Broadening Participation in the Life Sciences with Social–Psychological Interventions

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ABSTRACT

Randomized controlled trials (RCTs) have recently documented the positive effects of social–psychological interventions on the performance and retention of underrepresented students in the life sciences. We review two types of social–psychological interventions that address either students' well-being in college science courses or students' engagement in science content. Interventions that have proven effective in RCTs in science courses (namely, utility-value [UV] and values-affirmation [VA] interventions) emphasize different types of student values—students' perceptions of the value of curricular content and students' personal values that shape their educational experiences. Both types of value can be leveraged to promote positive academic outcomes for underrepresented students. For example, recent work shows that brief writing interventions embedded in the curriculum can increase students' perceptions of UV (the perceived importance or usefulness of a task for future goals) and dramatically improve the performance of first-generation (FG) underrepresented minority students in college biology. Other work has emphasized students' personal values in brief essays written early in the semester. This VA intervention has been shown to close achievement gaps for women in physics classes and for FG students in college biology. By reviewing recent research, considering which interventions are most effective for different groups, and examining the causal mechanisms driving these positive effects, we hope to inform life sciences educators about the potential of social–psychological interventions for broadening participation in the life sciences.

INTRODUCTION

Increasing participation in science, technology, engineering, and mathematics (STEM) fields has long been a part of the national agenda. From the publication of a "A Nation at Risk" in 1983 to a recent pledge from the Obama administration to commit $3.1 billion to improve STEM education and inspire students to pursue STEM careers, educators have been concerned that the increase in STEM jobs in America will eventually exceed the supply of qualified candidates (National Research Council, 2007). Although graduation rates for underrepresented ethnic minority students (URMs) in STEM have increased over the past 30 years, these students remain underrepresented among STEM graduates (Gerald and Haycock, 2006) and in STEM occupations (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011). For example, even though African Americans, Hispanics, and Native Americans comprise 29% of the total U.S. population, they represent only 9% of college-educated Americans in STEM occupations. Similarly, first-generation (FG) students (i.e., students for whom neither parent has obtained a 4-year degree) struggle in college STEM courses compared with their continuing-generation (CG) peers (i.e., students for whom at least one parent has a 4-year degree), contributing to what has been labeled the social class achievement gap (Stephens *et al.*, 2012a; Terenzini *et al.*, 1996). The underrepresentation of women in STEM disciplines has also been a focus of educators

Pat Marsteller, *Monitoring Editor*
Submitted January 1, 2016; Revised June 8, 2016; Accepted June 14, 2016
CBE Life Sci Educ September 1, 2016 15:es4
DOI:10.1187/cbe.16-01-0001
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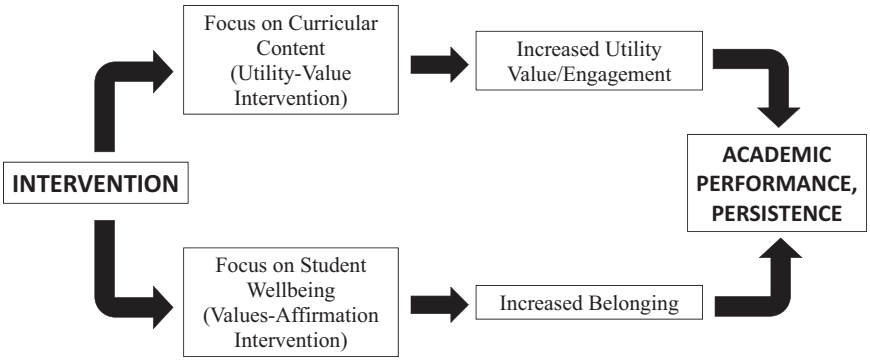

FIGURE 1. Theoretical model of intervention effects.

and policy makers, with some STEM fields being composed of nearly 80% male students (e.g., engineering, physics, computer science; National Science Foundation, 2015). Promoting performance and retention for underrepresented students in STEM courses is imperative to increase the total number of students pursuing STEM careers and capitalize on students' potential.

Recently, researchers have leveraged social–psychological principles to develop interventions specifically designed to benefit underrepresented students in STEM fields and college more generally. Although a number of review papers have documented the positive effects of social–psychological interventions in education (Yeager and Walton, 2011; Walton, 2014; Lazowski and Hulleman, 2015; Rosenzweig and Wigfield, 2016), these reviews have primarily concentrated on interventions with adolescents and high school students and have not focused on issues of underrepresentation in STEM or how students adapt to large-enrollment college science classes that may act as gateways to future careers. More recently, a small number of randomized controlled trials (RCTs) have been conducted in college science classes, but a detailed review of these interventions has yet to be conducted.

SCOPE OF THE CURRENT REVIEW

We believe that an early review of the existing literature is necessary to inform researchers and practitioners about the potential for social–psychological interventions to impact science education at the postsecondary level. Thus, in the present review, we provide a brief overview of two types of social–psychological interventions that have been shown to improve academic outcomes for underrepresented students in higher education: those that focus on students' well-being in college, with an emphasis on academic fit and adjustment to college, and those that focus on curricular content, with an emphasis on engagement and interest in course material. We also provide a more in-depth review of three recent intervention studies conducted in college science classes that represent the first RCTs to test whether social–psychological interventions can improve academic outcomes in this important context. Although these studies were not all conducted in the life sciences (two in biology, one in physics), all were conducted in critical gateway courses relevant to broadening participation in the life sciences.

TWO TYPES OF SOCIAL–PSYCHOLOGICAL INTERVENTION

Social–psychological interventions in higher education have primarily focused on one of two issues: either students' well-being (e.g., adjustment to college) or students' engagement in course content. Interventions focused on well-being often target students' sense of belonging, a key psychological factor in determining students' experiences and performance in their courses (Freeman *et al.*, 2007; Ostrove and Long, 2007; Johnson *et al.*, 2011). Underrepresented students may experience debilitating anxiety related to their perception that they do not belong in a college course or the possibility that others have negative stereotypes about their groups (e.g., that they are untalented/unintelligent). This type of anxiety can hinder students' abilities to focus on academics and often impairs performance on challenging tasks (Steele, 1997; Lewis and Sekaquaptewa, 2016; Spencer *et al.*, 2016). Interventions that target student well-being are often posited to work by reducing anxiety associated with belonging concerns (Walton, 2014).

In contrast, social–psychological interventions that focus on students' engagement in curricular content take a different approach. These interventions target psychological processes thought to promote motivation and interest in specific course content. Students may become disengaged in their college science courses if they struggle to see the relevance of course material to their lives or career goals (Hidi and Harackiewicz, 2000; Harackiewicz and Hulleman, 2010). However, researchers have found that students become more engaged in courses when they have the opportunity to actively participate in the learning process (e.g., activities and discussions that promote cognitive processing of information and problem-solving strategies; Gasiewski *et al.*, 2012). Some motivational interventions seek to engage students in active learning and encourage students to think about course content in novel ways not typically emphasized in traditional pedagogy. These interventions are posited to work by increasing perceptions of course value and thus students' interest and engagement (see Figure 1 for a theoretical model detailing intervention effects and the processes through which they work).

INTERVENTIONS FOCUSED ON STUDENT WELL-BEING

Students experience college differently depending on their backgrounds. For example, FG students often report more uncertainty about their belonging than their CG peers, which carries detrimental consequences for academic performance (Ostrove and Long, 2007; Johnson *et al.*, 2011; Harackiewicz *et al.*, 2014a). Furthermore, it is important to note that different groups of students face unique sets of challenges. For example, whereas URM students experience discrimination and stereotyping, FG students may struggle with navigating academia with fewer educational and financial resources than CG students. Furthermore, given that race and social class are increasingly correlated in American society (Duncan and Murnane, 2011; Reardon, 2011), some students (i.e., FG-URM students) contend with multiple challenges.

Social–psychological interventions that target student well-being aim to mitigate psychological barriers, such as feeling "out of place," that can impede the academic success of underrepresented students. For example, Walton and Cohen (2011) implemented a social-belonging intervention with first-year college students in which students 1) read reports from senior students about how almost all students worry about their belonging during their first year and how an increased sense of belonging develops over time and then 2) wrote and recorded a speech for incoming first-year students about how their own experiences were similar. This RCT reduced belonging uncertainty and improved grade point averages (GPAs) for African-American students through senior year. A similar social-belonging intervention in which first-year engineering students first read quotes from senior engineering students and then wrote letters to future students improved first-year engineering GPAs for women in male-dominated engineering majors with gender gaps (Walton *et al*., 2015).

Using a different approach, Stephens *et al*. (2014, 2015) tested a difference-education intervention that highlighted college students' diverse backgrounds as a strength of the college community and found that it led to better college adjustment and improved grades for FG students. This intervention takes a key source of belonging uncertainty (i.e., coming from a background different from that of one's peers) and helps students to see it as a strength, rather than a cause for anxiety. Thus, both the social-belonging and difference-education interventions take a direct approach to addressing concerns about belonging: they try to convince college students that their concerns are normal and that diversity is valued. Indeed, in each of these studies conducted in college contexts, students experienced greater belonging, as indexed by either reduced levels of belonging uncertainty (Walton and Cohen, 2011) or increased levels of belonging and fit (Stephens *et al*., 2014, 2015; Walton *et al*., 2015).

The results of both social-belonging and the difference-education interventions are promising, but these RCT studies were all conducted outside classes, with interventions administered by researchers to students who volunteered to participate in an extracurricular program. Given the nature of these interventions (an explicit focus on issues of belonging and diversity) and the time commitment (both interventions take roughly an hour to complete), they may be difficult to implement in the context of a college science course. Indeed, such interventions may be most effective when used at the level of general academic advising and could be implemented in large-scale first-year orientation activities or as students enter specific academic majors, which would hold great promise for helping students adjust to college or scientific disciplines (Paunesku *et al*., 2015).

RCTs IN SCIENCE COURSES: VALUES AFFIRMATION

The values-affirmation (VA) intervention, which instructs students to write essays about why their personal values (e.g., relationships with friends and family, learning and gaining knowledge) are important to them, has been shown to alleviate belonging concerns *indirectly*, by having students focus on their strengths and what is really important to them (Harackiewicz *et al*., 2014a). Affirming personal values in this way is theorized to help students reestablish a feeling of self-integrity and self-worth in contexts in which they may feel as though they do not belong (Cohen and Sherman, 2014). The VA intervention has been studied extensively in the laboratory (for a review, see Cohen and Sherman, 2014), and has been shown to have positive effects on academic performance for underrepresented students from middle school through college (Cohen *et al*., 2006; Cohen and Sherman, 2014; Sherman *et al*., 2013; Brady *et al*., 2016). More recently, the VA intervention has been successfully integrated into college science courses (e.g., Miyake *et al*., 2010; Harackiewicz *et al*., 2014a), and we discuss this intervention and two RCT studies that test it in greater detail.

Miyake *et al*. (2010) were the first researchers to conduct a VA intervention using RCT methodology in a college science course (RCT 1; see Table 1). In the context of an introductory physics course (in which men typically outperformed women), they had students select their most important values from a list of 12 values (being good at art; creativity; relationships with family and friends; government or politics; independence; learning and gaining knowledge; athletic ability; belonging to a social group [such as your community, racial group, or school club]; music; career; spiritual or religious values; sense of humor) and write about why those selected values were important to them (students in the control condition wrote about why their least important values might be important to someone else). The VA intervention was introduced as a course activity during the first week of the semester by the professor, who told students that they would be completing a brief writing exercise during that week's recitation. Specifically, the professor told the students that effective communication was an important skill for success in physics-related careers and that to practice communication they would complete a 10–15 minute writing exercise. Students later completed the same writing assignment in week 4 of the semester (just before the first midterm exam) as part of a weekly online homework assignment. Thus, in contrast to the social-belonging or differences-education interventions, the VA intervention was fully integrated into the class and presented as a course assignment. The effects of the intervention on course performance were noteworthy. Whereas the gender gap on course exams was large in the control condition (d = 0.93), it was substantially smaller in the affirmation condition (d = 0.18). In terms of exam scores, this translated to a 61% reduction in the gender gap.

Other research has documented the efficacy of VA to address the social class achievement gap (i.e., the performance discrepancy between FG and CG students) in college biology courses. Closely replicating the methods first used by Miyake *et al*. (2010), Harackiewicz *et al*. (2014a) implemented a VA intervention in an introductory biology course (RCT 2a; see Table 1). This was a large lecture class with many lecturers (a different lecturer for each unit), and the writing assignment was announced via a weekly newsletter from course coordinators and administered in laboratory sections. The social class achievement gap, evident in final course grades in the control condition (d = 0.39), was significantly smaller when FG students wrote about their important values in the intervention condition (d = 0.18), reflecting a 50% reduction of the social class gap. In fact, FG students in the VA condition outperformed FG students in the control condition by nearly a quarter of a grade point (0.24 GPA points). In addition, FG students in the VA condition were more likely to enroll in the second course of the biology sequence than FG students in the control condition (85.7% of FG students in the VA condition vs. 66.2% of FG

TABLE 1. Overview of selected social–psychological interventions to improve academic outcomes for underrepresented students in college science courses

Study	Sample (*N*)	Theoretical approach *Intervention*	Summary of intervention	Summary of results
Miyake *et al.* (2010)	Physics students (116 women, 283 men)	Self-affirmation *Values affirmation*	Students selected their most important values from a list of 12 and wrote about why those values were important to them. This was completed twice: once in class during the first week of the semester and again as a homework assignment in week 4, just before the first midterm exam. Each essay took ~15 minutes to write.	Women in the affirmation condition performed significantly better on course exams.
Harackiewicz *et al.* (2014a)	Biology students (154 FG students, 644 CG students)	Self-affirmation *Values affirmation*	Students selected their most important values from a list of 12 at time 1, and 16 at time 2, and wrote about why those values were important to them. This was completed twice: once during the third week of the semester and again in week 8, just before the second exam. Each essay took ~15 minutes to write and was completed in students' laboratory sections.	FG students in the VA condition earned higher course grades and overall semester grades. They were also more likely to enroll in the second course of the biology sequence and felt less uncertainty about their biology background preparation (a measure of academic belonging).
Tibbetts *et al.* (2016)	Biology students (154 FG students, 644 CG students)	Self-affirmation *Values affirmation*	This was a 3-year follow-up of Harackiewicz *et al.* (2014a) study examining long-term effects of the original intervention and mediating mechanisms.	FG students in the VA condition earned higher postintervention cumulative GPAs.
Harackiewicz *et al.* (2015)	Biology students (423 CG-majority, 427 FG-majority, 126 CG-URM, 64 FG-URM)	Expectancy value *Utility value*	Students wrote three essays about how curricular content related to their lives or the lives of close others. One essay of one to two double-spaced pages was written for each of the three units of the course as a homework assignment.	On average, all students performed better in the course and identified more UV in their course work in the UV condition. The effect on course grade was strongest for FG-URM students, who also displayed the most engagement with the assignments.

students in the control condition enrolled in the second course of the biology sequence). The VA intervention also impacted students' sense of belonging in the class. FG students in the VA condition reported feeling less uncertainty about the adequacy of their biology background (a factor in FG students' sense of belonging) over the course of the semester, compared with FG students in the control condition (Harackiewicz *et al.*, 2014a).

Tibbetts *et al.* (2016) conducted a longitudinal follow-up of the students in this study and found that FG students continued to earn higher grades in their courses, even after the semester in which VA was implemented (RCT 2b; see Table 1). Three years after the initial intervention, FG students in the VA condition had an overall GPA in their subsequent course work that was, on average, 0.18 grade points higher than FG students in the control condition. The social class achievement gap, evident in the control condition ($d = 0.40$), was significantly smaller in the VA condition ($d = 0.17$), in which students had written about their important values 3 years earlier, reflecting a 59% reduction in the social class gap in overall college GPA (Tibbetts *et al.*, 2016; see Figure 2).[1] Thus, VA improved academic performance as well as subjective perceptions of belonging for FG students and also increased students' likelihood of continuing in the two-semester biology course. The longevity of the treatment effect on students' academic performance suggests that successfully intervening in critical gateway courses (such as introductory biology) sets students up for success in future semesters as well.

INTERVENTION MECHANISMS: BELONGING

Social–psychological interventions that focus on student well-being target belonging concerns in two different ways: they attempt to normalize students' doubts about their belonging by assuring them that feeling out of place is part of the college experience for all students (in the case of belonging and difference-education interventions), or they help students reestablish a sense of self-integrity and self-worth that allows them to cope with their belonging concerns (as in VA interventions). In this way, social–psychological interventions are "psychologically precise," because they address specific processes that are critical for adjustment to college and academic performance (Walton, 2014). All of the interventions reviewed here worked to alleviate belonging concerns, but they did so in different ways, depending on the intervention and the population the intervention was intended to serve.

The power of the social-belonging intervention comes, in part, from its two-pronged approach. The intervention lets students know that feeling out of place is a normal part of the college experience and also gives them the opportunity to write a speech or letter conveying that message to younger students. In this way, the intervention helps students to internalize and take ownership of the idea that belonging concerns are normal and temporary rather than an indication that they may not be able to succeed in college, thus relieving students' anxiety about their own belonging uncertainties (Walton and Cohen, 2011). Similarly, the difference-education intervention reframes a possible source of anxiety for FG students (i.e., having a different background than one's peers) as a strength that could contribute to the college learning environment. Thus, both the social-belonging and

[1]For this analysis, GPA was calculated based courses taken after the semester in which the VA intervention was implemented.

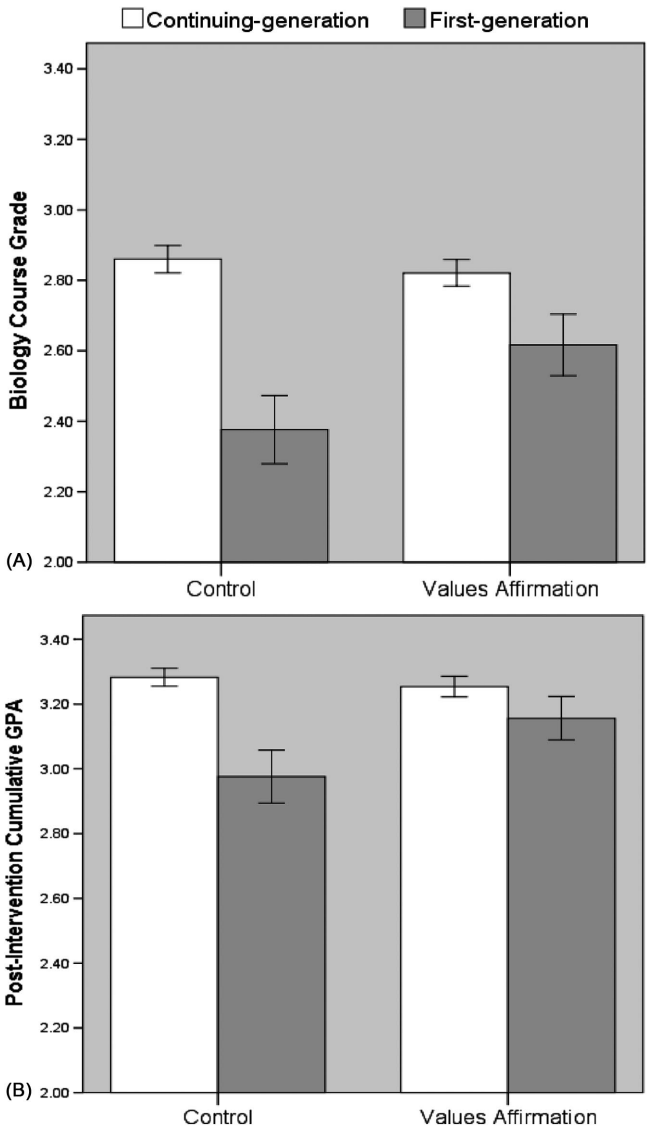

FIGURE 2. Mean biology course grade (A) and postintervention GPA (B) with ± 1 SE for performance among CG and FG students as a function of the VA condition. (A) *N* = 798; (B) *N* = 788.

difference-education interventions address key psychological barriers that can impede underrepresented students' academic success and promote important components of students' well-being, such as adjustment to college, social fit, and sense of belonging (Stephens *et al*., 2014, 2015; Walton *et al*., 2015).

Based in self-affirmation theory (Steele, 1988), VA interventions were originally designed to help stereotyped groups overcome stereotype threat (e.g., to help women perform better on math tests when they worried about people discounting their math ability because of their gender), but they have proven useful in a variety of contexts, in part because of their potential to influence belonging. Writing about important values may bolster students' self-worth and integrity, thereby allowing them to cope with belonging concerns and academic stressors that threaten students' well-being. It is also worth noting that different groups of students may be concerned about their belonging for different reasons. For example, recent research has demonstrated that FG students' belonging concerns may stem from a mismatch between the middle-class norms of independence prevalent in the American university system (e.g., valuing becoming an independent thinker) and their own interdependent motives for attending college (e.g., to give back to their families). Whereas middle-class CG students may have been socialized with independent norms and might therefore be accustomed to the independent culture of higher education, FG students may experience that same independent culture as unfamiliar and threatening (Stephens *et al*., 2012a).

Accordingly, these belonging concerns may be best alleviated by encouraging FG students to reflect on their own values that are consistent with university norms, reminding them that, although they bring a unique set of values to the university, they share many values with the university as well. Tibbetts and colleagues (2016) found support for this hypothesis by evaluating the content of students' VA essays from the Harackiewicz *et al*. (2014a) study. They found that, when FG students wrote about their independence (i.e., their values that were consistent with university norms), they incurred the greatest benefit from the intervention. In fact, writing about independence mediated intervention effects such that FG students in the VA condition wrote more about their independence than FG students in the control condition, and this increase was associated with higher grades and less concern about their backgrounds. In this way, writing about independence may help FG students focus on the values they have in common with the university context, thus alleviating belonging concerns.

Physiological data also support the notion that VA may help students by relieving the stress and anxiety associated with belonging concerns. Previous work has shown that students who complete a VA assignment before a stressful event have less-elevated cortisol levels (an index of stress) than students who do not have the opportunity to affirm their personal values (Creswell *et al*., 2005). Similarly, Stephens *et al*. (2012b) have noted that, when FG students experience a "cultural match" with university norms (i.e., feel a sense of belonging due to shared values with the university), their cortisol levels decrease before participating in a stressful task.

In sum, recent research suggests that we can improve underrepresented students' academic performance in the life sciences by leveraging social–psychological principles and focusing on students' well-being and their sense of belonging. Different groups of students may have belonging concerns for different reasons, and interventions work best when the source of those concerns is identified and subsequently targeted by interventions (Shapiro *et al*., 2013; Walton, 2014).

INTERVENTIONS FOCUSED ON CURRICULAR CONTENT

Other researchers take a different approach to improving academic outcomes for underrepresented students by addressing issues related to motivation and engagement in courses. Using interventions focused on specific course content, researchers and educators aim to help students become more deeply engaged in what they are learning, so they will be more motivated and interested in the topics, which should ultimately improve learning and performance outcomes.

One intervention that uses this content-specific approach is the utility-value (UV) intervention, in which students are asked to write essays about the personal relevance of course material to their own lives or to the life of a family member or close friend (Hulleman and Harackiewicz, 2009; Harackiewicz and Hulleman, 2010). Students are instructed to provide concrete examples of how the content they are studying is personally relevant and useful (students in the control condition are instructed to summarize the course material in their own words). This intervention helps students find personal value in the material and fosters engagement with course content. The UV intervention has been tested in laboratory studies and with RCTs in high school biology and college psychology classes and has been shown to work best for students who doubt their competence or have a history of poor performance (Hulleman and Harackiewicz, 2009; Hulleman *et al*., 2010; Canning and Harackiewicz, 2015). Evidence from RCTs indicates that UV interventions have been successful at encouraging students to identify the personal relevance and applicability of course material, which has resulted in increased engagement, interest and course performance (Hulleman and Harackiewicz, 2009; Hulleman *et al*., 2010).

RCTs IN SCIENCE COURSES: UV

Building on prior research, Harackiewicz *et al*. (2015) tested the UV intervention with an RCT in an introductory college biology class, the gateway course taken by all pre–medical and pre–health students at the university (RCT 3; see Table 1). The UV writing assignments, which were required for course credit and listed in the course syllabus, were completed three times during the semester. Students were asked to write a 500-word essay as homework each time, and their essays were turned in online using course-management software. Course coordinators emailed assignments to students (for purposes of random assignment to condition). Assignments were sent midway through each unit of the class, so students could write about what they had learned thus far in the unit and feedback could be provided before each unit exam. Essays were graded by experienced teaching assistants for scientific content and for following directions (i.e., In UV conditions, did they make connections? In control conditions, did they summarize content?).

Harackiewicz *et al*. (2015) found that the UV intervention was effective in promoting performance for all students and particularly effective for the group of students who tended to struggle the most in the course: FG-URM students. On average, all students in the UV condition identified more UV in course topics and earned higher course grades. However, the effect on course grade was strongest for FG-URM students. The UV intervention was remarkably effective for this group: FG-URM students in the UV condition performed about a half of a grade point (0.51 GPA points) higher than their FG-URM peers in the control condition. The achievement gap was large in the control condition ($d = 0.98$) but smaller in the UV condition ($d = 0.53$), resulting in a 61% reduction of the achievement gap on course grade for these students (see Figure 3).

This group of students had a unique motivational profile, which may have made them more receptive to the UV intervention. At the outset of the semester, FG-URM students reported a number of challenges: they had the lowest incoming GPAs, the lowest levels of background in biology, and the highest levels of

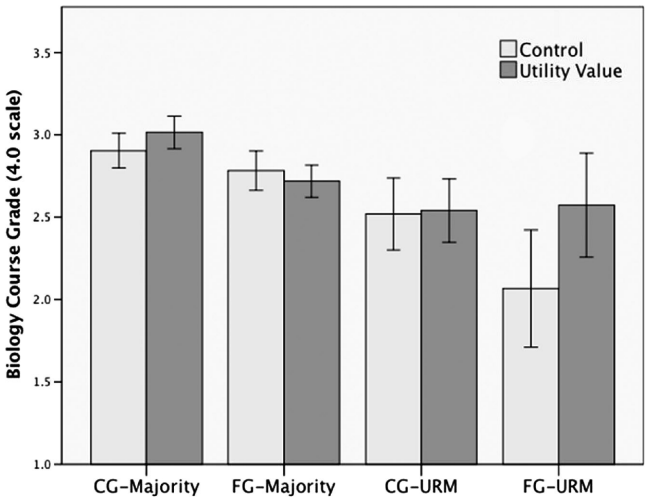

FIGURE 3. Course performance as a function of treatment condition (UV or control) and both URM (majority or URM) and generational status (CG or FG). Error bars are 95% confidence intervals.

belonging uncertainty relative to all other students. However, they also reported a number of motivational strengths: consistent with previous research, FG-URM students were especially motivated by communal goals, such as giving back to their families and communities and contributing to society (Stephens *et al*., 2012a; Smith *et al*., 2014, 2015; see Figure 4). Although all students tended to become engaged in the UV assignment, FG-URM students became particularly engaged (i.e., they wrote longer UV essays than all other students), perhaps because they were able to connect the course material to their communal goals.

INTERVENTION MECHANISMS: PERCEIVED UV AND ENGAGEMENT

UV interventions are theorized to promote engagement and interest, and thus increase students' motivation in courses. By writing

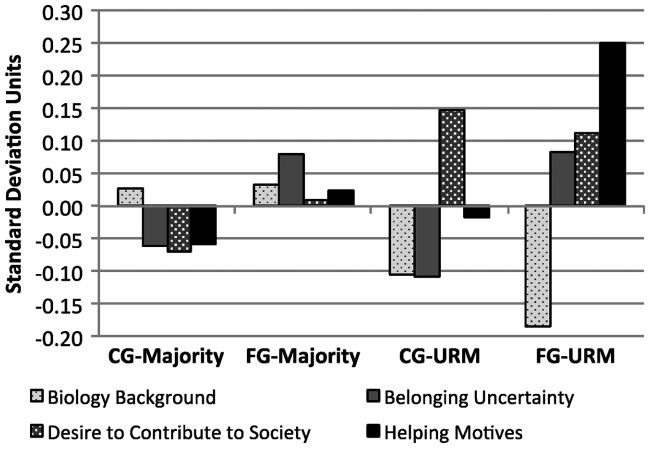

FIGURE 4. Standardized measures of biology background, belonging uncertainty, desire to contribute to society, and helping motives as a function of URM (majority or URM) and generational (CG or FG) status.

essays about the value of course topics, students identify course material that is relevant to their lives and future goals, and this process has been shown to engage students in actively thinking about the curriculum (Harackiewicz and Hulleman, 2010). As a result of the intervention, students become more interested and involved in their studies and, in turn, perform better in the course. Harackiewicz *et al*. (2015) found that the UV intervention was effective in helping students to reflect on the usefulness of course material. For example, on average, all students wrote more about the UV of course topics in the UV condition, compared with controls. Students also became more engaged in the UV assignment than the control assignment, writing longer essays despite having identical length requirements for the assignments. Furthermore, FG-URM students became particularly engaged in the UV writing assignments, and this increased engagement partially mediated the intervention effects on course grade; longer essays were associated with higher grades for FG-URM students in the UV condition. These mediation results provide support for increased engagement as the mechanism that accounts for the powerful performance effects of the UV intervention.

Harackiewicz *et al*. (2015) hypothesized that the UV intervention may have been particularly effective for FG-URM students because it allowed them to connect course material to their valued communal goals. Indeed, these authors reported that the essays of FG-URM students in the UV condition included more content related to communal themes (e.g., words related to family and social processes), which may explain why FG-URM students were particularly engaged in the assignment and, on average, wrote more than all other students. Considered together, these findings suggest that, when FG-URM students were given the opportunity to write about the UV of course content (i.e., the connections between course content and their personal goals), they became particularly engaged in the assignment (as evidenced by their longer essays), which may have helped them perform better in the course.

These findings are also consistent with the literature on active learning. When students participate actively in structured learning activities such as group problem solving or writing a UV essay (rather than listening passively to lectures), they often perform better in difficult science courses (Deslauriers *et al*., 2011; Freeman *et al*., 2014; Harackiewicz *et al*., 2015). These active-learning strategies have produced improved learning outcomes for many STEM students (Handelsman *et al*., 2007) and may be particularly beneficial for underrepresented students in the life sciences (Stephan and Stephan, 2001; Haak *et al*., 2011; Gasiewski *et al*., 2012; Eddy and Hogan, 2014). By giving students the opportunity to be active participants in the learning process, educators provide students more autonomy in terms of how they learn course material, which can support the development of interest (Hidi and Renninger, 2006) and help students think about science in new ways.

RECOMMENDATIONS FOR IMPLEMENTATION

Importance of Value

It is worth noting the importance of leveraging values in all of the interventions summarized in Table 1. Both VA and UV intervention approaches involve values, but at different levels. Students' personal values, which VA interventions target, concern what is most important to students (e.g., friends and family, learning and gaining knowledge), whereas UV concerns the value that students perceive in tasks or domains of study (e.g., genetics is valuable to me because it helps me understand my family's health patterns). Both types of value can be critically important in influencing students' success in college, and thus provide two potentially powerful levers for intervention.

Consider the Population and the Context

By using psychological theory to develop interventions that target specific barriers to academic success faced by particular groups of underrepresented students in the life sciences (e.g., women and URM and FG students), researchers have begun to highlight the potential of social–psychological interventions to have a profound impact on students' academic trajectories. Different groups of students have different motivational characteristics that may make them more or less likely to benefit from a given intervention. Therefore, an important consideration for practitioners who would like to implement an intervention is the characteristics of their student bodies. When reviewing the literature, researchers and practitioners should be cognizant of exactly which groups of students are being helped by these interventions. Belonging and affirmation interventions have been proven to alleviate belonging concerns, thus promoting the well-being of underrepresented students (e.g., women in physics, FG students in biology) in important academic contexts. UV interventions were powerful in improving the performance of FG-URM students by increasing their engagement with course content and helping them to connect the material to their own lives and goals (Harackiewicz *et al*., 2015). To implement an intervention with maximum effectiveness, it is important to consider the specific mechanisms that social–psychological interventions target and how those mechanisms vary across different populations.

What may be beneficial for one group of students (e.g., FG college students), may not necessarily be as helpful for another (e.g., African Americans). Furthermore, it is important to remember that these groups overlap in ways that are relevant for intervention. For example, the UV intervention (Harackiewicz *et al*., 2015) was remarkably effective for FG-URM students but had no effect for FG-majority students. The analysis of motivational profiles (see Figure 4) helps identify which groups might be most responsive to different interventions, and the analysis of the content of students' essays provided clues about how and why the UV interventions worked for particular groups. Researchers and practitioners alike need to think carefully about how the findings reviewed here apply to other populations. The social–psychological interventions reviewed here were each designed to address distinct issues for the students they were intended to serve, and thus they worked through different mechanisms.

In addition to identifying the appropriate intervention for the particular issues faced by a given group of students, it is also important to administer interventions at the optimal point of the semester. For example, belonging and VA interventions are believed to work best when implemented early in the semester, so students may feel more comfortable in stressful academic settings and better able to handle upcoming challenges (for a review, see Cohen and Sherman, 2014). UV interventions, however, are best implemented after students have covered enough material to write an essay on how they personally connect with the material (Harackiewicz *et al*., 2014b). Each intervention works differently, and researchers

and educators alike should be cognizant of the goals of the intervention and the implementation details that can maximize success in broadening participation.

Another important point for practitioners to note is that all of this work has benefited greatly from interdisciplinary collaborations between science educators and social scientists. The collective expertise from both fields is crucial to assess the particular challenges, strengths, and needs of the target student body. Identifying and effectively implementing the appropriate intervention is reliant on productive interdisciplinary collaborations.

Future Directions

Despite a record of positive impacts, the body of literature on social–psychological interventions in college science courses is small at this point, and more research is needed. The first and most obvious limitation of the present review is that there are very few studies that use well-controlled experimental designs (e.g., RCTs) to test the effectiveness and mechanisms of social–psychological interventions in college life sciences courses. Moreover, the RCT studies that test the effectiveness and mechanisms of these interventions are relatively recent, with longitudinal follow-up data still being collected. The long-term effects of one intervention may be different from the long-term effects of another. For example, interventions that focus on student well-being (e.g., VA) may persist throughout a college student's tenure, as these interventions focus on shifting a student's overall college experience. Indeed, researchers have noted that these interventions can influence future college performance years after the intervention is first implemented (e.g., Cohen *et al*., 2009; Sherman *et al*., 2013; Tibbetts *et al*., 2016). Conversely, interventions that focus on curricular content (e.g., UV) may only impact the course in which an intervention is implemented or other related courses in the same field. Given that these interventions are content specific, it follows that intervention effects may only be present in courses in which that specific content is part of the curriculum. Nonetheless, the significance of stronger performance in a critical, foundational course may have long-term consequences for students. Future research needs to explore these possibilities.

Although we have highlighted potential mechanisms for the intervention effects observed here, further compelling evidence would come from studies that present physiological evidence related to the mediating mechanisms. For example, recent research investigating neural correlates of curiosity and early phases of interest may represent a step toward being able to discern when students become more or less engaged and interested in content (Kang *et al*., 2009; Hidi, 2015). This could be particularly useful when considering how different kinds of UV connections may increase students' motivation.

Finally, it is also important to note that these interventions are not equally effective across every implementation. Indeed, the robustness of intervention effects have proven variable, and a number of replication studies have found null effects (Dee, 2015; Harackiewicz *et al*., 2015; Hanselman *et al*., in press, 2016). For example, the VA intervention has been shown to have larger effects when observed achievement gaps are larger and when salient threats are more readily perceived (Hanselman *et al*., 2014; Harackiewicz *et al*., 2015). Reports of null effects have noted strict adherence to implementation fidelity as a critical component to intervention success and called for identifying necessary and sufficient preconditions for intervention success (Hanselman *et al*., in press, 2016). It is critically important to conduct further research in college science classes to determine the robustness of intervention effects (e.g., the magnitude of intervention effect sizes) in these contexts and to identify the necessary conditions to ensure their continued success in broadening participation in the life sciences.

CONCLUSION

We have reviewed three RCTs that document the potential of social–psychological interventions (and value interventions in particular) to improve academic outcomes for underrepresented students in college science courses. These studies afford causal conclusions and provide compelling evidence for the utility of the social–psychological approach to intervention. Whereas some earlier research investigating the effectiveness of various training programs for underrepresented students has been criticized for its lack of scientific rigor and evidence-based conclusions (Mervis, 2006), recent work with social–psychological interventions has utilized randomized blocked designs and double-blind procedures to accurately assess true causal intervention effects (e.g., Cohen *et al*., 2006; Hulleman and Harackiewicz, 2009; Miyake *et al*., 2010; Walton and Cohen, 2011; Harackiewicz *et al*., 2014a, 2015).

It is important to note, however, that we do not think that social–psychological interventions are a panacea for persisting STEM achievement gaps; instead, we should be thinking about increasing STEM participation for underrepresented students on multiple fronts. Indeed, programs that provide research training and mentorship to URM students, such as the Research Initiative for Scientific Enhancement (RISE), offer valuable opportunities for students to engage with the life sciences and have proven effective in promoting diversity in the life sciences (Schultz *et al*., 2011; Hernandez *et al*., 2013). Brief social–psychological interventions cannot replace valuable research experience or capable mentors. Rather, they are meant to complement these approaches by helping students succeed in the difficult introductory courses that are often the gateway to research experiences and mentorship that come later in the academic career. It is our hope that our description of these successful social–psychological interventions and the mechanisms through which they operate will supply information policy makers and educators can use to create a more inclusive and supportive culture for students who are currently underrepresented in the life sciences. More research is clearly needed, but the studies highlighted here illustrate the potential for progress in broadening participation in the life sciences.

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