test or did not answer any question correctly, which were 2% of the sample, were excluded from all subsequent analyses. A total of 1284 participants were included in the analyses.

Manipulation Check

Manipulation check analyses were conducted prior to performing hypotheses testing. A MANOVA was conducted to test differences among conditions on importance of social support, importance of hard work, and anti-essentialism beliefs to examine whether the manipulations influenced participants' beliefs about the importance of non-biological factors in STEM abilities and success. The overall MANOVA was significant, *Wilks' Lambda* = .937, $F(9, 2901.16) = 8.74$, $p < .001$. Separate ANOVAs revealed a significant effect on importance of hard work, $F(3,1274) = 5.03$, $p < .01$ and on anti-essentialism beliefs, $F(3, 1274) = 13.78$, $p < .001$. There was no significant effect on importance of social support, $F(3, 1274) = 2.48$, $p = .06$.

A planned contrast was performed for the importance of hard work and anti-essentialism measures. A planned contrast for the importance of hard work measure compared the biography only condition and the combination condition with the information only condition and the control condition, as the biographies in the biography only condition and the combination condition were designed to emphasize the importance of hard work for STEM success. Results revealed that participants in the biography only condition and the combination condition reported greater agreement with the belief that hard work is important for STEM success (biography only condition: $M = 6.09$, $SD = 1.08$; combination condition: $M = 6.02$, $SD = 1.17$) than those in the information only condition and the control condition (information only condition: $M = 5.77$, $SD = 1.28$; control condition: $M = 5.84$, $SD = 1.23$), $t(1274) = 3.73$, $p < .001$. These findings suggest that participants who read the biographies that were created to emphasize the importance of hard work in STEM success agreed more afterwards with the view that hard work is an important contributor of STEM success compared to those who were not exposed to such a message. These findings support the hypothesis that the role model biographies influenced participants' beliefs about the importance of hard work for STEM success.

Moreover, a planned contrast for the anti-essentialism beliefs measure compared the information only condition and the combination condition with the other two conditions that did not have an explicit anti-essentialism message (biography only condition and the control condition). As expected, participants in the information only condition and the combination condition reported greater agreement with anti-essentialism beliefs (information only condition: $M = 5.00$, $SD = 1.38$; combination condition: $M = 5.07$, $SD = 1.24$) than the biography only condition and the control condition participants (biography only condition: $M = 4.88$, $SD = .1.22$; control condition: $M = 4.48$, $SD = 1.29$), $t(1274) = 4.96$, $p < .001$. These findings suggest that participants who read about information challenging essentialist views through research articles or combination of both agreed more afterwards with anti-essentialism beliefs compared to those in the biography only condition and the control condition. These findings support my prediction that genetic basis for STEM abilities (i.e., essentialist beliefs) were challenged in the research articles.

Additional manipulation checks for the biography only condition and the combination condition revealed that the role models in the biographies were perceived as being relevant (M = 5.96, SD = 2.40), similar (M = 5.91, SD = 2.19), competent (M = 8.20, SD = 1.93), likeable (M = 7.49, SD = 1.88), inspiring (M = 7.47, SD = 2.11), and their success was perceived to be obtainable (M = 6.57, SD = 2.24). One sample t-test revealed that these mean scores were significantly greater than the midpoint of each scale: relevant, $t(648) = 4.91$, $p < .001$; similar, $t(648) = 4.73$, $p < .001$, competent, $t(648) = 35.66$, $p < .001$; likeable, $t(648) = 26.88$, $p < .001$; inspiring, $t(648) = 23.71$, $p < .001$; obtainability of role models' success, $t(648) = 12.18$, $p < .001$.

An additional manipulation check for the information only condition and the combination condition revealed that participants reported that the research articles were credible (M = 4.79, SD = 1.24) and this mean score was significantly greater than midpoint of the scale, $t(634) = 16.10$, $p < .001$.

Hypotheses Testing

Correlations, means, and standard deviations of all major study variables by condition are reported in Table 1. A MANCOVA and chi-square tests revealed no significant difference among the four conditions on pretest measures (STEM interest, non-STEM interest, academic identification) as well as on demographic characteristics (age, race, gender, major, SAT scores, and undergraduate GPA) indicating that random assignment was successful.

Hypotheses 1 and 2. To test Hypothesis 1 that both STEM and non-STEM participants in the three experimental conditions (biography only condition, information only condition, combination condition) would show greater interest in STEM, greater perceived identity compatibility between self and STEM, higher STEM self-efficacy, greater intention to take courses in STEM, greater academic sense of belonging, and lower expectations of dropping out of STEM compared to those in the control condition, and moreover that this effect would be greatest for combination condition (Hypothesis 2), a 4 (condition: biography only, information only, combination, control) x 2 (major: STEM vs. non-STEM) MANCOVA was conducted. The dependent variables were STEM interest, non-STEM interest, academic sense of belonging, STEM self-efficacy, intention to take STEM courses, intention to take non-STEM courses, perceived identity compatibility between self and STEM, and perceived identity compatibility between self and non-STEM. Pretest STEM interest, pretest non-STEM interest, and pretest academic sense of belonging as well as SAT, undergraduate GPA, and cohort were entered as covariates.

The overall MANCOVA for the effect of major (STEM vs. non-STEM) was significant, *Wilks' Lambda* = .97, $F(10, 1211) = 4.02$, $p < .001$ on STEM interest, $F(1, 1220) = 16.01$, $p < .001$, intention to take humanities courses, $F(1, 1220) = 4.33$, $p < .05$, and perceived identity compatibility between self and STEM, $F(1, 1220) = 21.44$, $p < .001$. Follow-up analyses revealed that the STEM sample had higher interest in STEM ($M = 4.87$, $SE = .04$) than the non-STEM sample ($M = 4.64$, $SE = .03$) and the STEM sample reported greater perceived identity compatibility between the self and STEM ($M = 4.57$, $SE = .06$) than the non-STEM sample ($M = 4.22$, $SE = .04$). Also, expectedly, the non-STEM sample reported being more likely to take humanities courses in the future ($M = 5.03$, $SE = .07$) than the STEM sample ($M = 4.78$, $SE = .09$).

The overall MANCOVA for condition was not significant, *Wilks' Lambda* = .969, $F(30, 3555.20) = 1.28$, $p = .14$. The overall MANCOVA for the interaction was also not significant, *Wilks' Lambda* = .979, $F(30, 3555.20) = .85$, $p = .70$. Thus, no further analyses were performed

Because the expectation of dropping out of STEM measure was only given to the STEM sample, a separate ANCOVA was conducted with only the STEM participants. The ANCOVA for predicting expectations of dropping out for the STEM sample was not significant, $F(3, 444) = .70$, $p = .55$, and thus no further analysis was performed.

Hypotheses 3a and 3b. To test the hypothesis that the experimental conditions would have positive effects on women's perceived identity compatibility between STEM and gender (Hypothesis 3a), a 4 (condition: biography only, information only, combination, control) x 2 (gender) MANCOVA was conducted, in which the dependent variables were perceived identity compatibility between gender and STEM and perceived identity compatibility between gender and non-STEM. Covariates included were undergraduate GPA, SAT, cohort, and major (STEM vs. non-STEM).

The overall MANCOVA for gender was significant, *Wilks' Lambda* = .915, $F(2, 1221) = 57.07$, $p < .001$ for predicting perceived identity compatibility between gender and non-STEM, $F(1, 1222) = 82.29$, $p < .001$. Follow-up analysis showed that women were more likely to perceive non-STEM to be compatible with their gender ($M = 4.96$, $SE = .07$) than men ($M = 3.92$, $SE = .09$) ($p < .001$). There was no gender difference in perceived identity compatibility between gender and STEM, $F(1, 1222) = 1.72$, $p = .19$.

The overall MANCOVA for condition and for the interaction were non-significant, *Wilks' Lambda* = .993, $F(6, 2442) = 1.36$, $p = .23$; *Wilks' Lambda* = .998, $F(6, 2442) = .47$, $p = .83$, respectively and thus no further analysis was performed.

Similarly, a 4 (condition: biography only, information only, combination, control) x 4 (race/ethnicity: African American, Latino, European American, Asian) MANCOVA was conducted to test the effects of condition on African American and Latino samples' perceived identity compatibility between STEM and their race (Hypothesis 3b), in which the dependent variables were perceived identity compatibility between race and STEM and perceived identity compatibility between race and non-STEM. The same covariates used in Hypothesis 3a were included in the analysis.

The overall MANCOVA for the effect of race was significant, *Wilks' Lambda* = .873, $F(10, 2416) = .16.94$, $p < .001$, on perceived identity compatibility between race and STEM, $F(5, 1209) = 6.77$, $p < .001$ and perceived identity compatibility between race and non-STEM, $F(5, 1209) = 10.11$, $p < .001$. Follow-up analysis showed that the European American sample showed higher perceived compatibility between race and STEM ($M = 4.68$, $SE = .09$) than the African American sample ($M = 4.00$, $SE = .19$) ($p < .05$), and the Latino/Hispanic sample ($M = 3.91$, $SE = .18$) ($p < .01$). The Asian sample also showed greater perceived identity compatibility between race and STEM ($M = 4.78$, $SE = .09$) than the African American sample ($M = 4.00$, $SE = .19$), ($p < .01$) and the Latino/Hispanic sample ($M = 3.91$, $SE= .18$) ($p < .001$). For the perceived identity compatibility between race and non-STEM measure, the African American sample and the European American sample scored higher ($M = 4.53$, $SE = .19$; $M = 4.63$, $SE = .09$, respectively) than the Asian sample ($M = 3.78$, $SE = .09$) ($p < .01$).

The overall MANCOVA for the effect of condition and for the interaction were non-significant, *Wilks' Lambda* = .994, $F(6, 2416) = 1.26$, $p = .27$; *Wilks' Lambda* = .986, $F(24, 2416) = .69$, $p = .86$, and thus no further analysis was conducted.

Hypotheses 4a and 4b. To test the hypothesis that the experimental conditions would have a positive effect on the European American sample's attitudes toward African Americans and Latinos (Hypothesis 4a), a MANCOVA was conducted with the European American sample in which the dependent variables were European American sample's bias against African American, ingroup bias against Latino, and ingroup bias against Asian, and the covariate was cohort. Hypothesis 4a was not supported as the overall MANCOVA was not significant, *Wilks' Lambda* = .983, $F(9, 1146.44) = .88$, $p = .54$. No further analysis was performed.

To test the hypothesis that there would be a positive effect of condition on men's attitude toward women in non-traditional fields (Hypothesis 4b), a 4 (condition: biography only, information only, combination, control) x 2 (gender) ANCOVA was conducted with feelings toward women in non-traditional fields as the dependent variable and cohort and major (STEM vs. non-STEM) as covariates. The main effect of condition was not significant, $F(3, 1242) = 1.86$, $p = .13$, while the main effect of gender was significant, $F(1, 1242) = 27.58$, $p < .001$ with women reporting more positive feelings toward women in non-traditional fields ($M = 87.10$, $SE = .79$) than men ($M = 80.30$, $SE = 1.02$). The interaction effect was not significant, $F(3, 1242) = 1.50$, $p = .21$, and thus no further analysis was conducted.

Discussion

Advancement in STEM is one of the key contributors of a nation's innovation, economic growth, and competitiveness. However, the number of STEM graduates in the U.S. is not projected to meet the growing need of STEM professionals (PCAST, 2012). Low enrollment rates and high attrition rates of STEM students in higher education contribute to this issue (Chen, 2013). Further, the underrepresentation of women, African Americans, and Latinos in STEM exacerbates the STEM workforce shortage issue (NSF, 2015). The current study aimed to address this issue by testing the potential effects of different theoretically-driven strategies on increasing STEM interests for both STEM and non-STEM students.

In this study, participants were exposed to one of the following conditions: 1) biography only condition, 2) information only condition, 3) combination condition, or 4) control condition. Participants in the biography only condition read a series of biographies about successful STEM role models who were underrepresented in STEM and also who succeeded through hard work and effort. Participants in the information only condition read a series of research articles that showed that there is no genetic basis for STEM success or interest and that STEM success or interest is due to non-biological factors, such as parenting and early exposure to STEM. Participants in the combination condition read both the biographies from the biography only condition and the research articles from the information only condition. The main goal of the biographies and the research articles was to challenge the common stereotypes that STEM is for European American men and that those who succeed in STEM are naturally and genetically gifted. Participants in the control condition read a series of articles about a neutral topic, vacuum cleaners.

Manipulation checks revealed that the role models in the biographies were perceived to be relevant, similar, competent, likeable, inspiring, and their success was perceived to be obtainable, which are key characteristics of an effective role model (e.g., Rosenthal et al., 2013; Shin et al., 2016). Manipulation checks also revealed that the research articles in the information only condition and the combination condition were considered credible (rated above the midpoint of the credible response scale). Additionally, the manipulation checks revealed that the biographies in the biography only condition and the combination condition influenced participants' belief that hard work is important for STEM success, such that the participants in these conditions agreed more afterwards with the belief that hard work is important for STEM success compared to those in the information only condition and the control condition. Moreover, the research articles in the information only condition and the combination condition influenced participants' ratings of essentialist beliefs, such that the participants in these conditions agreed more afterwards with anti-essentialism beliefs than those in the biography condition and the control condition.

Despite the promising findings from the manipulation checks, the experimental conditions did not seem to differentially influence participants' academic interests. That is, none of the hypotheses (Hypothesis 1, Hypothesis 2, Hypotheses 3a and 3b, and Hypotheses 4a and 4b) were supported. There are a number of considerations that may account for the lack of statistically significant condition effects. One of the manipulation checks revealed that the biographies did not seem to influence participants' beliefs that social support is important for STEM success, which is another component in the biographies that was included. I had anticipated that pointing out the social support of successful role models would in part challenge the STEM stereotypes that genetics contributed to STEM success. This point may have been too indirect, with participants possibly not drawing the connection between the presence of social support and genetic stereotypes of STEM abilities. Thus, it may be that the social support component of the experimental conditions was not strong enough. Future studies that more strongly and directly emphasize that the role models' success in STEM was achieved in part through social support may strengthen the experimental materials. For instance, role models in the present study discussed the academic challenges they faced as a student and how they overcame them (e.g., "there were times when she considered giving up her dream to be a physician. In college in particular, she became overwhelmed at times by the demanding coursework…Her academic advisors who were her role model kept her engaged in STEM…She also began to reach out to her professors and teaching assistants...As a result, she was able to complete all the required undergraduate courses with outstanding grades"). Adding more information such as the following may further emphasize the important role of hard work and social support: "She felt that she was not naturally gifted to succeed in these science courses. However, she later realized that hard work and support from people who care about her were important for her to succeed, not natural gifts or talents").

It is also possible that the overall experimental conditions were not strong enough (i.e., persuasive enough) to yield any significant effects of condition. The manipulations in the present study were approximately 2400 to 2900 words in lengths, and included four role model biographies and four research articles, each in the field of science (e.g., biology), technology (e.g., computer science), engineering, and mathematics. It is worth highlighting that the role model condition in this study included four biographies whereas the Shin et al. (2016) study included six biographies. If it is the case that the experimental materials were not strong enough, more details and more examples could be added to strengthen the experimental conditions and thereby potentially influence participants' ratings of academic interests. For instance, including more biographies and research articles to cover a wider range of fields in STEM might be helpful in promoting participants' ratings of interests in various STEM fields. Further, providing more details of the role models' struggles and how they overcame their struggles may strengthen the messages delivered through the biographies. Likewise, for the research articles, including more research findings as well as providing more details of how the research was conducted and the implications of the findings may strengthen the impact of the research articles.

It is also possible that the changes made to the biographies from the past role model study (Shin et al., 2016) for the present study reduced the strengths of the biographies. For instance, only four out of six biographies from Shin et al. (2016) were used for the present study. Due to this change, the current biographies did not include a male African American and a Latina role models, whereas the biographies from Shin et al. (2016) included these two role models in addition to a female African American, a male Latino, a female Asian, and a female European American role models who are included in both the present study and the past study. As for the field of study and the occupations of the role models, the present study included a surgeon with a background in biology, an UX designer with a background in computer science, a data analyst with a background in math, and an engineer, whereas Shin et al. (2016) included a biology professor and a postdoctoral researcher in physics in addition to the same four biographies from the present study. It may be that excluding these two biographies reduced its impact to the participants as it limited the number of fields represented as well as limiting its impact to the male African American and Latina participants.

There are several other considerations about the current study that could be considered in understanding the unexpected non-significant effects of the conditions on the dependent measures. First, having the pretest measures in the same study session as the experimental and control condition materials could be a limitation of the study as it may yield a testing effect. Administering pretest measures and controlling for the baseline differences in STEM interest, non-STEM interest, and academic sense of belonging was thought of as beneficial in this study as it provides a within-subject analysis within the larger between-subject analyses. Indeed, in a past study (Shin et al., 2016), the same set of pretest measures (STEM interest, non-STEM interest, and academic sense of belonging) were controlled for in the analyses, and that study revealed a statistically significant condition effect predicting STEM interest and academic intentions.

Despites its advantages, pretest measures may produce testing effects such as cueing participants about the goals of the study or creating demand characteristics, and thereby confounding the findings. Since the interval between the pretest and posttest measures in this study was short (pretest measures were immediately followed by the manipulations and the posttest measures), participants' responses on the pretest measures may have influenced their responses on the posttest measures. One way to address this limitation is by administering the pretest measures in a separate session prior to exposing participants to the manipulations. For example, the pretest measures could have been administered weeks before the manipulations and could have been presented as an unrelated study with filler items. However, constraints of this study such as lack of funding to cover multiple sessions limited my ability to pursue such a design.

Another possible limitation of the study was demand characteristics. Although a cover story was used to somewhat mask the true purpose of the study, the majority of the measures assessed participants' STEM interest and attitudes, which may have revealed the true purpose of the study. Past studies (e.g., Rosenthal et al., 2013; Shin et al., 2016; Stout et al., 2011) also used cover stories to mask the goal of the study. For instance, in the past role model study (Shin et al., 2016), the study was described to the participants as a study examining college students' beliefs, expectations, and attitudes toward their future career paths. Similarly, the current study used a cover story and was described as a study about reading comprehension so that participants can concentrate on the details of the articles. Using a cover story such as these may reduce participants' suspicion of the study's true purpose and reduces demand characteristics. However, given that the majority of the questions in the pretest and posttest measures were about STEM and academic interests, attitudes, and beliefs, participants may have speculated that the current study measures STEM and academic intentions. Adding more filler questions may avoid demand characteristics; however, adding more filler questions or items increases the length of the questionnaires, which may result in a fatigue effect. Future studies may address potential demand characteristics of this type by adding a few filler items and also by adding a question to probe participants' suspicion and eliminating data from participants who are aware of the true purpose of the study.

Lastly, another possible explanation for the lack of positive effects of experimental conditions on participants' STEM interests may be due to an unexpected campus wide campaign that was launched at the participants' institution (Stony Brook University) at the time when the current study was launched (November 2015). One of the priorities of the campaign is to advance STEM and medical research and innovation. In support of this campaign, Stony Brook University campus as well as the university website display images of successful STEM faculty and alumni from diverse background often with the message emphasizing the importance of STEM (e.g., "*Leading the way: Through research and discovery, we are changing the world*", "*Healing through discovery: Meeting regional healthcare needs, exceeding our own expectations*" [The Campaign for Stony Brook, 2016]). The campaign included billboard size posters on the sides of the library and other main buildings on the center of campus, which have remained on those building for many months. The main page of the university website also featured the same themes including video links. One video shows a young African American man from Harlem who is on his way to medical school and who overcame hardships through hard work and with the help of others. Research suggests that even subtle contextual cues (e.g., posters in a room, conference video) can have a significant impact people's interest and sense of belonging in STEM (Cheryan et al., 2009; Murphy et al., 2007) and thus the images and videos on campus and institution website may have had a significant impact on all participants' interest in STEM. In addition, these various campaign efforts in the institution mirror strategies used in the current study for increasing STEM interests for college students (e.g., using diverse STEM role models, emphasizing the importance of STEM, demonstrating STEM success obtained through hard work and social support). It is possible then at least some of my study participants were exposed to these themes outside of the experimental context such that, for example, even those in my control condition were exposed to the experimental messages outside the laboratory situation.

If it is the case that the university-wide campaign had some effects on the results of the present study, conducting the study with a different college sample may be needed to examine the effects of manipulations. For instance, institutions that lack diversity in STEM (e.g., lack of diverse students, faculty, and staff), institutions that do not having strong STEM programs or do not emphasize the importance of STEM education to their students, and/or institutions that value natural gifts for STEM success, may be ideal candidates to test the effectiveness of the manipulations. Unlike the participants from the present study who may had been exposed to the stereotype-challenging efforts through their institution's campaign, participants in other institutions may not have the opportunity to encounter information that challenge the common STEM stereotypes. Therefore, conducting the study with different samples of college students is needed to understand what is effective and ineffective in challenging STEM stereotypes and increasing STEM interest.

Further, extending the current study to study graduate students is also important given that the underrepresentation of women, African Americans, and Latinos are just as severe or often more severe in some of the STEM fields. For instance, only about 20% of the doctoral recipients are women, and 1-3% of the doctoral recipients are African Americans and Latinos in many STEM fields (NSF, 2015). Although graduate students are further along in their education, and have demonstrated their academic abilities and commitment to STEM careers, stereotypes are still relevant to them (e.g., Leslie et al., 2015). Challenging the two common STEM stereotypes with graduate students may be one way to address the underrepresentation issue in higher education as past research suggests that the belief that innate gifts are required for STEM success is one contributing factor of underrepresentation of women, African Americans, and Latinos in graduate programs in STEM (Leslie et al., 2015).

In addition, conducting the study with younger students (e.g., elementary, middle, and high schools) may also be beneficial as STEM stereotypes may be a barrier for these students as well (e.g., Bages & Martinot, 2011; Good, Aronson, & Inzlicht, 2003; Hong & Lin-Siegler, 2012) and they may benefit from the present experimental materials, if adapted for their age group. A past study with high school students found that among students who had low initial science interest, exposure to biographical information about prominent scientists (e.g., Newton) that emphasized how their personal, social, and intellectual struggles led to their remarkable discoveries and accomplishments had a positive influence on their interest in physics lessons (Hong & Lin-Siegler, 2012). Therefore, the experimental materials in the present study may benefit younger students in increasing their interest in STEM majors and careers as early interventions are important for younger students who are beginning to develop their identity and interest in STEM (Moomaw, 2013).

Future studies may also consider investigating whether promoting STEM interests through a brief exposure such as the one in the present study or a prolonged exposure through campaigns, such as the one launched at the participants' institution produces more cost-efficient, long-term benefits in recruiting and retaining more STEM students. Since university-wide interventions would involve the faculty and staff at the institutions, and would impact the whole atmosphere of the students' academic environment (e.g., posters throughout the campus, school website contents), students would be constantly exposed to the stereotype challenging messages, and thereby producing a stronger effect than a brief, one-time experiment session. Similarly, school-wide interventions targeted for elementary, middle, and high school students may also be beneficial for increasing STEM interests for these students, which may affect their STEM performance as well as their decision to pursue STEM majors and careers in the future.

Although institution-wide interventions may produce long-term benefits, these types of interventions may be difficult to carry out as they require cooperation from faculty and staff who may or may not have interest in these institutional goals. Further, institution-wide interventions may not be feasible to carry out in some institutions, as they would be time-consuming and would require financial resources. For instance, at Stony Brook University, $473 million dollars have been raised to support the current campaign, which may be a difficult goal to meet for some institutions. For these reasons, a brief, online experiment session may be beneficial as they are cost- and time-efficient and can be conducted with great flexibility. Past role models studies (e.g., Rosenthal et al., 2013; Shin et al., 2016) used an online method to influence participants' interest in STEM. These studies suggest that brief online interventions can be a promising method for increasing STEM interests, especially when it is not feasible to conduct institution-wide interventions.

Conclusion

As the need for skilled STEM professionals has grown in the U.S., it has become crucial to recruit more students into STEM and also to reduce high attrition rates among STEM students. Additionally, recruiting more underrepresented groups (women, African Americans, and Latinos) into STEM has been an important educational agenda as the persistent underrepresentation of women, African Americans, and Latinos further exacerbates the STEM workforce shortage issue.

One promising method to increase STEM interest is by challenging the stereotype that STEM is for naturally gifted individuals, which can be a barrier for everyone, and the stereotype that STEM is best suited for European American men, which can be a barrier for non-European American men (e.g., women, African American men). I look forward to future research in this area that brings us closer to meeting the nation's goal of producing more STEM professionals

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Table 1

Correlations, Means, and Standard Deviation for All Major Study Variables by Condition

Variables	1	2	3	4	5	6	7	8	9	10	11
Biography only condition (n = 325)											
1	-	-	-	-	-	-	-	-	-	-	-
2	-.50***	-	-	-	-	-	-	-	-	-	-
3	.63***	-.36***	-	-	-	-	-	-	-	-	-
4	.45***	-.22***	.51***	-	-	-	-	-	-	-	-
5	.62***	-.34***	.61***	.52***	-	-	-	-	-	-	-
6	.001	.11*	.03	.17**	-.04	-	-	-	-	-	-
7	-.18**	.41***	-.09	.05	-.06	.29***	-	-	-	-	-
8	.74***	-.44***	.63***	.42***	.55***	.05	-.15**	-	-	-	-
9	-.47***	.65***	-.27***	-.23***	-.32***	.03	.37***	-.31***	-	-	-
10	.32***	-.02	.42***	.31***	.27***	.16**	.12*	.33***	-.03	-	-
11	-.47***	.28***	-.43***	-.26***	-.36***	.06	.15*	-.44***	.21**	-.28***	-
M	4.86	4.30	5.09	4.81	5.67	3.36	4.76	4.37	4.22	4.74	2.45
SD	1.98	1.90	1.57	2.13	1.85	1.85	1.93	1.65	1.72	1.43	1.67
Information only condition (n = 313)											
1	-	-	-	-	-	-	-	-	-	-	-
2	-.51***	-	-	-	-	-	-	-	-	-	-
3	.59***	-.28***	-	-	-	-	-	-	-	-	-
4	.41***	-.18**	.44***	-	-	-	-	-	-	-	-
5	.64***	-.30***	.60***	.50***	-	-	-	-	-	-	-
6	-.05	.11	.07	.11	-.09	-	-	-	-	-	-
7	-.17**	.41***	.07	.11	.03	.25***	-	-	-	-	-
8	.77***	-.38***	.58***	.39***	.53***	.02	-.13*	-	-	-	-
9	-.38***	.66***	-,20***	-.10	-.20***	-.03	.31***	-.29***	-	-	-
10	.19**	.02	.28***	.23***	.14*	.11	.13*	.21***	.02	-	-
11	-.42***	.39***	-.35***	-.12	-.35***	.20**	.07	-.28***	.19**	-.16*	-
M	4.58	4.52	4.91	4.72	5.61	3.39	4.94	4.41	4.43	4.80	2.52
SD	2.07	1.76	1.58	2.21	1.90	2.00	1.85	1.57	1.67	1.43	1.74

Table 1 *(Continued)*

Correlations, Means, and Standard Deviation for All Major Study Variables by Condition

Variables	1	2	3	4	5	6	7	8	9	10	11
Combination condition (n =320)											
1	-	-	-	-	-	-	-	-	-	-	-
2	-.55***	-	-	-	-	-	-	-	-	-	-
3	.57***	-.32***	-	-	-	-	-	-	-	-	-
4	.41***	-.26***	.39***	-	-	-	-	-	-	-	-
5	.66***	-.37***	.50***	.49***	-	-	-	-	-	-	-
6	-.10	.09	.02	.14*	-.10	-	-	-	-	-	-
7	-.21***	.45***	-.03	.06	-.02	.16**	-	-	-	-	-
8	.76***	-.52***	.60***	.38***	.57***	-.06	-.17**	-	-	-	-
9	-.53***	.68***	-.32***	-.31***	-.39***	.03	.41***	-.43***	-	-	-
10	.20***	.002	.31***	.17**	.18**	.02	.08	.22***	-.07	-	-
11	-.20**	.20**	-.31***	-.04	-.27***	.14*	.02	-.23***	.26***	-.28***	-
M	4.85	4.62	4.98	4.69	5.68	3.35	5.11	4.38	4.39	4.75	2.55
SD	1.97	1.82	1.48	2.22	1.83	1.86	1.76	1.62	1.57	1.34	1.70
Control condition (n = 320)											
1	-	-	-	-	-	-	-	-	-	-	-
2	-.50***	-	-	-	-	-	-	-	-	-	-
3	.61***	-.23***	-	-	-	-	-	-	-	-	-
4	.48***	-.17**	.45***	-	-	-	-	-	-	-	-
5	.59***	-.33***	.56***	.51***	-	-	-	-	-	-	-
6	.02	.14*	.12*	.11*	.007	-	-	-	-	-	-
7	-.13*	.34***	-.02	.07	.05	.32***	-	-	-	-	-
8	.76***	-.45***	.61***	.44***	.58***	-.04	-.16**	-	-	-	-
9	-.43***	.67***	-.15**	-.18**	-.22***	.17**	.35***	-.37***	-	-	-
10	.24***	.02	.39***	.20***	.22***	.20***	.02	.24***	.03	-	-
11	-.32***	.23***	-.39***	-.01	-.26***	.19**	.14*	-.37***	.13	-.12	-
M	4.64	4.70	4.95	4.69	5.63	3.66	4.93	4.22	4.56	4.69	2.51
SD	2.04	1.83	1.48	2.23	1.80	1.97	1.86	1.58	1.53	1.37	1.68

Note. $*p < .05$; $**p < .01$; $***p < .001$
1 = STEM interest (scale range = 1 – 7)
2 = Non-STEM interest (scale range = 1 – 7)
3 = STEM efficacy (scale range = 1 – 7)
4 = Intention to take math/statistics classes (scale range = 1 – 7)
5 = Intention to take science classes (scale range = 1 – 7)
6 = Intention to take business classes (scale range = 1 – 7)
7 = Intention to take humanities classes (scale range = 1 – 7)
8 = Perceived identity compatibility between self and STEM (scale range = 1 – 7)
9 = Perceived identity compatibility between self and non-STEM (scale range = 1 – 7)
10 = Academic sense of belonging (scale range = 1 – 7)
11 = Expectations of dropping out of STEM (scale range = 1 – 7)